
# Final Report

For more information and guidance on completion and submission of the report contact the Euphresco Call Secretariat (bgiovani@euphresco.net).

| **Project Title (Acronym)** |
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| International Plant Sentinel Network (IPSN) |

**Project Duration:**

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| **Start date:** | 01/04/13 |
| **End date:** | 31/03/16 |

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# 2. Executive Summary

## Project Summary

**IPSN: EUPHRESCO Project 2013-2016 - Establishing the basis for an International Plant Sentinel Network as an Early-Warning System for Future Pest Threats**

Introduced plant pests and diseases have had, and will continue to have, devastating impacts on plant species around the world. Plant pests and diseases not only destroy the environment and change landscapes forever, they also cost governments, businesses and homeowners, among others, large amounts of money each year (Aukema *et al.,* 2011, Tomoshevich *et al.*, 2013). Introduced pests and diseases cause such devastation due, to a great degree, to a lack of natural enemies in their introduced range, and a lack of immunity within their new hosts as they have not previously been exposed to them (Tomoshevitch *et al.,* 2013). The threat from new pests and pathogens is only set to rise as the rate of international trade increases, involving greater numbers of countries and trade routes, creating new pathways for their introduction. Similarly, the change in climate, e.g. increased temperatures and changed rainfall patterns, creates new habitats in which these damaging organisms can establish and thrive, making them a threat to more countries and plants. A key issue that scientists face is trying to predict which of these organisms could/will cause problems for plants in the future, and where.

The overall aim of this project was to establish the basis for an International Plant Sentinel Network (IPSN) as an early-warning system for future pest and disease threats. The network would use enhanced monitoring of plants that are growing outside their natural regions for damage by all the organisms that exist in the new environment; i.e. 'sentinel plants'. Research has shown the potential power of using sentinel plants for identifying new pest organisms (Fagan *et al.,* 2008, Baker *et al.,* 2009, Britton *et al.,* 2010, Kenis *et al.*, 2011; Tomoshevitch *et al.*, 2013, ISEFOR, 2015). As well as helping to identify 'unknowns' or 'future threats', research can also provide key information about pests and diseases that scientists already know but which are poorly characterised. The more scientists (and botanical institute) know, the better the management plans that can be put in place to prevent the introduction of such pests and/or slow or stop their establishment and spread. For this reason, the aim of the IPSN is to bring together experts from different backgrounds who work in plant health, including those working in governments, academic institutions and NGOs combined with staff working in botanic gardens and arboreta.

Although botanic gardens and arboreta offer excellent sites to carry out sentinel plant research; they are currently often overlooked by researchers. Through the Euphresco project, the IPSN aimed to raise awareness and train staff working in botanic gardens and arboreta so that they could look for pests and diseases within their gardens and share this information with appropriate experts.

The IPSN Euphresco project had 3 key objectives:

1.) International network and collaboration; this included building a network of scientists from countries around the world, bringing together contributors from a wide range of backgrounds including scientists, garden staff and governments. It also included publishing a website to provide a place where all information and newly developed IPSN resources could be stored and disseminated.

2.) Developing and sharing best practice; this included searching for and collating existing resources so that staff from botanic gardens and arboreta could easily access and use them. It also involved developing forms and processes that helped users record the required information needed in a consistent and easy to read form.

3.) Ensuring a long-term future: this included making sure the network would be able to continue into the future by moving towards a sustainable funding model.

**Methods and Results**

The IPSN was led by the UK's Fera, which has leading experts in the field of plant health and provides diagnostic support to the stakeholders in the UK. The project was then coordinated by Botanic Garden Conservation International (BGCI) who works with botanic gardens and arboreta to

improve the conservation of plants around the world. Other UK partners were CABI and Forest Research who also play integral parts in safeguarding plant health. All the UK's Euphresco partners were funded by the Department for the Environment, Food and Rural Affairs (Defra). In addition, the project had key European partners in the Julius Kühn-Institut (JKI) from Germany and the Plant Protection Services (PPS) from the Netherlands. The Department for Innovation in Biological, Agro-food and Forest systems (DiBAF) from Italy also joined the project.

The project created a new network of scientists, researchers, government organisations, botanic gardens and arboreta. This includes 29 botanical institutes and 12 representatives from leading organisations from around the world including the USA, New Zealand, China, Russia and Australia as well as a large number of European countries (appendices 1 and 2). Five workshops were held in USA, China and UK, bringing together experts in plant health and diagnostics with botanical garden and arboreta staff (Appendix 4). Participants represented >30 botanic gardens. The IPSN also held a European conference in collaboration with Observatree, a UK-based, EU Life+ citizen science project. The conference was on early warning systems for new and emerging risks to plant health in Europe, and had over 150 participants from 19 countries.

A key IPSN output was a recording form - the Plant Health Checker (Appendix 6). This enables users to systematically record signs and symptoms of pests and diseases in a consistent format. These novel forms can be utilised by staff in botanic gardens to keep track of the decline in health, or sometimes recovery, of a sick tree and by scientists to aid in the diagnosis of observed symptoms. The forms provide a simple way to evaluate damage and help identify those issues which are of greatest concern. The form was tested by a number of diagnosticians, botanic garden staff, botanic garden volunteers, arboreta staff and university students. The form's development is on-going, and the project welcomes all feedback to ensure the further development of a user-friendly and robust tool, which is suitable for use in botanical institutes of all sizes. During the project CABI ran a pilot project aimed at developing an electronic version of the form. It was well-received by the two gardens that tested it. Their staff provided excellent feedback on how to improve its suitability for use in their day-to-day activities. Future work will address feedback from these gardens and develop the forms further; potentially through collaboration with institutes that have experience in this area.

The IPSN worked in collaboration with its network to collect existing resources and develop new materials that can help raise awareness and help train staff in gardens. This included creating 'look-up' links between BGCI's PlantSearch database and CABI's Invasive Species Compendium. Over 600 users were introduced to the Compendium through this new facility within 16 months. Throughout the project the IPSN has developed a number of resources to increase capability and capacity for early warning systems of new and emerging threats, including producing a number of guides. These included: implementing good biosecurity, sending packages to laboratories for diagnosis, taking photographs of signs and symptoms, as well as producing a guide to common leaf-eating pests and a guide accompanying the Plant Health Checker. The latter guide gives a breakdown of common signs and symptoms that may indicate damage caused by a pest or pathogen. The project also ran a number of small-scale targeted surveys, which received good initial feedback, though participation levels were slightly lower than expected.

**Conclusion**

During its initial phase, the EUPHRESCO project partners with BGCI co-ordination have been successful in establishing an international network (IPSN) and putting in place the tools and resources needed for the network to function effectively. During the project, it was recognised that an important balance exists between meeting the needs of researchers and government organisations, and the assistance and incentives required by botanic gardens and arboreta who will often be carrying out work with no financial support in addition to normal workloads. Understanding and addressing this balance will be vital in creating a network that is sustainable in the long-term. The next stage of the IPSN will focus on fully utilising the network and using it to provide globally important research that helps safeguard plant health. The IPSN will continue to work closely with gardens as well as government bodies and plant health scientists to ensure that it is and is demonstrated to be a useful tool for all stakeholders, moving towards a self-sustaining business model requiring only minimal support from BGCI and funding bodies.

# 3. Report

## Objectives and tasks of the project

The International Plant Sentinel Network (IPSN) aims to enhance activities that provide an early warning of new and emerging pests and diseases and thus address a major issue in plant health. Damaging invasive organisms have detrimental impacts on plant species and consequently incur huge environmental and economic costs (Aukema *et al.,* 2011, Tomoshevich *et al.,* 2013). With the ever-increasing globalisation of trade and the impacts of a changing climate, the threat these organisms pose is only set to rise as the likelihood of their accidental introductions and ability to establish in new regions increases. Conventional pest risk analysis (PRA) is reliant upon lists of organisms which are known to be damaging and considered a significant threat to a country's native plant species. However, the majority of invasive alien species that have caused outbreaks in temperate forests in recent years were either unknown to science or not known to be damaging before their introduction (Kenis *et al.,* 2011). This is largely due to organisms being controlled in their native regions by natural predators and/or due to evolved resistance by host species, factors often absent in new regions (Tomoshevich *et al.,* 2013).

The IPSN has been developed to provide support and coordination for research using sentinel plants to provide early warning of potential future threats. Sentinel research involves monitoring plants growing outside their native regions, so-called sentinel plants, for damage by local organisms. Such research has the power to provide anecdotal evidence of potential future threats, often termed 'unknowns', and increase information about those already known but that require rigorous risk assessments (e.g. PRAs). Previous studies involving plant sentinels illustrated the potential for such projects; including the projects PRATIQUE and ISEFOR (Baker *et al.,* 2009, Kenis *et al.,* 2011; Tomoshevich *et al.,* 2013, ISEFOR, 2015) which are discussed in more detail below, along with two other comparable projects.

Botanic gardens and arboreta offer unique locations in which to carry out sentinel research (Britton *et al.,* 2010, Roques *et al.,* 2015). There are over 3,000 botanical institutes around the world and these play host to a wide range of exotic species. Introduced plants in these gardens are already established in non-native regions, so unlike sentinel plantings, which rely on planting seeds and/or young saplings, researchers can bypass issues relating to importation, planting and growing. All of these issues can impede studies by costing valuable time and money, as well as potentially diminishing the health of the specimens being studied in the first place, thus skewing results. Botanic gardens also provide the opportunity to study older specimens, which can be important when assessing the risk a pest poses to a particular species. On top of this, botanic gardens and arboreta have trained and passionate staff that work on a day-to-day basis with the plants in their care. Garden staff's ability to recognise, and importantly understand, unusual changes in a plant's health will be central to the identification of damaging organisms.

A number of papers cited that a global network of botanical institutes working collaboratively with plant protection scientists and National Plant Protection Organisations (NPPOs) could provide a warning system for new and emerging threats (Britton *et al.,* 2010, Kramer 2010 and Tomoshevich *et al.,* 2013). Further to this, a 2011 survey revealed that botanical institutes have the resources and expertise to help, but are lacking support and coordination, which would help expand already existing efforts (Kramer & Hird, 2011). The IPSN has been developed to provide this coordination in order to facilitate such research and support botanical institutes in their participation.

The EUPHRESCO project's overall aim was to establish the basis for such a network as an early-warning system for future pest and disease threats. It did this by working towards 3 key objectives:

1.) International network and collaboration; this included building a network of scientists from countries willing to cooperate, developing bilateral and multi-lateral partnerships and exchanges of information, and prototyping and future-proofing a database and website

2.) Developing and sharing best practice; exploring platforms for providing diagnostic advice or support, developing protocols, examples of best practice, training material, translations, etc. and developing consistent methods for trials and collection of experiences

3.) Ensuring a long-term future: developing a framework for a long-term IPSN, including options for future self-sustainability or future resourcing.

## Methods and Results

The project provided funding for a network coordinator to establish both national and international partnerships between scientists and botanic gardens and arboreta around the world. This coordinator worked for BGCI but was based at the offices of the UK's Fera. BGCI is a global network for plant conservation that includes more than 500 botanic gardens from 96 countries. BGCI are the owners of two unique databases; GardenSearch, a database of all known botanical institutes around the world, and PlantSearch, a database of plants included in botanical collections from around the world. Fera provide diagnostic support to the UK's NPPO, thus the project coordinator provided an important link between botanic gardens and plant health.

Initial IPSN partners were from the UK's Fera, CABI and Forest Research (UK) as well as BGCI, all of which received funding from the UK's Department for the Environment, Food and Rural Affairs (Defra). Outside of the UK Euphresco partners were the Julius Kühn-Institut (JKI) from Germany and the Plant Protection Services (PPS) from the Netherlands. In turn, the Department for Innovation in Biological, Agro-food and Forest systems (DiBAF) from Italy became another project partner.

*International network and participation*

The first role for the project coordinator was to carry out a comprehensive review of all existing plant health resources, literature surrounding sentinel research and similar/existing projects. This yielded an array of materials, many of which have since been linked to through the IPSN website in order to provide a centralised space to share resources. It also identified a number of key projects and/or institutes that had experience working in a similar area and established participation from each:

- The New Zealand Expatriate Plant Programme which monitored endemic species existing in living collections outside of New Zealand. This was a Better Border Biosecurity (B3) project where, after climate matching to locate suitable gardens, specialists would travel to them in order to survey individuals. It was a 5 year project which identified a total of 10 previously unknown pest-host associations (Fagan *et al.,* 2008, Britton *et al.,* 2010).
- PRATIQUE (Enhancements of Pest Risk Analysis Techniques) was a FP7 project aiming at refining pest risk analysis. One work package investigated the potential use of sentinel research in aiding PRAs. Sentinel plots were planted in China with 5 European species of tree and Eurasian tree species in Russian botanic gardens were surveyed. Large numbers of colonising insects were seen, 5 of which were seen as significant risks to European species and proposed for PRAs, and 29 pest-host associations previously unknown to science were identified (Kenis *et al*., 2011, Tomoshevich *et al*., 2013).
- ISEFOR (Increasing sustainability of European forests: Modelling for security against invasive pests and pathogens under climate change) was another FP7 project which aimed at identifying ways to detect invasive plant pests and pathogens within a common pathway for introduction; plants for planting (ISEFOR 2015). The project established and now monitors sentinel nurseries of Chinese plants regularly traded with European countries in China.
- The Sentinel Plant Network (SPN) which is funded by the United States Department of Agriculture – Animal Plant Health Inspection Services (USDA-APHIS). The SPN provides training and outreach to botanical institutes in America. Coordinated by the American Public Gardens Association (APGA) and the National Plant Diagnostic Network (NPDN) it extends the existing NPDN 'First Detector' programme and provides training and resources for gardens (Britton *et al.,* 2010, Sentinel Plant Network 2015).

All of the above projects and associated institutes/individuals were contacted regarding the IPSN. Consultation with these projects has been instrumental in shaping the development of the project.

Representatives from each project participate in the network; either as Euphresco Partners or as part of the International Advisory Group (as below).

*Member Gardens and the IAG*

A key output of the IPSN was the creation of a network of institutes and individuals willing to cooperate. The IPSN coordinator, alongside partners, employed many methods to build participation in the network, including speaking at national and international meetings and conferences, writing in newsletters and journals, and contacting specific gardens (identified through PlantSearch and GardenSearch) and partners. So far, the IPSN has gained participation from 12 leading institutes and 29 botanic gardens and arboreta from around the world (Appendix 2). All of these institutes give 'in kind' contributions to the project. In order to ensure the network was truly international, these participants are from countries around Europe and further afield, including Australia, Brazil, China, New Zealand, Russia, South Africa, the USA.

The IPSN began with a core group of Euphresco partners as above, however early on it was agreed that in order to ensure the success of the network it would need to be truly international. An International Advisory Group (IAG) was therefore established to ensure that there was participation in countries around the world (Appendix 1). The IAG includes 12 individuals who are leading figures in their field that give their time free of charge to shape and champion the network. IAG members provide comments, guidance, additional materials as well as ideas for future work and small scale research projects. Individuals also champion the IPSN in their own countries, providing contact with other institutes willing to participate, reaching out to botanic gardens and arboreta in their area and representing the IPSN at local meetings and conferences.

*Workshops and Conferences*

Recognising that participating in the IPSN requires botanic garden and arboreta staff to give their time free of charge, much work has centred around raising capacity and capability in order to promote the benefits of being part of such a network. Five workshops were held in 3 different countries. The IPSN also held a European conference in collaboration with an EU Life+ project called Observatree (a UK plant health citizen science project). The conference was on early warning systems for new and emerging risks to plant health in Europe (and beyond) and was held at the Royal Botanic Gardens, Kew (UK) in February 2016.

*Website and Access to Resources*

The IPSN aims to provide easy access to resources in order to promote engagement from garden staff who will have to carry out training/surveying alongside their normal working. The website was developed in order to provide a 'centralised hub' for network participants to share general information about the IPSN, examples of best practise, current news and events. The website has been visited >16,000 times since May 2015, with >7,000 active users from 130 different countries. This website has its own identify but is housed within BGCI's content management system, allowing it be easily maintained by BGCI in the future. A key feature of the website has been its 'Members Only' area which has been developed to share resources including training materials, standardised protocols, links and forums. The members only area also aims to promote participation in the network by encouraging gardens to join so that they can have access to these resources. The website is available at: http://www.plantsentinel.org/

To facilitate BGCI members access to information on plant health a link has been created between the BGCI PlantSearch database and the CABI Invasive Species Compendium. This allows users to access key factsheets listing the pests and diseases of specific hosts. The link also indicates where a host species is invasive itself. A Google Analytics report for the period 1/12/14 to 31/03/16 identified 1,100 referrals from the BGCI website to CABI's compendia representing 634 users from 55 different countries (top 10; USA, UK, Germany, India, France, Australia, China, Colombia, Hong Kong and Argentina). 43,912 2.5% of visitors were utilising the Cabi Invasive Species Compendium link.

**Developing and Sharing Best practice**

*Plant Health Checker*

The IPSN Plant Health Checker was a major output for the IPSN. Early on it was identified that the project required a tool to enable member gardens to assess and record changes in plant health in a

consistent, systematic and rigorous way. Specifically, due to the main aim of the IPSN, users would need to be able to record damage with an unknown cause in a format that could then be used by their peers or sent to diagnosticians to aid in diagnosis. The form would also act as a way to build capacity by introducing and familiarising users with types of damage indicative of a pest or disease. It also aimed to engage and enthuse those who have little plant health knowledge and thus promote ongoing participation in the network. Initially it was presumed that the IPSN could use pre-existing materials to, at the very least, leverage the development of such a tool. Consequently, the first step involved an extensive search for such materials. Although this search identified a number of useful protocols for surveying and reporting, they were often tailored for specific audiences and therefore not appropriate for the IPSN. Similarly, many were a closed system, directed at identifying known damaging organisms or types of organism. However, these examples provided a good basis for the general structure of such a form.

Initial development involved close collaboration with plant health professionals, including all IPSN Euphresco partners, and botanic garden and arboretum staff. In collaboration with professionals in this area, a list of required questions (e.g. species, age of plant etc.) and signs and symptoms indicative of pest and pathogen damage were used to draft a version of the Plant Health Checker. This draft was then tested by diagnostic staff at a local arboretum alongside the arboretum staff (including its director) and volunteers, and revised to address feedback and ensure it was a valuable tool for its target audience. The form was then circulated wider and tested by a number of diagnosticians, garden staff, garden volunteers and university students; including involvement from >20 botanic gardens and arboreta. While we believe the Plant Health Checker now provides a user-friendly and robust tool suitable for use by a range of botanic garden staff and volunteers, the tool will continue to evolve as further feedback and suggestions are received. This evolution will be furthered by work CABI are undertaking developing an electronic version of the form.

The Plant Health Checker is a significant output of the Euphresco project and has been recognised as the first of its kind; providing users with a tool to help them investigate and record changes in plant health that might be of an unknown cause. The form was very well received by both botanic gardens and arboreta staff and those working in plant health. It was designed with botanic garden and arboretum staff and volunteers in mind; however, it could easily be adapted for use by a wider audience. A pilot project to test the potential for an electronic version was led by CABI with the aim of aiding data entry and handling and enabling in-field recording. This used their existing knowledge of similar CABI owned online reporting systems, developed for their Plantwise initiative (www.plantwise.org), to build an app-based form using an off-the-shelf software package, Fulcrum (Fulcrum Mobile Solutions, LLC). This was tested in collaboration with two UK botanic gardens by both staff and volunteers. Feedback for the system was positive, with users finding it extremely helpful and unique. However, there were a number of features (including expanding the form) that would be beneficial to address before wider release. The next phase of its development will be to work on these points and expand its development, potentially through collaboration with other institutes that already have experience in this area.

*Development of resources*

The IPSN has also worked in collaboration with individuals and organisations to develop other guides and resources that could be of use to botanic gardens and arboreta. This has included guides for implementing good biosecurity, sending packages for diagnostic purposes, taking photographs for diagnostic purposes, a guide to common leaf eating pests and a comprehensive guide accompanying the Plant Health Checker. The latter guide gives a breakdown of common signs and symptoms that are indicative of damage by organisms with images of typical cases.

All materials were developed in collaboration with botanic gardens and arboreta (20 gardens from 7 countries) and diagnosticians. Efforts were made to ensure that the materials could be used by people from a large variety of backgrounds, from volunteers that work in the gardens on an ad hoc basis to dedicated entomologists and pathologists who work in the gardens. As a result, these were tested by a range of people and feedback was used to further develop resources and make them as user friendly as possible. The IPSN also developed a series of posters for new and emerging threats to various iconic British tree species; including ash, oak and plane trees. These were developed as an output from an IPSN workshop in collaboration with the Royal Botanic Gardens, Kew.

*Targeted Surveys*

Two small scale surveys have been run to encourage botanic gardens and arboreta to monitor for known pests and pathogens that have been identified as of high concern to aid in the production of PRAs, or to generally just increase our understanding of them. The first was for *Enigmadiplosis agapanthi* (Agapanthus gall midge), an undescribed pest affecting Agapanthus that belongs to the Cecidomyiidae family of flies that was identified in the UK in 2014. Its origin was unknown, though it was presumed to be native to South Africa and other southern hemisphere countries. The survey was therefore targeted at gardens in South Africa, New Zealand and Australia, though other gardens were also welcomed to contribute. The second survey was for *Sirococcus tsugae*, a fungus that has been described as the cause of shoot blight and defoliation on cedars and hemlocks in the United States. It was detected in the UK in 2013, since which time researchers have been eager to establish its current distribution in Europe, where it is inevitably spreading. This survey therefore focused on European gardens, though again was open to any who wished to contribute.

**Trap Plant Module**

This module was led by the German partner, Julius Kühn-Institute. In addition to surveying plants occurring in participating gardens, this module aimed at evaluating the feasibility of planting trap plants to survey for pests and diseases and draft protocols to ensure consistent approaches. The added value of this approach lies in the opportunity to use homogenous planting material and comparable procedures.

Due to operational delays in the funding phase, the Julius Kühn-Institute started its participation later than expected. The original idea to have participating gardens grow plants from identical plant material and to survey these plants in the same growing season was dropped due to the late start of the project's funding period in Germany. Instead, the aim was to demonstrate the principal functioning of a trap plant approach.

*Choice of Plant Species*

For ease of cultivation and in order to get results within one growing season, annual plant species were used. In the beginning, a proposal from the consortium was to use *Vinca* and *Cataranthus* species as trap plants. Staff in participating gardens in Germany, however, were unfamiliar with cultivation of *Vinca* spp. from seeds. In 2015, after the delayed start of the JKI, there was no time for running a full experiment. *Cataranthus roseus* plants were purchased from a local garden centre, placed in two gardens in Berlin and in Braunschweig and surveyed in weekly intervals. No pest damage was recorded.

In 2016, a larger set of plant species were studied. Plants were chosen to represent different families and origins (table 1). Seeds were purchased in a single 'lot' and distributed to participating gardens in sufficient quantities to plant c. 50 plants per species.

| **Species** | **Family** | **Origin** |
|---|---|---|
| *Calendula officinalis* | Asteraceae | S-Europe |
| *Gazania rigens* | Asteraceae | S-Africa |
| *Rudbeckia hirta* | Asteraceae | E. N-America |
| *Schizanthus pinnatus* | Solanaceae | Chile |
| *Nolana paradoxa* | Solanaceae | W. S-America |
| *Pennisetum rueppellii* | Poaceae | E-Africa |

*Planting protocol*

Gardens were given instructions concerning germination conditions, pricking out, planting out and tending. Garden staff were asked to check the plants for any sign of usual appearance of the plants.

*Participating Gardens*

Of the IPSN partner gardens, the Botanischer Garten der Universität Potsdam, and the Rhododendron-Park Bremen, both in Germany were chosen. In addition, the JKI in Braunschweig took part.

*Results*

All plants were put out for germination in mid-April. Of *Pennisetum rueppellii* only two seedlings germinated in Braunschweig and none in the other gardens. All other species developed as planned and were in flower in early June in all gardens. All plants appeared healthy until flowering. During flowering, *Schizanthus pinnatus* began to wilt in late June in all three plantations. The plants were completely dead in July. A detailed test was not possible, Chytridiales were assumed to be the agent responsible.
All other plants survived without signs of damage until the end of the experiment in August.

*Conclusion*

The experiment showed that a simultaneous planting of plants from a common seed source and with a common protocol can be achieved. Plants growing in comparable conditions were produced in three gardens. The level of detail necessary for the germination and planting was assessed. As such the test run of the trap plant approach can be used as a pilot study for later application in a larger set of participating gardens in more distant areas. The test run also showed that willingness of participating gardens can be achieved. It must however be noted that other gardens did not volunteer to participate in the trap plant module.

**Ensuring a long-term future**

IPSN resources have been developed so that they can be integrated into day-to-day working by botanic gardens and arboreta in the future. This will ensure participation can continue with minimal coordination and support. All protocols and resources have been developed with this eventual goal in mind.

To aid this, an online reporting form and supporting app has been proposed and discussed with two leading organisations working in this field – CABI and Bugwood (http://www.bugwood.org/). A pilot project to test the potential for the electronic version was led by CABI. This used their existing knowledge of similar CABI owned online reporting systems to develop an app based form using an off-the-shelf software package, Fulcrum (Fulcrum Mobile Solutions, LLC). This was tested in collaboration with two UK botanic gardens by both staff members and volunteers and initial reports show positive feedback for the idea. This project is currently in the process of being written into a publishable article and will be made available when complete.

## Discussion of results and their reliability

*International network and collaboration*

The network has benefitted from participation by 12 leading institutes to form the IAG (Appendix 1), and 29 botanic gardens and arboreta (Appendix 2) from around the world, all of which give ‘in kind’ contributions to the project. These individuals are all from leading institutes in their field, and give their time free of charge to shape and champion the network in their countries. Further to this, there was representation from each of the key projects that preceded the IPSN. Individuals from these projects were able to give key insight into sentinel research and guide the project’s development accordingly.

The five international workshops were all well attended with garden staff from >30 botanic gardens from countries including China, Mexico, the USA and the UK who were a mix of plant health scientists, university staff, students and representatives from NPPOs, as well as staff members from gardens. Feedback was positive; workshops were the first of their kind in China and the UK, and offered a unique networking and capacity building opportunity. The overseas workshops also provided an up-skilling opportunity for UK diagnosticians, as they gained first-hand experience of exotic pests, gathered information for the UK Plant Health Risk Register on five pests (which influenced risk ratings, e.g. for the polyphagous shothole borer, *Euwallacea sp. nov.*) and established good links with individuals from ‘hard to reach’ areas (Mexico and China). The two-day IPSN/Observatree conference

was attended by over 150 people from 19 different countries. There was a mix of stakeholders, including researchers, government bodies, charities and botanic gardens and arboreta. The conference showcased the current interest and enthusiasm for early warning systems and provided a great networking and learning opportunity.

An IPSN website has been developed with a 'Members Only' area holding materials, links and forums - http://www.plantsentinel.org/. This website has its own identify but is housed within BGCI's content management system, allowing it be easily maintained by BGCI in the future. In addition, a link was created between the BGCI PlantSearch database and the CABI Invasive Species Compendium (www.cabi.org/isc). As mentioned in 'methods and results', a Google Analytics report revealed that this link is being utilised by PlantSearch users from a large variety of countries.

*Developing and sharing best practice*

The project sought best practice, developed standardised approaches and provided training materials, guidance on diagnostic approaches, databases and methodologies for the monitoring and surveying of invasive alien plant pests and diseases. Consequently, the IPSN has created a range of tools to advise and support gardens in providing good biosecurity and carrying out activities related to plant health. These include:

- The IPSN Plant Health Checker (Appendix 6) a standard format recording form for reporting damage/change in deciduous and coniferous trees. Its value has been recognised by the IPSN members and it has been translated into Chinese. It is currently being developed into an online reporting system by CABI (as below)
- A comprehensive guide to accompany the Plant Health Checker
- 2 reference guides for types of organisms and damage they cause
- 4 guides detailing good biosecurity practise, taking photographs for and packaging physical samples for diagnostic purposes and plant health governance worldwide (including NPPO/RPPO contact information)
- A poster series (and standard template for use by any institute/country) for new and emerging pest risks to the UK for hosts of interest (oak, pine, plane and ash), which was a novel way of raising awareness for plant health issues. The IPSN also developed one for the globally important pathogen *Xylella fastidiosa* which is known to cause varying symptoms dependent on host species.

All of these are stored on the IPSN's website and are available to all IPSN member gardens. In due course a number of IPSN resources will be made available to all BGCI member gardens through their new online training resource which, it is hoped, will also encourage those who are not IPSN member gardens to officially participate in the network.

The two targeted surveys have been piloted and, thus far, have yielded no positive results and have had only small contribution from member gardens. However, in principle they have been well received by those who have completed them. A template has been established for the survey documents, a fact sheet and survey form, so that new surveys can be developed reasonably easily. It is hoped that in the new IPSN phase these surveys can be pushed more, targeted better and participation levels will increase.

*Ensuring a long-term future*

IPSN resources have been developed so that they can be integrated into day-to-day working by botanic gardens and arboreta in the future. This will ensure participation can continue with minimal coordination and support.

To aid this, an online reporting form and supporting app have been proposed and discussed with two leading organisations working in this field – CABI and Bugwood (http://www.bugwood.org/). CABI have completed the pilot project for an IPSN reporting system based on the developed Plant Health Checker system. This pilot phase was trialled in two UK botanic gardens (both active IPSN member gardens) by staff and volunteers. The project concluded that there was a benefit from the use of electronic reporting using tablets and smartphones.

The importance of the IPSN is recognised by BGCI and the organisation's strategy 2015-2020 includes a continued commitment to supporting the network in the longer term.

## Main conclusions

The IPSN Phase 1 achieved its original objectives, as above, there is now a significant opportunity to realise the benefits from the network. Throughout the last 3 years the IPSN has recognised that an important balance exists between meeting the needs of NPPOs and RPPOs whilst supporting botanic gardens and arboreta. In order to ensure that the IPSN is able to continue on as a self-sustaining network supported by key stakeholders, the project requires further work to address this balance and ensure there is appropriate financial and in-kind support in place. The proposed IPSN Phase 2 will rely upon botanic gardens and arboreta to carry out work with no financial support and in addition to normal workloads. Throughout this first Euphresco project it has become obvious that understanding and addressing this balance will be vital in creating a network that is sustainable in the long-term.

While a key focus of Phase 2 will be to demonstrate the potential of the network to NPPOs/RPPOs and plant health institutes, there will also be a need to continue to provide co-ordination and support to participating botanic gardens and arboreta. The IPSN will also work to continue building the network by engaging additional gardens and institutes from around the world. The Observatree/IPSN conference (held at Royal Botanic Garden Kew in February 2016) illustrated the current interest worldwide. A key take-home message from this conference was that countries needed to work together

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## References


- Aukema J. E, Leung B., Kovacs K., Chivers C., Britton K. O., Englin J., Frankel S. J., Haight R. G., Holmes T. P., Liebhold A. M., McCullough D. G. & Holle B. V. (2011) Economic Impacts of Non-Native Forest Insects in the Continental United States PLoS ONE DOI:10.1371/journal.pone.0024587
- Baker R. H. A., Battisti A., Bremmer J., Kenis M., Mumford J., Petter F., Schrader G., Bacher S., De Barro P., Hulme P. E., Karadjova O., Lansink A. O., Pruvost O., Pyšek P., Roques A., Baranchikov Y. & Sun J.H. (2009) PRATIQUE: a research project to enhance pest risk analysis techniques in the European Union *OEPP/EPPO Bulletin* 39: 87-93
- Britton K.O., White P., Kramer A. and Hudler G. (2010) A new approach to stopping the spread of invasive insects and pathogens: early detection and rapid response via a global network of sentinel plants *New Zealand Journal of Forestry Science* 40: 109-114
- Fagan L. L., Bithell S. L. & Dick M. A. (2008) Systems for identifying invasive threats to New Zealand flora by using overseas plantings of New Zealand native plants *In: K. J. Fourd, A. I. Popay & S. M. Zydenbos (Eds.), Surveillence for biosecurity: pre-border to pest management* 51-62
- ISEFOR (2015) http://www.isefor.com/ accessed March 2016
- Kenis M., Roques A., Sun J. H., Fan J. T., Kirichenko N., Baranchikov Y., Tomoshevich M., Yart A., Holmes K. & Péré (2011) PRATIQUE Enhancements of pest risk analysis techniques
- Kramer A. and Hird A. (2011) Building an International Sentinel Plant Network *BG Journal* 8**:** 3-6
- Roques, A., Fan, J.T., Courtial, B., Zhang, Y.Z., Yart, A., Auger-Rozenberg, M.A., Denux, O., Kenis, M., Baker, R. and Sun, J.H. (2015) Planting sentinel European trees in Eastern Asia as a novel method to identify potential insect pest invaders *PloS one* 10(5), p.e0120864.
- Sentinel Plant Network (2015) http://sentinelpn.vm-host.net/who-we-are accessed March 2016
- Tomoshevich M., Kirichenko N., Holmes K. and Kenis M. (2013) Foliar fungal pathogens of European woody plants in Siberia: an early warning of potential threats? *Forest Pathology* 43: 345-359

# Appendix 1: International Advisory Group

- Alain Roque – INRA, France
- Alberto Santini - Istituto per la Protezione Sostenibile delle Piante (IPSP), Italy
- Carlos Frederico Wilcken - Dept. Plant Protection, FCA/UNESP - Campus de Botucatu, Brazil
- Daniel Stern – American Public Gardens Association (APGA), USA
- John Wilson - South African National Biodiversity Institute (SANBI) & Centre for Invasion Biology (CIB), South Africa
- Kerry Britton – USA
- Martin Ward – European and Mediterranean Plant Protection Organization (EPPO)
- Natalia Kirichenko - Siberian Branch of Russian Academy of Sciences, Russia
- Nigel Bell – Better Border Biosecurity (B3), New Zealand
- Sara Redstone – Royal Botanic Gardens Kew, UK
- Shiroma Sathyapala - FAO, Rome Headquarters, Italy

# Appendix 2: IPSN Member Gardens

- Auckland Botanic Gardens, New Zealand
- Beijing (southern) Botanical Garden, China
- Botanischer Garten der Universitat Potsdam, Germany
- Charles University Botanic Garden (Botanicka zahrada University Karlovy), Prague
- Christchurch Botanic Gardens, New Zealand
- Core Facility Botanical Garden, Vienna, Austria
- Department of planting design and maintenance, Slovakia
- Dunedin Botanic Gardens, New Zealand
- The Eden Project, United Kingdom
- Giardino Botanico Alpino alle Viotte di M. Bondone, Italy
- Helsinki University Botanic Garden, Finland
- Marwell Zoo, United Kingdom
- Melbourne Royal Botanic Gardens, Australia
- Mlyňany Arboretum SAS, Slovakia
- Museo Orto Botanico di Roma, Italy
- National Botanic Gardens, Glasnevin, Ireland
- Orto Botanico dell`Univerita della Tuscia, Italy
- Royal Botanic Gardens Edinburgh, United Kingdom
- Royal Botanic Gardens Kew, United Kingdom
- Royal Botanic Gardens Sydney, Australia
- Royal Horticultural Society's Garden Wisley, United Kingdom
- Shanghai Botanical Gardens, China
- Shanghai Chenshan Botanical Garden, China
- Shenzhen Fairy Lakes Botanical Gardens, China
- South China Botanical Garden, China
- Stellenbosch University Botanical Gardens, South Africa
- Wellington Botanic Gardens, New Zealand
- The Yorkshire Arboretum, United Kingdom
- Xiamen Botanical Garden, China

# Appendix 3: Publications


- Barham, E., Sharrock, S., Lane, C., & Baker, R. (2015) An International Plant Sentinel Network. Sibbaldia: the Journal of Botanic Garden Horticulture, (13), 83-98.
- Barham, E., Sharrock, S., Lane, C., & Baker, R. (2016) The International Plant Sentinel Network: a tool for Regional and National Plant Protection Organizations. EPPO Bulletin, 46(1), 156-162.
- BGCI (2016) BGjournal 13(2) – Early warning systems for plant health; the role of botanic gardens
  - Barham, E. (2016). An Early Warning System for New and Emerging Plant Pest and Disease Risks: A Network of Botanic Gardens and Arboreta. BGjournal, 13(2), 04-08
  - Grimshaw, J. (2016). Tree Health, IPSN and the Yorkshire Arboretum. BGjournal, 13(2), 09-11
  - Clemens J. & Brockerhoff E. (2016). Contributions of Christchurch Botanic Gardens to Plant Health and Biosecurity in New Zealand. BGjournal, 13(2), 12-15
  - Dong, H. (2016). Morphological and Molecular Identification of Common Nursery and Landscape Pests in Shenzhen, China. BGjournal, 13(2), 16-19
  - Stern, D. and McCarthy, R. (2016) The sentinel plant network: enhancing biosecurity by leveraging the capacity of public gardens to support early detection of and rapid response to invasive alien pests. BGjournal, 13(2), 20-22
  - Barta, M., Ferus P., and Hot´ka P. (2016) Biosecurity of woody plant collections in Mlyňany Arboretum. BGjournal, 13(2), 23-27
  - Warmington, R. and Treseder, K. (2016) Surveying, monitoring and quarantining for notifiable pests and diseases at the Eden Project. BGjournal, 13(2), 28-30
- Barham, E (2016) The unique role of sentinel trees, botanic gardens and arboreta in safeguarding global plant health. *Plant Biosystems,* 150 (3), 377–380, http:/dx.doi.org/10.1080/11263504.2016.1179231 Published by Taylor & Francis online
- Harju, V., Flint, L., Jackson, L., Skelton, A., Forde, S., Fairless, N., Daly, M., Field, C., Marsden, S., Lane, C., Barham, E. and Fox, A. (2016) A follow up report regarding New hosts of European mountain ash ringspot virus in the UK - *in prep*

# Appendix 4: Dissemination Activities

The IPSN has given oral and poster presentations at a large number of conferences and meetings around the world since its launch in November 2013. The below are a list of key events, workshops and conferences which the IPSN has helped coordinate and/or facilitate:

- November 2013 – Launch of the IPSN at BGCI's 5th Global Botanic Gardens Congress: Side Session 'International Plant Sentinel Network Symposium', Dunedin, New Zealand
- September 2014 – IPSN Workshop for UK Botanic Gardens and Arboreta: Introduction to Plant Pests and Pathogens, Royal Botanic Gardens Kew, UK
- March 2015 – IPSN Workshop for Mexican and USA Botanic Gardens and Arboreta: 'Plant Pest Monitoring and Prevention Workshop', Huntington Botanical Gardens, USA
- March 2015 - IPPC Commission for Phytosanitary Measures – 10: Side session 'Developing an early warning system for new and emerging plant pests and diseases; An International Plant Sentinel Network', Rome, Italy
- March 2015 – IPSN Workshop for Chinese Botanic Gardens and Arboreta: 'The Identification and Diagnosis of Longhorn Beetles in China and nearby Countries', Shenzen Fairy Lakes Botanical Gardens, China
- May 2015 - Invasive Alien Plants Panel of the European and Mediterranen Plant Protection Organisation (EPPO), Paris - Starfinger, U.: Report on the IPSN project
- February 2016 - Observatree/IPSN Conference on Tree and Plant Health Early Warning Systems in Europe, Royal Botanic Gardens, Kew, UK

The IPSN has also held a Euphresco partner's meeting, either a face-to-face meeting or a teleconference, approximately every 6 months since its launch.

A volume of BGCI's own biannual publication, BGjournal, was developed to coincide with the Observatree/IPSN conference. This publication focused on 'Early warning systems for plant health: the role of botanic gardens'. It featured papers from a number of key collaborators to the project, as well as editorials from Fera, BGCI and an IPSN update and examples of IPSN resources (as listed in Appendix 3). This was distributed to all conference attendees, as well as being circulated to all current BGCI members (>700, of which around 500 are botanical institutes). The project also produced posters and leaflets, the latter of which are available in Chinese, English and Russian. The website is also available in Chinese, English, Russian and Spanish.

# Appendix 5: Abbreviations

| | |
|---|---|
| APGA | American Public Garden Association |
| B3 | Better Border Biosecurity, New Zealand |
| BGCI | Botanic Gardens Conservation international |
| Defra | Department for Environment, Food and Rural Affairs |
| DiBAF | Department for Innovation in Biological, Agro-food and Forest systems |
| EPPO | European and Mediterranean Plant Protection Organization |
| IAG | International Advisory Group |
| IPSN | International Plant Sentinel Network |
| ISEFOR | Increasing Sustainability of European FORests |
| JKI | Julius Kühn-Institut |
| NPDN | National Plant Diagnostic Network |
| NPPO | National Plant Protection Organisation |
| PPS | Plant Protection Services – Netherlands |
| PRA | pest risk analysis |
| PRATIQUE | Enhancements of Pest Risk Analysis Techniques |
| RPPO | Regional Plant Protection Organisation |
| SPN | Sentinel Plant Network |

# Appendix 6: Plant Health Checker (Broadleaf example)

International Plant Sentinel Network

## Plant Health Checker - Step 1

| | |
|---|---|
| **Name of Botanic Garden / Arboretum:** | |
| Country: | |
| Address: | |
| Name of IPSN contact: | |

**Survey details**

| | |
|---|---|
| Survey carried out by: | |
| Date of survey: | |
| Best description of season: | |
| Main reason for surveying this particular individual: | |

**Plant details**

| | |
|---|---|
| Species (Cultivar): | |
| Accession number: | |
| GPS | |
| Country/region species is native to: | |
| Age/amount of time plant has been present in gardens: | |
| General Comments: | |

**General description** (please tick)

| | | | |
|---|---|---|---|
| Generally healthy | ✓ | Some damage | ✓ |
| Dying | ✓ | Dead | ✓ |

Any recent changes in health or overall look:

| General description of environment |
|---|
| Any management issues (e.g. irrigation, soil pH, sun bleaching) or any recent use of pesticides/ fungicides/ herbicides: |
| |
| Description of environment (focusing on recent changes and individuals in close proximity): |
| |

For each section of the plant give it a rating dependent on how healthy it appears:

Red (R) = In very poor health and of imminent concern due to significant damage potentially resulting in death of individual

Orange (O) = Not currently a concern but could develop; should be checked frequently to monitor progress

Green (G) = As would be expected on a 'healthy plant'

Black (X) = Absent/not applicable

Where an **orange or red** rating is given, ensure you give a description of why you've given it this rating in notes.

**1.) Crown**

R ✓ O ✓ G ✓ X ✓

**2.) Flowers / Fruits** *(circle)*

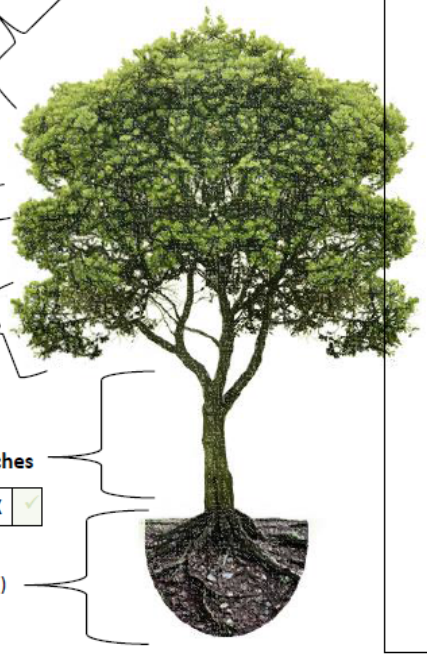
R ✓ O ✓ G ✓ X ✓

**3.) New growth**

R ✓ O ✓ G ✓ X ✓

**4.) Leaves**

R ✓ O ✓ G ✓ X ✓



**5.) Trunk & branches**

R ✓ O ✓ G ✓ X ✓

**6.) Base and Roots** (if exposed)

R ✓ O ✓ G ✓ X ✓

Notes:

| What do you think is wrong with this plant? *(give an indication of how sure you are of this diagnosis)* | | | | Reference/file name of any photographs taken: | |
|---|---|---|---|---|---|
| 1.) Is a re-survey required? | ✓ | 2.) If yes, in what timeframe (include a suggested date) | | 3.) Should this be escalated to an appropriate staff member to carry out STEP 2? | ✓ | 4.) Name of person escalated to *(if applicable)*: | 5.) Date: |

Broadleaf trees

Accession number:_____ Survey completed by:_____ Date:_____

## Plant Health Checker – Step 2

**Please read:** This section should be completed if escalation is specified by STEP 1. It should be carried out by an appropriately trained staff member who has the relevant knowledge concerning the plant's history and/or pest and pathogen identification skills.

**Tick** all signs/symptoms that are at abnormal levels or are unexpected for the individual, and are thus cause for concern (e.g. are out of the ordinary/new to the plant). Give a description and an indication of severity/abundance in the **notes**, plus note anything else of importance or interest.

| 1. Crown | | |
|---|---|---|
| Thin /sparse | ✓ | Notes: |
| Yellow leaves | ✓ | |
| Dead wood | ✓ | |
| **2. Blossom/Flowers** | | |
| Dead | ✓ | Notes: |
| Malformed | ✓ | |
| Swollen | ✓ | |
| **3. New Growth (Shoots and Buds)** | | |
| Dead | ✓ | Dieback ✓ |
| Wilted | ✓ | Malformed ✓ |
| Notes: | | |
| **4. Leaves** | | |
| Dead | ✓ | Malformed ✓ |
| Smaller than expected (stunted) | ✓ | Mosiacs / mottled / variation in colour ✓ |
| Sticky | ✓ | Galls ✓ |
| Rust | ✓ | Mildew ✓ |

| 4. Leaves continued (leaf spots) | | | |
|---|---|---|---|
| Single | ✓ | Numerous | ✓ |
| Present only at the edge | ✓ | All over leaf | ✓ |
| Only on old growth | ✓ | Only on new growth | ✓ |
| Yellowing (chlorotic leaves) | ✓ | Brown/blackeing (necrotic leaves) | ✓ |
| Notes: | | | |
| **5. Trunk & Branches** | | | |
| Canker or lesion | ✓ | Approx. number | |
| Dry | ✓ | Gummy/sticky | ✓ |
| Approx. height of canker from ground (m) | | | |
| Galls | ✓ | Approx. size (m) | |
| Trunk bleeding ('weeping patches') | | | ✓ |
| Approx. height of bleed from ground (m) | | | |
| Approx. number of bleeds over trunk | | | |
| Vertical bleeds (in a line up the trunk) | ✓ | Horizontal bleeds (around the trunk) | ✓ |
| Loose Bark / bark flaking / comes off easily | | | ✓ |
| Notes: | | | |
| **6. Base and Roots (if exposed)** | | | |
| Bootlaces/black strands *(1-2mm wide)* | | | ✓ |
| Fungal mycelium/white strands | | | ✓ |
| Mushrooms/toadstools on plant | | | ✓ |
| Damage by mammals | ✓ | Notes: | |
| Decay / Rotting | ✓ | | |
| Wet ✓ | Dry ✓ | | |

| 7. General pest damage | | Location (e.g. leaf) |
|---|---|---|
| Insect galleries under loose bark | ✓ | |
| Insect eggs | ✓ | |
| Chewing damage | ✓ | |
| Insect webbing | ✓ | |
| Insect mines | ✓ | |
| Frass | ✓ | |
| Bore holes *(circle below)* | ✓ | |
| <5mm / 5-10mm / >15mm | | |
| Notes: | | |

| 8. Pest sightings *(give an indication of how sure you are of this identification)* | | Location (e.g. leaf) | Photo (file name) |
|---|---|---|---|
| | ✓ | | |
| | ✓ | | |
| | ✓ | | |
| | ✓ | | |
| | ✓ | | |

**9. General Observations and Additional Notes**

Reference/file name of any photographs taken:

| What do you think is wrong with this plant? *(give an indication of how sure you are of this diagnosis)* | | 1.) Is a re-survey required? | ✓ | 2.) If yes, in what timeframe *(include a suggested date)* | |
|---|---|---|---|---|---|
| 3.) Should this be reported to the local diagnostic laboratory - a physical sample may be required *(this is only if symptoms are severe or if a pest of concern)* | ✓ | 3.) Date reported: | | 4.) Should this be escalated to local National Plant Protection Organisation (NPPO)? *(as advised by local diagnostic laboratory)* | ✓ | 5.) Date reported: | |

Broadleaf trees