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A worldwide perspective of the legislation and regulations governing sentinel plants

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Abstract Sentinel plants, plants in exporting countries that are inspected at regular intervals for signs and symptoms of invertebrate pests and microbial pathogens, are a promising tool for detecting and identifying harmful organisms of woody plants prior to their introduction into importing countries. Monitoring of sentinel plants reveals crucial information for pest risk analyses and the development of mitigation measures. The establishment of sentinel plants requires the import and plantation of non-native plants, which may be affected by the laws, regulations and administrative procedures in the individual countries. To evaluate the feasibility of sentinel plants as a global approach, this study aimed to summarise regulations and administrative procedures that affect the establishment of sentinel plants using non-native plants in countries worldwide. Information about national regulations of import and planting of non-native plant species was collected through a questionnaire survey, conducted among national representatives to the International Plant Protection Convention. Over 40 countries responded. The results show that legislations and regulations should not be major obstacles for a global use of the sentinel plants approach. However, the few existing experiences show that it can be complicated in practice. Here we describe the current state of art of the procedures that should be adopted to establish sentinel plants and we propose a strategy to circumvent the shortcomings resulting from the lack of a specific regulation.

Keywords Sentinel plants · Import · Plantations · Alien tree species · National regulations

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Introduction

Woody plants and forests are important resources in all countries, but their biodiversity and economic and livelihood benefits are under threat from alien pests and diseases ("pests"; FAO 2010). Although most alien pests do not cause significant damage on their own, some are able to cause the death of woody plants on a large scale (Aukema et al. 2011; Santini et al. 2013). Some examples include *Cryphonectria parasitica*, an East Asian fungal pathogen that severely affects chestnuts in North America and Europe (Anagnostakis 1987; Rigling and Prospero 2018; Jeger et al. 2016), and the Sirex woodwasp (*Sirex noctilio*), of European origin, which cause significant economic damage to pine plantations in the southern hemisphere (Carnegie et al. 2006; Hurley et al. 2007). Recently, the American bacterium *Xylella fastidiosa* received much media attention after its establishment and subsequent widespread killing of olive trees in southern Italy (Almeida and Nunney 2015). In the years following its initial detection it has been reported in many European countries, where it lived undetected for years, probably since late 1970s (Soubeyrand et al. 2018) in association with different hosts (Delbianco et al. 2018; EPPO Global database: https://gd.eppo.int/).

National regulations governing plant imports, as well as phytosanitary measures, aim at preventing the entry of alien pests and in most countries such regulations and measures target specific organisms (Eschen et al. 2015a). Indeed, international conventions, such as the International Plant Protection Convention (IPPC, FAO 1997) and the Agreement on Sanitary and Phytosanitary Measures (SPS Agreement, WTO 1995), stipulate that trade restrictions must be based on scientific evidence, thus, on already known pests (Vettraino et al. 2018). However, many of those pests that established in new countries were not known, or were not known to be harmful, before their introduction and no measures were taken to prevent their arrival (Eschen et al. 2015b). Many of the pests that established in Europe and in the US have probably been introduced through trade, in particular the trade in live plants (Liebhold et al. 2012; Santini et al. 2013). Consequently, the increase in intercontinental trade volume and connections are expected to result in an increasing number of new introductions (Chapman et al. 2017). Since it is not possible to halt the trend of globalization, which is neither realistic nor necessarily desirable, we should focus on alternative means of preventing pest introductions, including the development and implementation of procedures and tools allowing the identification of new pests prior to their introduction. This approach would broaden the knowledge base for pest risk analyses and, if deemed necessary, for the development of risk mitigating regulations or phytosanitary measures. Sentinel plants, i.e. non-native or native plants that are monitored for pest presence and damage in an exporting country, have been proposed as efficient ways to provide adequate information about potentially harmful organisms before they arrive in an importing country (Britton et al. 2010). A comprehensive definition of sentinel plant is provided in Eschen et al. (2019).

Several studies using the sentinel plant approach yielded valuable data on new pest-host relationships and on potential risk associated with their introduction into importing countries (Tomoshevich et al. 2013; Groenteman et al. 2015; Roques et al. 2015; Vettraino et al. 2015; Kirichenko and Kenis 2016; Vettraino et al. 2017; Kenis et al. 2018). However, establishing the sentinel plants has revealed some legislative and practical issues. For example, Roques et al. (2015), who established the first sentinel plant in China with European trees, identified problems related to the import procedure. Broadleaved species, which must be imported bare-rooted, i.e. without soil, were insufficiently watered during the 4-week period of post-entry quarantine. This is likely to have affected the health and survival of the trees (Roques et al. 2015). Hence, to avoid damage to plants in post-entry quarantine and lower the risk of introducing pests on the imported sentinel plants, it may be preferable to import plant propagation material other than rooted plants, such as seeds, parts of plants or tissue cultures (Anonymous

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1999). The phytosanitary risk associated with imported plant propagation material is presumed to be lower than the risk associated with rooted plants (Cleary et al. 2019; Franić et al. 2019) and the regulations for import of such material are often more relaxed than those for other types of plants for planting (Eschen et al. 2015a).

In view of a wider implementation of sentinel plants, it is necessary to know how the import and the planting of non-native woody plant species are regulated in countries where this tool could be used. The aim of this study was to explore the legislative and administrative procedures to follow for the establishment of sentinel plants in potentially exporting countries around the world. This study is the first worldwide, comparative attempt at examining the legislation pertaining to the establishment of sentinel plantations in different part of the world, with particular reference to the European Union (EU). This research, together with data reported in literature (Eschen et al. 2015a) describes the state of the art of regulations for import and planting of non-native species in different countries.

Materials and methods

A "Sentinel Plantation Survey" was developed in the form of a questionnaire (see Appendix 1), which followed the procedural steps required for establishing a sentinel plantation. It was organized in two sections:

(a) "Import rules", with questions related to: (1) the competent authority taking decisions on the authorization of import of non-native plants, (2) differences between the regulations on import of plants for planting, and those regarding foodstuffs or plant propagation material, (3) conditions and procedures for importing forest reproductive material of non-native plant species. Additional questions concerned the use of pest risk analysis (PRA) and post entry procedures.

(b) "Planting non-native species", with questions related to: (1) the competent authority responsible for granting the authorization for planting non-native plants or plant propagative material, either in nurseries, in sentinel plants or in the wild (including in forests), (2) national provisions and procedures for the planting of non-native plant material in the wild and open field (including experimental facilities), and whether provisions exist for planting such species for scientific purposes, (3) the existence of national legislations, regulations or policies that specifically apply to the establishment of sentinel plants.

A questionnaire was co-designed and agreed by a diverse group of partners of COST Action Global Warning (FP1401: www.ibles.pl/cost) with expertise in pest science and plant health regulation. The questionnaire was sent to bodies in charge of the application of the national and international rules concerning import of plant material (National Plant Protection Organisations, NPPOs), specifically the national representatives to the International Plant Protection Convention (IPPC), in June 2016. It was sent a second time 1 month later to those who had not responded the first time. The questionnaire consisted of 19 questions of which 13 were closed-ended (answers: Yes, No, I don't know), and the request of adding more information in case the answer was "Yes". We used such a questionnaire structure because it is generally perceived by respondents as much easier than an open-answer questionnaires, and objectively take less time to be completed, ensuring a higher rate of response.

All data were analysed using descriptive statistics. In the analysis, the EU was considered as a single country, because of the common external border (most goods can be moved among EU countries without restrictions after entry into an EU country). In case of contrasting answers from EU countries, we referred to the Regulations and Directives in force, highlighting potential differences in procedures.

The complexity of procedures for a sentinel plant establishment was measured as number of positive answers to questions 3.2, 3.4, 3.5, 4.4 (see Appendix 1). Countries rank from 0 to 4, where score 0 corresponds to the least complexity, whereas score 4 corresponds to highest complexity.

Results and discussion

Of the 151 surveys that were mailed, 46 were returned, yielding an overall response rate of 30%. The respondents were distributed over five continents, but the Americas were underrepresented (Fig. 1). Responses

were received from over half of the EU countries, from developing countries and from countries known for their well-developed biosecurity system, such as New Zealand. Hence, the results appear to provide a good overview of the different approaches that are taken by countries worldwide.

The questionnaire method gave us the chance to get in contact with NPPOs all over the world.

In 30% of the returned surveys all questions were answered, while 12% (106 over 893) of the answers consisted of "I don't know". This answer was more provided for the questions pertaining to planting of non-native species (14%) than for the questions related to the section "import" (9%).

In most of the responding countries, the NPPO are is the competent authority for both the import of non-native plant material and the planting of non-native plant species. However, in some cases other departments are also involved, *i.e.* the Forest Office in Austria and the Wildlife Management Authority in Zimbabwe.

Import

All the responding countries adopt plant health regulations in accordance with the IPPC. Most of the responding countries apply preventive measures to mitigate the risk of introducing alien invasive species, which may include restrictions on import of certain plant species or genera. Such restrictions may be a barrier to the establishment of sentinel plants. However, exceptions for the import of plant material for scientific purposes are possible in about 84% of the cases.

In the EU, import and planting of non-native plant material are respectively regulated by the Plant Health Directive (2000/29/EC, Anonymous 2000) and by a set of other rules (e.g. the Wildlife Trade Regulations (Council Regulation (EC) 338/97, Anonymous 1997), various Marketing Directives (e.g. Directive 1999/105/EC regulating the marketing of forest reproductive material—Anonymous 1999), the Habitats Directive 92/43/EEC (Anonymous 1992), and regulation (EU) 1143/2014 (Anonymous 2014) relative to the prevention and management of the introduction and spread of invasive non-autochthonous species. These regulations are related to plant health, customs and nature conservation and are implemented by different departments in the EU Member States.

Some non-EU countries, such as Turkey (Eurasia) and Papua New Guinea (Oceania) have adopted the EU plant protection legislation. Turkey officially asked to join the EU and is in the process of harmonising its legislation with that of the EU. Papua New Guinea did not give an official motivation, but since it is a Commonwealth country and it has been controlled from 1884 to 1919 by some European countries, we presume that it harmonises its legislation to that of the EU for facilitating trade.

The majority of the countries (58%), including countries in the EU, consider that plant propagation material and plants for planting belong to the same

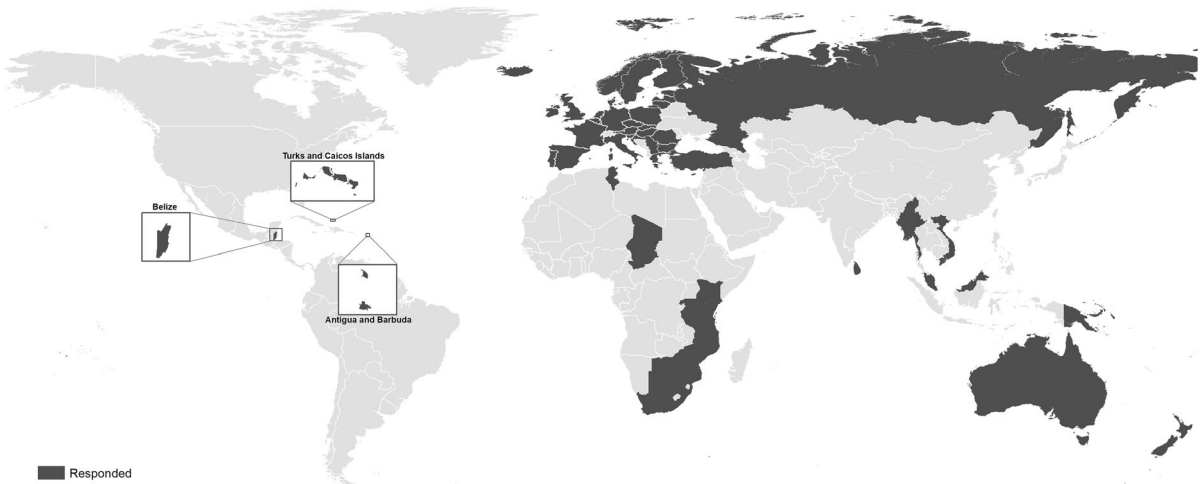

Fig. 1 Geographic distribution of the countries that responded to the questionnaire

category "plants" (Table 1). This is in accordance with the EU Directive 2000/29, Article 2 (Anonymous 2000), where the term "plants" means "living plants, fruit, in the botanical sense, other than that preserved by deep freezing, vegetables, other than those preserved by deep freezing, tubers, corms, bulbs, rhizomes, cut flowers, branches with foliage, cut trees retaining foliage, leaves, foliage, plant tissue cultures, live pollen, bud-wood, cuttings, scions, any other part of plants, which may be specified in accordance with the procedure referred to in Article 18 (2)". However, there are sometimes exceptions from requirements for imports from non-EU countries (i.e. "third countries"), where propagation material and plants for planting are considered separate categories. For example, Annex III, section A, of that document lists plants, plant products and other objects whose introduction into the EU is prohibited and in a number of occasions, the prohibition does not apply to fruit or seeds.

The comparison among countries concerning the existence of different restrictions on import of propagation material in comparison with plants for planting or foodstuffs (e.g. seeds for planting vs. seeds for human consumption) and forest reproductive material of non-native plant species is reported in Table 1. Generally, most of the respondents, except Serbia and Chad, considered plant propagation material, other plants for planting, foodstuffs and forest reproductive material as different commodities and their import is regulated by different regulations, which reflects the different uses for and risks associated with these commodities.

In most of the countries (69%) the import of plant parts for human or animal consumption is subject to different regulations than propagation material (Table 1). However, the EU has not banned the import of fruit and seeds of any forest tree species, with potential consequences on forest health (Cleary et al. 2019). It is worth remembering that if infected materials (fruits and seeds) are composted and used as a fertilizer the risk of pest establishment persists, since some organisms can survive the composting processing (Noble and Roberts 2004). A specific legislation for the import of forest propagation material of non-native species is applied in 58% of non-EU countries, mostly in African countries (89%).

A number of questions were related to PRA and post-entry quarantine (PEQ) as strategies to analyse the risk due to the introduction of alien species and to check the health status of imported plants, respectively. In 71% and 59% of the responding countries PRA and PEQ, respectively, are mandatory for imported plants.

Interestingly, even if it is not always compulsory, 28% and 22% of the responding EU countries have chosen to apply PRA and PEQ procedures, respectively. Historically Europe has been open to introduction of plant commodities for ornamental, food and forestry purposes. Since Roman times the history of Europe has been characterised by an intense trade across continents that has resulted in the introduction of many non-native tree species, such as Sweet

Table 1 Presence of specific regulations for import different plant materials in different countries. The European Union was considered as a single country

Question	No. of answering countries (%)	
	Yes	No
Is import of plant material regulated by a specific legislation?	79	21
Are there any different, or additional, or fewer restrictions on import of propagation material in comparison with plants for planting?	42	58
Are there any differences in regulations for import of reproductive plant propagation material and for import of plants or plant parts as foodstuffs (e.g. seeds for planting vs. seeds for human consumption)?	69	31
Is there any national regulation on the conditions and procedure for import of forest reproductive material of non-native plant species (for EU countries: other than Council Directive 1999/105/EC)?	58	42

chestnut from western Asia (Adua 1999), and also of pests of woody plants (Santini et al. 2018). PRA and PEQ are worth to be applied, even where are not compulsory, to strengthen a prevention to pest introduction based only on diagnostic procedures (Ioos et al. 2019). PEQ can be implemented in a variety of ways, ranging from secure quarantine greenhouses to surveyed open-field plantations, depending on country and perceived risk. The requirement that rooted plants are kept in PEQ prior to release into the country can affect their health (Roques et al. 2015) and preparations for the establishment of new sentinel plants using imported material should include an assessment of the conditions in PEQ.

Planting

The concept of "sentinel planting" as defined by Britton et al. (2010) and Eschen et al. (2019) is not yet considered in national legislations in 39 out of the 46 responding countries (mentioned in responses from Kenya, Chad, Sri Lanka, Malaysia, Greece, Lithuania, Norway), which could lead to different interpretations of the regulations and result in complex administrative procedures (Roques et al. 2015; Casarin et al. in preparation). Consequently, most of the countries (76%) refer to the general rules related to the planting of non-native plants or plant material. In many of the countries once the permit of import is released, non-native plants can be planted without further authorization. However, in 56% of the countries it is not permitted to plant non-native species into the wild without a permit. This is in accordance with the General Declaration of the Third EU Ministerial Conference on the Protection of Forest in Europe, which states that native species and local provenances should be preferred for reforestation and afforestation (Anonymous 1999). While this may affect the establishment of sentinel plants, it is worth exploring the possibility of obtaining a permit for scientific studies or considering collaboration with the NPPO of the home country, which should have an interest in the results and may be able to facilitate.

Administrative complexity/feasibility of establishing sentinel plantings

The responses to our survey indicate that the establishment of sentinel plantings requires consideration of country specific procedures for import or establishment of plant propagation material of non-native species (Casarin et al. in preparation). The differences in regulations among countries highlighted in this study could be the result of a combination of sociological, historical and cultural features specific of each country (sensu MacLeod et al. 2010). The variation in complexity of the bureaucratic procedures in the various countries stems from different legal requirements for a pest risk analysis prior to issuance of an import permit for the propagation material, involvement of different government institutions, the need for post-entry quarantine, the need to obtain special permission for the import or planting of non-native species for scientific purposes. On the basis of these differences countries were ranked according to the complexity of the bureaucratic procedures for import and planting of non-native woody plants, the requirement for PRA or PEQ, provisions for import of plant material for scientific purposes and the presence of procedures of the establishment of sentinel plantings (Fig. 2). In Norway, Kenya and Sri Lanka, for example, the process is the most demanding since all the procedures and permissions above-mentioned are compulsory, while in Russia no authorizations are required for the steps needed for the establishment of sentinel plantations using imported propagation material. This ranking should not be interpreted as exact and no quality is implied for either complex or simpler procedures; it is merely intended as an illustration of the diverse requirements of the different countries.

In order to avoid risks and delays resulting from regulatory requirements, alternative sources of the non-native plants may be considered. Plants of non-native species propagated in the country where a sentinel plantation has to be established may in some cases be easily obtained, but there are several drawbacks, e.g. adaptation/selection of different genotypes and due to the presence of local pests for example due to the presence of endophytic fungi that infected the trees at the place of production or the length of time the trees have been grown or growing prior to their use in the sentinel planting and low genetic variability of the plant material in the non-native country as compared to the native range of the species. These limitations may affect the pests and pathogens identified, as well as the extent of damage done in sentinel plantings and should therefore be considered when interpreting the

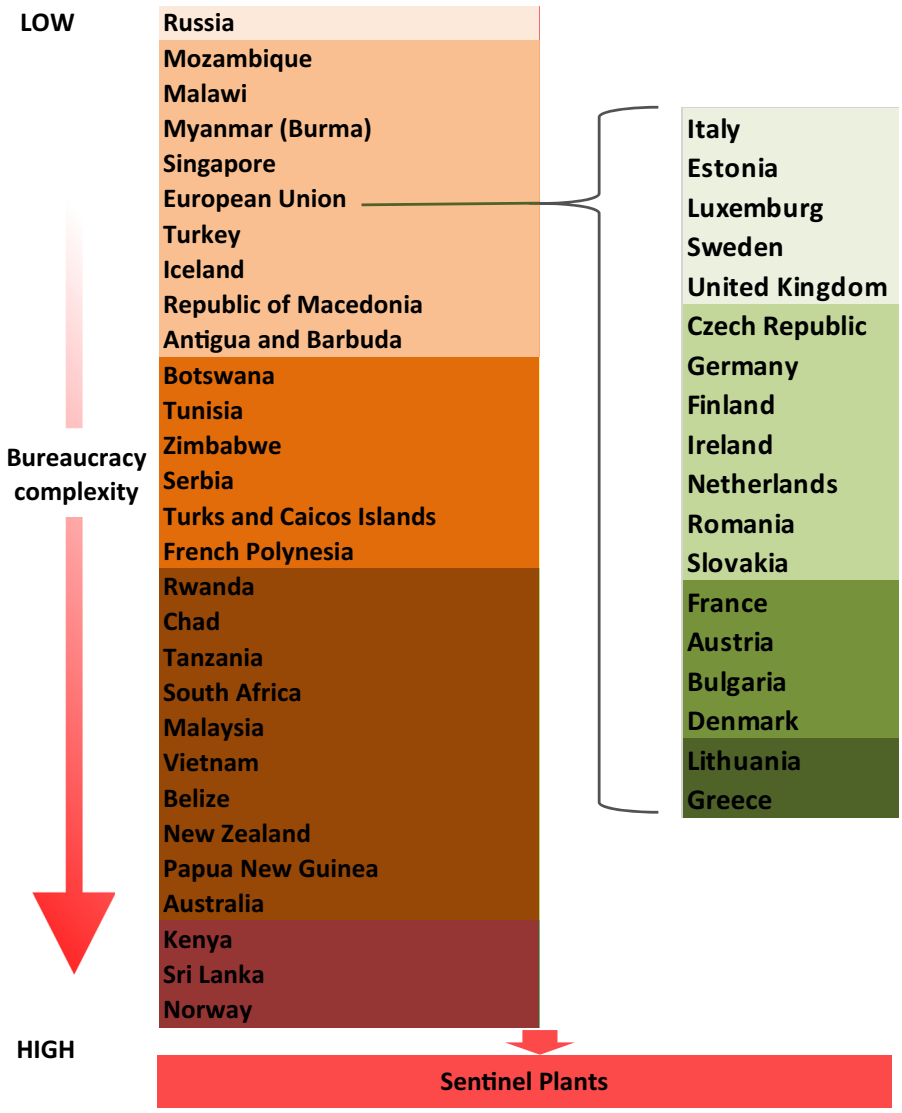

Fig. 2 Ranking of countries according to the complexity of the bureaucratic procedure needed to establish a sentinel plants with alien plant species, based on positive answers to questions 3.2, 3.4, 3.5, 4.4 (see Appendix 1). Darker colors correspond to a higher complexity. Countries rank from 0 to 4, where score 0 corresponds to no complexity, and score 4 corresponds to highest complexity

results of sentinel planting studies for risk assessment (Eschen et al. 2019).

No specific legislation concerning sentinel plantings is currently in place in the countries that responded to our questionnaire. Yet, our results clearly indicate that the combination of existing regulations for the import of plants and plant products, usually plant health regulations and environmental protection or forest regulations, covers the rules needed to establish sentinel plantings in all these countries. The introduction of the "sentinel planting" concept in national regulations would facilitate the use of this tool and avoid different and misleading interpretations of the present legislation that may lead to its scarce application. This appears to be especially the case when multiple government departments have a role in the decision process. Improved coordination on the national level, as well as collaboration between researchers or NPPOs in the exporting and importing countries, could result in streamlining the process leading to establishment of non-native sentinel plants. The development of a Standard for Phytosanitary Measures would contribute to the wider recognition and would result in acceptance of a single definition of sentinel plantings by multiple countries (Eschen et al. 2019).

The implementation of the "sentinel planting" tool requires thorough planning, long-term funding, strong local links and reliable collaborators. First experiences have been gained through national initiatives, in particular in New Zealand (Fagan et al. 2008; Mansfield et al. 2019), bilateral collaborations (e.g. Roques et al. 2015) and regional or global collaborative projects, such as COST Action "Global Warning" and the EUPHRESCO project "International Plant Sentinel Network" (http://www.plantsentinel.org/). Furthermore, the use of collected data requires agreements among countries, in particular NPPOs, and good relationships between scientists and the NPPO in the country where the sentinel planting is located. It would also be valuable to develop a common database on reports from different plantings (Kenis et al. 2018), with details of the methods used for establishment of the plantings and data collection.

Conclusion

The results of this study indicate that it should be possible to establish sentinel plantations using (imported) propagation material of non-native tree species in most of the countries and that there are national differences in the procedures to be followed. Even countries that have strict regulations concerning the import or planting of non-native woody plants usually have the possibility of exceptions for research purposes. A clear procedure would facilitate the establishment of sentinel plantations. Currently it is however difficult (e.g. Casarin et al. in preparation) to find the correct procedure to follow in each country because of the multiple government institutions involved and often no single procedure or department seems to know all relevant procedures.

The wider establishment of sentinel plantings would both help to prevent the introduction of new pests and pathogens and to facilitate the development of phytosanitary measures that mitigate the risk of introducing unknown pests or pathogens. The development of internationally accepted standards for the establishment of sentinel plantings, for example as an International Standard for Phytosanitary Measures under the IPPC, would increase awareness of the sentinel plantings as a tool to support the mission of NPPOs. This approach will be also useful to strengthen the links between the scientific community and the plant protection organizations.

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