European Food Safety Authority
EFSA Journal 2012;10(6):2755

SCIENTIFIC OPINION

Guidance on methodology for evaluation of the effectiveness of options for reducing the risk of introduction and spread of organisms harmful to plant health in the EU territory[1]

EFSA Panel on Plant Health (PLH)[2, 3]

European Food Safety Authority (EFSA), Parma, Italy

ABSTRACT

The European Food Safety Authority (EFSA) requested the Panel on Plant Health (PLH Panel) to provide guidance for the evaluation of the effectiveness of the options for plants and plant products for reducing the risk of introduction and spread of harmful organisms in the European Union territory. Two operational tools are presented: a checklist for evaluating a proposed risk reduction option (RRO) and a database of references corresponding to published guidance documents or experimental assessments of RROs. The checklist can be used by the Panel or the dossier-submitting parties to verify whether all required information is provided in support of a RRO, to quickly describe information supplied to EFSA and to identify major gaps in the data. Four types of RRO assessments are distinguished in the proposed checklist according to their purposes and characteristics: experimental assessment of the effectiveness of the option to reduce pest infestation in plant material/products under laboratory/controlled conditions; experimental assessment of the effectiveness of the option to reduce pest infestation in plant material/products under operational conditions; analysis of the applicability of the RRO; and assessment of the effectiveness of the option to reduce the risk of pest entry from an infested area to a pest-free area. The database of references is intended to assist the Panel in (i) identifying potential RROs for a given pest and plant material, and (ii) quickly retrieving relevant experimental data and guidance documents for assessing a proposed RRO. In addition, the current document provides recommendations for assessing RROs, specifically: on experimental design; on the use of statistical methods including approaches for studying uncertainty; on the use of quantitative pathway analysis and spread models describing their advantages and limitations; and on recommendations for general surveillance and specific surveys.

KEY WORDS

Checklist, effectiveness, experimental design, quantitative pathway analysis, risk reduction option, spread models, statistical methods.

[1] On request from EFSA, Question No EFSA-Q-2010-01343, adopted on 23 May 2012.

[2] Panel members: Richard Baker, Thierry Candresse, Erzsébet Dormannsné Simon, Gianni Gilioli, Jean-Claude Grégoire, Michael John Jeger, Olia Evtimova Karadjova, Gábor Lövei, David Makowski, Charles Manceau, Maria Navajas, Angelo Porta Puglia, Trond Rafoss, Vittorio Rossi, Jan Schans, Gritta Schrader, Gregor Urek, Johan Coert van Lenteren, Irene Vloutoglou, Stephan Winter and Marina Zlotina. Correspondence: plh@efsa.europa.eu

[3] Acknowledgement: The Panel wishes to thank the members of the Working Group on evaluation of risk reduction options, Erzsébet Dormannsné Simon, Jean-Claude Grégoire, Olia Evtimova Karadjova, David Makowski, Charles Manceau, Jan Schans, Gregor Urek and Marina Zlotina, for the preparatory work on this scientific opinion; Andy Hart, Alan MacLeod, Muriel Suffert and Marco Pautasso for their contributions as hearing experts; and EFSA staff, Olaf Mosbach-Schulz, Sara Tramontini and Sybren Vos, for the support provided to this scientific opinion.

Suggested citation: European Food Safety Authority; Guidance on methodology for evaluation of the effectiveness of options for reducing the risk of introduction and spread of organisms harmful to plant health in the EU territory. EFSA Journal 2012;10(6):2755. [92 pp.] doi:10.2903/j.efsa.2012.2755. Available online: www.efsa.europa.eu/efsajournal

SUMMARY

The European Food Safety Authority (EFSA) asked the Panel on Plant Health to deliver guidance on the methodology for evaluation of the effectiveness of options for reducing the risk of introduction and spread of organisms harmful to plant health in the European Union territory.

This guidance document was prepared by the Panel to address mainly the quantitative evaluation of the effectiveness of risk reduction options (RROs). When data and/or information are available, the quantitative methods described in this document can be applied. When only limited or no data and/or information are available, the Panel performs qualitative evaluations that are briefly described in this guidance document. The Panel developed this guidance document to be used for the assessment of RROs together with the guidance on a harmonised framework for risk assessment (EFSA Panel on Plant Health (PLH), 2010a) and the guidance on the evaluation of pest risk assessments and risk management options prepared to justify requests for phytosanitary measures under Council Directive 2000/29/EC (EFSA Panel on Plant Health (PLH), 2009). The guidance provided in this document complements and does not replace the two above-mentioned documents when responding to requests for scientific advice on issues related to the evaluation of the effectiveness of options for reducing the phytosanitary risks within the EU in order to support the decision-making process under Council Directive 2000/29/EC.

Two operational tools are presented in this guidance document:

- a checklist for evaluating a proposed RRO
- a database of references of scientific documents presenting recommendations on how to assess RROs and/or describing experimental assessments of RROs.

The two tools have different purposes. The checklist includes a series of items that can be used by the Panel to check whether all required information is provided to support a RRO. Four types of RRO assessments are distinguished in the proposed checklist according to their purposes and characteristics:

i. experimental assessment of the effectiveness of the option for reducing pest infestation in plant material/products under laboratory/controlled conditions

ii. experimental assessment of the effectiveness of the option for reducing pest infestation in plant material/products under operational conditions

iii. analysis of the applicability of the RRO

iv. assessment of the effectiveness of the option for reducing the risk of pest entry from an infested area to a pest-free area.

The checklist can be used by experts to make a preliminary assessment of documents and data submitted to EFSA to support a RRO (e.g. a temperature treatment of plant material) and, more specifically:

- to quickly describe the information provided to EFSA (i.e. report and experimental results) to support a proposed RRO
- to identify major gaps in data submitted to EFSA
- to organise the work of the Panel when evaluating a dossier.

This checklist could also be used by the author of the submitted dossier or by the author of a pest risk analysis to verify whether all the requested data have been provided.

The second tool is a database of references corresponding to published guidance documents or experimental assessments of RROs.

The content of these documents is summarised in a table presented in Appendix B. This database of references can be used by the Panel to find some specific experimental results on the effectiveness of a given RRO, or to find guidance documents for designing RROs. Although this database does not intend to include all existing references on RRO assessment, it may help the Panel experts to quickly

retrieve the relevant experimental data and guidance documents for assessing a proposed RRO, or for assessing a range of options in a pest risk analysis. It can also be used to identify potential RROs for a given pest and/or plant material.

Finally, based on the literature review described in this guidance document and on its own experience, the Panel is able to formulate several recommendations on the use of quantitative methods for assessing the effectiveness of RROs.

Recommendations on surveillance (as defined in ISPM No 5, Glossary of phytosanitary terms)

- General surveillance should evaluate the possible occurrence of a pest in an area, using all relevant (quantitative and qualitative) information on the current pest distribution in and near the area, the ecological conditions of the area, the presence of host plants and other potential pest niches, and the import and trade rates of host plant products in the area. The conclusion of general surveillance and a discussion of the level of uncertainty should be presented along with all information used to reach the conclusion.

- Specific surveys should be conducted to test an explicitly formulated hypothesis on the occurrence of a pest in an area and/or on its incidence. They should be performed on a statistical basis, using relevant quantitative and qualitative information on the area, the pest, the host plants and other potential pest niches. They should provide a conclusion on pest occurrence and the uncertainty of the conclusion, expressed as the confidence level to detect the pest above the threshold prevalence of the survey.

- Methodology to integrate the results from general surveillance and specific surveys should be implemented in cases in which a conclusion on pest occurrence is difficult to reach.

Recommendations on the design of experiments

- The checklist provided herewith should be used prior to, and during, the experimentation.

- The information requested in the checklist and pertaining to the plant and to the pest should be first as complete and precise as possible.

- The objectives (e.g. mortality rates, maximal pest density acceptable) and confidence levels of the tests should be clearly stated and, when relevant, compared with the current standards.

- A complete description of the experimental or observational design should be provided, including: variables used to measure effectiveness; factors influencing effectiveness that were or were not taken into account in the experiments; description of facilities and equipment; description of treatments; methodology followed for monitoring critical parameters; description of experimental design; presentation of the data; and description of the statistical analysis.

The complete datasets produced by the experiment and/or the observations and used in the analyses should be kept available with a full definition of all the variables.

Recommendations on the use of statistical methods for assessing the effectiveness of options for reducing pest infestation

- Uncertainty about the effectiveness of RROs should be studied by computing confidence intervals with classic statistical methods or credibility intervals with Bayesian methods.

- The probit 9 threshold for mortality rate should not be systematically used as the reference threshold for assessing the effectiveness of RROs. Instead of using a specific threshold for mortality rate, it is recommended that the risks of pest entry and establishment associated with the RRO under consideration be analysed.

- Although not frequently used in plant pathology, equivalence tests and, more specifically, non-inferiority tests are useful tools for comparing two RROs and testing whether a proposed RRO is at least as good as a currently implemented RRO.

- Depending on the nature of the available experimental results, different types of generalised linear models can be fitted to data to study the relationship between the dose of a treatment and its effectiveness. Such models are commonly used in chemical risk assessment, but are also applicable in treatment effect assessment.

Recommendations on the use of quantitative pathway analysis and spread models

Quantitative pathway analysis and spread models have several advantages compared with experimental and/or observational studies:

- They allow risk assessors to quantify the effects of RROs, singly or in combination, on several variables such as probabilities of entry, establishment and spread, or magnitude of impact. They do not restrict the assessment of RROs to their capabilities for reducing pest infestation.
- Quantitative pathway analysis and spread models can address uncertainties and can be used to study the effect of different sources of uncertainty on the risk of entry, establishment, spread and impact.
- They enable to perform a sensitivity analysis to identify the most influential parameters in a model that define the most effective RRO.

These advantages make these quantitative tools attractive for assessing the effectiveness of different RROs. However, their application can be difficult in practice owing to the amount of data required to develop such models. In the case of missing data, the uncertainty associated with the model outputs could be high and decrease the ability of the model to discriminate between different RROs, thus diminishing the usefulness and value of the models.

TABLE OF CONTENTS

BACKGROUND AS PROVIDED BY EFSA

The EFSA Scientific Panel on Plant Health provides independent scientific advice on the risks posed by organisms which can cause harm to plants, plant products or plant biodiversity in the European Union. The Panel reviews and assesses those risks to assist risk managers in taking effective and timely decisions on protective measures under the Council Directive 2000/29/EC[4] to prevent the introduction and further spread of organisms considered harmful to plants or plants products in the European Union.

To assist the Panel in its work, the Panel has developed Guidance on the evaluation of pest risk assessments and risk management options[5] and Guidance on harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA[6]. These documents are constructed upon the international framework for pest risk analysis for quarantine pests, laid down in the International Standards for Phytosanitary Measures[7] (ISPM), and implement the EFSA principles of separation of risk assessment from risk management, and transparency.

In methodological terms the Guidance highlighted the need to develop quantitative approaches, in particular for the purpose of evaluation of the effectiveness of pest risk management options in reducing pest risks.

The Panel receives an increasing number of requests for evaluation of technical dossiers relating to options proposed to reduce pest risk and is also asked to identify and/or compare options that reduce the risk of introduction and spread of harmful organisms in the EU territory. Some of the requests require an urgent response from the Panel.

It is therefore opportune for the Panel to develop methodology for evaluation of the effectiveness of options to reduce pest risk. To enhance consistency and efficiency of the Panel response further guidance is needed on the information and data to be included in technical dossiers submitted for the Panel's evaluation.

TERMS OF REFERENCE AS PROVIDED BY EFSA

The Panel on Plant Health is requested to produce a scientific opinion in the format of guidance on methodology for the evaluation of the effectiveness of options for plants and plant products to reduce the risk of introduction and spread of harmful organisms in the EU territory.

The Panel will include in its opinion guidance on:

a) quantitative methods to be applied by the Panel for evaluation of the effectiveness of options to reduce the pest risk;

b) information and data to be provided to demonstrate the effectiveness of options to reduce the pest risk;

c) experimental designs and statistical methods for assessing the effectiveness of options to reduce the level of risk of introduction and spread of harmful organisms in the EU territory.

[4] Council Directive 2000/29/EC of 8 May 2000 on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community. Official Journal of the European Communities L 169/1, 10.7.2000, pp. 1–112.

[5] Guidance of the Panel on Plant Health on the evaluation of pest risk assessments and risk management options prepared to justify requests for phytosanitary measures under Council Directive 2000/29/EC, EFSA Journal (2009) 2654, 7–18.

[6] Guidance on a harmonized framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA, EFSA Journal 2010; 8(2): 1495, 66 pp.

[7] FAO IPPC International standards for phytosanitary measures 1 to 29 (2007 edition).

In the development of this opinion, the Panel will consider other guidance documents of EFSA's scientific Panels and outcomes of relevant research projects including the EFSA Art 36 project Prima Phacie.

The Panel's draft guidance document will be available for public consultation on its proposals in 12 months and delivery of the guidance document will follow 6 months after.

ASSESSMENT

INTRODUCTION

The European Food Safety Authority (hereinafter referred at as EFSA) is the keystone of the European Union (hereinafter referred at as the EU) risk assessment regarding food and feed safety. EFSA's remit covers food and feed safety, nutrition, animal health and welfare, plant protection and plant health. In all these fields, EFSA's most critical commitment is to provide objective and independent science-based advice grounded in the most up-to-date scientific information and knowledge.

The Scientific Panel on Plant Health of the European Food Safety Authority (hereinafter referred at as the Panel) was established in 2006 by Regulation (EC) No 575/2006[8] amending Regulation (EC) No 178/2002[9]. The mandate of the Panel, as adopted by the EFSA Management Board, is to address the increasing need expressed by the European Commission, the European Parliament or the Member States, or on its own initiative (as for the present opinion), for assessing, in an independent and scientific manner, the risks posed by organisms harmful to plants, plant products and/or biodiversity.

As the Panel was initiated to contribute to the overall activity of EFSA as the EU's independent risk assessor, it produces different types of scientific opinions on the request of the European Commission as demonstrated by the examples below:

- pest risk assessments for the EU territory, including identification and evaluation of risk reduction options (e.g. *Dryocosmus kuriphilus*, *Gibberella circinata*, *Monilinia fructicola*, pospiviroids, citrus canker);
- extension of the scope of national pest risk assessments to the entire EU (e.g. *Thaumetopoea processionea*, *Bactrocera zonata*) and evaluation of relevant European and Mediterranean Plant Protection Organization (EPPO) pest risk analyses (e.g. *Lysichiton americanus*, *Hydrocotyle ranunculoides*);
- re-evaluation of existing EU level pest risk assessments due to new evidence (e.g. *Phytophthora ramorum*);
- evaluation of risk assessments prepared by individual Member States (e.g. French overseas departments (DOM) pest risk analyses);
- evaluation of technical files proposed by third countries requesting derogations of the phytosanitary requirements included in Council Directive 2000/29/EC (e.g. *Agrilus planipennis*, *Bursaphelenchus xylophilus*, *Anoplophora chinensis, Bemisia tabaci*).

The Panel has developed two guidance documents (EFSA Panel on Plant Health (PLH), 2009; EFSA Panel on Plant Health (PLH), 2010a) defining the criteria for evaluating evidence used in support of the conclusion that an organism may pose a risk to plant health. In the above-mentioned guidance document (EFSA Panel on Plant Health (PLH), 2010a), it is explicitly stated that the EFSA procedures for pest risk assessment and the identification and evaluation of risk reduction options should be kept under review to take into account the experiences of the Panel and development work funded by EFSA under Article 36 of its founding regulation (EC) 178/2002 and by other organisations worldwide. Furthermore, in the same guidance document, a description of the full scheme "Identification of management options and evaluation of their effect on the level of risk and of their technical feasibility" is given (p. 54). In this context, indication is given regarding which aspects should be considered (e.g. effectiveness of combining measures, stringency, safety, applicability, etc.) and which should be excluded as being outside the EFSA remit, namely:

[8] Commission Regulation (EC) No 575/2006 of 7 April 2006 amending Regulation (EC) No 178/2002 of the European Parliament and of the Council as regards the number and names of the permanent Scientific Panels of the European Food Safety Authority. OJ L 100, 8.4.2006, p. 3.

[9] Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety.

- the decision on acceptability of the risk
- the selection of risk reduction options, and
- the evaluation of risk reduction options in terms of their cost-effectiveness and economic feasibility, minimal impact and non-discrimination.

Therefore, in the context of its past mandates, and considering the methodological advancements in the field of pest risk assessment, the Panel expressed a need to further develop guidance describing the methodology it considers to use when addressing the evaluation of risk reduction options.

This guidance document has been prepared by the Panel to address mainly the quantitative evaluation of the effectiveness of risk reduction options. When data and/or information are available, the quantitative methods described in this document can be applied. When only limited or no data and/or information are available, the Panel performs qualitative evaluations that are briefly described in this guidance document. The Panel developed this guidance document to be used for the assessment of risk reduction options together with the guidance on a harmonised framework for risk assessment (EFSA Panel on Plant Health (PLH), 2010a) and the guidance on the evaluation of pest risk assessments and risk management options prepared to justify requests for phytosanitary measures under Council Directive 2000/29/EC (EFSA Panel on Plant Health (PLH), 2009). The guidance provided in this document complements and does not replace the two above-mentioned documents when responding to requests for scientific advice on issues related to the evaluation of the effectiveness of options for reducing the phytosanitary risks within the EU in order to support the decision-making process under Council Directive 2000/29/EC.

1.1. Purpose of the document

The purpose of this document is to provide guidance for the Panel in order to support the decision-making process under Council Directive 2000/29/EC, when performing:

- the assessments of documents and technical files prepared by EU Member States or third parties to justify requests for phytosanitary measures to be considered by the European Commission under Council Directive 2000/29/EC, and
- the identification and evaluation of options for reducing the phytosanitary risks within the EU.

The present guidance document clarifies the types of information and the methods that may be considered by the Panel when evaluating the evidence provided to justify requests for phytosanitary measures for consideration by the European Commission under Council Directive 2000/29/EC. The focus is on quantitative approaches; however, qualitative methods to evaluate the effectiveness of the risk reduction options are also briefly addressed.

More specifically, the guidance document aims to:

- list the different types of information that need to be provided in order to assess risk reduction options
- present a database, including references, of some key documents (guidance documents, and documents presenting the results of experimental assessment of options) that may be useful to the Panel when assessing risk reduction options
- present possible statistical methods and quantitative tools for assessing risk reduction options.

The Panel has adopted the following definitions used in the present guidance document:

Risk reduction options (hereinafter referred to as RROs): options to reduce the risk of introduction and spread of a pest and/or the risk that a pest causes a biological impact. In consideration of EFSA principles of separation of risk assessment from risk management and transparency defined in EFSA's founding regulation EC No 178/2002, the Panel uses the term "risk reduction options" to replace "risk management options".

Effectiveness of a risk reduction option: capability of an option to reduce the risk caused by a harmful organism. In its assessment the Panel should also consider the reliability and reproducibility of the option, as well as noting the limitations of its application in practice, as recommended by the Panel (EFSA Panel on Plant Health (PLH), 2010a).

1.2. Methods

1.2.1. Checklist: required information and data for assessing risk reduction options

The information and data required for assessing the effectiveness of RROs were categorised, and a checklist was developed by the Panel. The checklist was then tested using seven RRO assessments submitted to the Panel (Table 1) and the criteria were adjusted and finalised.

The final checklist could be used both by the authors of the documents supporting a particular request and by experts commissioned to analyse this request. It includes five parts:

- description of the proposed RRO
- experimental assessment of the effectiveness of the presented option in reducing pest infestation in plant material/products under laboratory/controlled conditions
- experimental assessment of the effectiveness of the presented option in reducing pest infestation in plant material/products under operational conditions
- analysis of the applicability and feasibility of the proposed RRO
- assessment of the effectiveness of the proposed option in reducing the risk of pest entry from an infested area to a pest-free area.

1.2.2. Review of existing approaches

The literature review performed by the Panel concerned:

i) existing guidance documents on the assessment of RROs and published experimental assessments of RROs
ii) experimental designs, statistical methods, and quantitative tools for assessing RROs.

1.2.2.1. Review of existing guidance documents and of experimental assessments of risk reduction options

During the literature search, the principles of the extensive literature search (EFSA, 2011), corresponding to the first steps of a systematic review process (EFSA, 2010), were followed. After the literature search, a study selection was performed by the Panel to identify as many relevant studies as possible.

The fundamental aspects of the extensive literature search are the tailored search strategy/strategies (i.e. combination of search terms and Boolean operators) and the extensive list of information sources used (i.e. bibliographic databases and other sources, such as journal tables of contents). The process of extensive literature search is clearly reported to allow transparency and reproducibility and is an essential step of the systematic review process. Its output is an extensive collection of evidence (to be screened for relevance).

The extensive literature search was performed according to the following steps:

- Background legislation (Council Directive 2000/29/EC, emergency measures in the plant health field[10] and legislation concerning plant reproductive material) was screened and the cited RROs and requirements were extracted and categorised.

- The resulting classification was compared with the categories proposed in the relative International Standard for Phytosanitary Measures (hereinafter referred to as ISPM) (i.e. ISPM Nos 4, 11, 14, and others in FAO (2011)) and in the EFSA PLH guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options (EFSA Panel on Plant Health (PLH), 2010a).

- Seventeen categories of RROs were defined after the first two steps (see section 3.1.1).

- The literature search was conducted in the ISI Web of Knowledge by defining specific key words for each identified group and combining them in one or more strings (the full list of search strategies is presented in Appendix A).

- For each category, the Panel listed the documents considered as guidance (describing and prescribing the RROs), the documents in which the evaluation of specific RROs was described (e.g. field experiments, study designs and statistical and probabilistic models) and other documents of more general interest or not fitting into one of the predefined groups.

- The lists of references resulting from the specific literature searches were distributed among experts for screening for relevance, and if needed were reallocated to a more adequate category. The screening process was unmasked (the reviewer screened the abstracts considering the details of the articles: authors' names, year, editor, journal name). The full texts of the selected references were considered. The resulting lists of publications comprised peer-reviewed articles, PhD theses, technical reports from various organisations, and international, regional, and national guidance documents. In addition, miscellaneous literature was included as a result of specific searches in other more specific portals (Agricola, European Commission, EPPO, International Plant Protection Convention (IPPC), United States Department of Agriculture (USDA), Biosecurity New Zealand, Biosecurity Australia, etc.) and from the screening of the lists of references found within those previously selected documents described above.

- All documents were screened and selected for their relevance and included in a database of references (Appendix B).

1.2.2.2. Review of experimental or observational designs, statistical methods, and quantitative tools for assessing risk reduction options

Literature reviews were performed on the following topics:

- experimental designs for RRO assessment
- experimental designs for pest survey
- statistical methods for assessing option efficiency to reduce pest infestation
- quantitative pathway analysis (principles, advantages, limitations, examples)
- spread models (principles, advantages, limitations, examples)
- quantitative tools used by other EFSA Panels.

In each case, representative examples and key guidance documents were identified. Recommendations were formulated on the basis of the reviewed documents and on the Panel's past experience.

[10] http://ec.europa.eu/food/plant/organisms/emergency/index_en.htm

Information and data required to assess the effectiveness of risk reduction options

This section describes the information and data required by the Panel to assess the effectiveness of RROs. The items listed below can be used by the Panel to check whether all required information is provided to support a RRO and can also be used by the author of the submitted dossier to verify whether all the requested data are included.

1.3. Types of assessment

Four types of RRO assessments can be distinguished according to their purposes and characteristics:

i. experimental assessment of the effectiveness of the option for reducing pest infestation in plant material/products under laboratory/controlled conditions

ii. experimental assessment of the effectiveness of the option for reducing pest infestation in plant material/products under operational conditions

iii. analysis of the applicability of the RRO

iv. assessment of the effectiveness of the option for reducing the risk of pest entry from an infested area to a pest-free area.

The first two assessments aim to evaluate the capability of a given RRO to reduce pest infestation in plants, plant materials (e.g. wood packaging) or products (e.g. grains) either under laboratory/controlled conditions (type i) or under operational conditions (type ii). As a RRO found to perform well under laboratory/controlled conditions may not be as effective under operational conditions, these two types of assessment need to be distinguished (FAO, 2009a).

The third type of assessment aims to analyse the applicability of the RRO, more specifically how the option will be implemented (plan of implementation) and how its implementation will be monitored (e.g. how the temperature of a plant material will be monitored during a temperature treatment).

The fourth type of assessment aims to estimate the probability of pest entry in the EU territory (or part of this territory) when the considered RRO is implemented. This type of assessment differs from type i-ii assessments because it needs to take into account factors other than the effectiveness of the considered RRO to reduce pest infestation such as the quantity of exported plant product/material, survival during transport, detection at the border, etc. (e.g. Stansbury et al., 2002; EFSA Panel on Plant Health (PLH), 2010b).

Owing to their different purposes and characteristics, the four types of assessment defined above require different information and data, as explained in the next section.

1.4. A checklist for evaluating a proposed risk reduction option

The checklist presented below was derived from FAO (2009a), Bartell and Nair (2003), EFSA Panel on Plant Health (PLH) (2009), and from the information and data considered by the Panel in previous opinions. It can be used by experts to make a preliminary assessment of documents and data submitted to EFSA in support of RROs (e.g. a temperature treatment of plant material) and, more specifically:

- to quickly describe the information provided to EFSA to support a proposed RRO
- to identify major gaps in the documents and data submitted to EFSA
- to organise the work of the working group in charge of the dossier.

This checklist could also be used by the author of the submitted dossier to verify whether all the requested data have been provided.

Section 2.2.1 aims to describe the proposed RRO. When the option is based on a combination of several treatments, all treatments should be listed. Pest and plant material should be described, based on the information available in the submitted documents, and any discrepancies in the terms of reference should be mentioned in the "Comments" column.

Section 2.2.2 can be used by the experts to analyse the quality of any experiment carried out to assess the effectiveness of the proposed option (or combination of options) in reducing pest infestation under laboratory/controlled conditions.

When an experiment has been carried out to assess the effectiveness of a new option in reducing the pest infestation under operational conditions, i.e. under the conditions of actual implementation (same equipment and environment), the quality of that experiment should be evaluated in section 2.2.3.

Elements related to the applicability of the RRO and to its monitoring should be reported in section 2.2.4.

Finally, when a specific study has been performed to assess the effectiveness of the option in reducing the risk of pest entry from infested areas to pest-free areas (e.g. quantitative pathway analysis), the quality of that study can be analysed in section 2.2.5.

1.4.1. Description of the proposed risk reduction option

Item	**Description based on the submitted document(s)**	**Comments**
Name		
Target pest	(e.g. species, strain)	
Target plant material/product	(e.g. species, cultivar)	
Origin of plant material/product		
Type of RRO	(e.g. heat treatment, fumigation, combination of several treatments)	
Place of implementation		
Other relevant information		

1.4.2. Experimental assessment of the effectiveness of the option for reducing pest infestation in plant material/products under laboratory/controlled conditions

Source (indicate the reference of the supporting documents and data and their confidentiality status if applicable):

Item	**Description based on the submitted document(s)/data**	**Comments**
Plant material information		
Type of plant material/product used in the experiment		
Plant identity (e.g. botanical name, variety)		
Conditions under which plant materials/products are managed		
Conditions of the plant commodity (e.g. degree of ripeness, presence of bark, etc.)		
Pest information		
Identity (species, strains, biotypes as applicable)		
Conditions under which the pests		

are cultured, reared or grown		
Method of infestation		
Level of infestation		
Stage of the pest that is most resistant to the treatment		(Refer to research data if relevant)
Was the most resistant stage used in the experiment?		
Potential development of resistance to the option		
Experiment(s) description and analysis		
Variables used to measure effectiveness and target values	(e.g. mortality rate, count)	
Factors influencing effectiveness that were taken into account in the experiment	(e.g. wood humidity)	
Factors influencing effectiveness that were **not** taken into account in the experiment	(e.g. wood humidity)	
Description of facilities and equipment		
Description of treatment	(e.g. temperature/duration, chemicals, concentration, control/baseline)	
Methodology followed for monitoring critical parameters	(e.g. number and placement of temperature sensors)	
Description of experimental design	(e.g. randomisation, blocks, number of replicates)	
Presentation of the data		
Description of the statistical analysis	(e.g. analysis of variance, regression, test)	
Conclusions of the experiment		
Other relevant information		

1.4.3. Experimental assessment of the effectiveness of the option for reducing pest infestation in plant material/products under operational conditions

Source (indicate the reference of the supporting documents and data and their confidentiality status if applicable):

Item	Description based on the submitted document(s)/data	Comments
Plant material information		
Type of plant material/product used in the experiment		
Plant identity (e.g. botanical name, variety)		
Conditions under which plant materials/products are managed		
Conditions of the plant commodity (e.g. degree of ripeness, presence of bark, etc.)		

Pest information		
Identity (species, strains, biotypes as applicable)		
Conditions under which the pests are cultured, reared or grown		
Method of infestation		
Level of infestation		
Stage of the pest that is most resistant to the treatment		(Refer to research data if relevant)
Was the most resistant stage used in the experiment?		
Potential development of resistance to the option		
Experiment(s) description and analysis		
Variables used to measure effectiveness and target values	(e.g. mortality rate, count)	
Factors influencing effectiveness that were taken into account in the experiment	(e.g. wood humidity)	
Factors influencing effectiveness that were **not** taken into account in the experiment	(e.g. wood humidity)	
Description of facilities and equipment		
Description of treatment	(e.g. temperature/duration, chemicals, concentration, control/baseline)	
Methodology followed for monitoring critical parameters	(e.g. number and placement of temperature sensors)	
Description of experimental design	(e.g. randomisation, blocks, number of replicates)	
Presentation of the data		
Description of the statistical analysis	(e.g. analysis of variance, regression, test)	
Conclusions of the experiment		
Other relevant information		

1.4.4. Analysis of the applicability of the risk reduction option

Source (indicate the reference of the supporting documents and data and their confidentiality status if applicable):

Item	Description based on the submitted document(s)/data	Comments
Plan of implementation		
Place of implementation		
Characteristics of the treated material	(e.g. maximum size of the lot)	
Description of the required facilities and equipment		
The degree to which the proposed option complements	(e.g. potential for the treatment to be used as part of a systems	

other phytosanitary measures	approach for one pest or to complement treatments for other pests)	
Consideration of potential indirect effects	(e.g. impacts on the environment, impacts on non-target organisms, human and animal health)	
Monitoring of the plan		
Parameters that will be monitored	(e.g. wood temperature, presence of pest)	
Critical thresholds considered for these parameters	(e.g. minimum temperature value)	
Equipment used for the monitoring	(e.g. temperature probes, detection techniques)	
Other relevant information		

1.4.5. Assessment of the effectiveness of the option to reduce the risk of pest entry from an infested area to a pest-free area

Source (indicate the reference of the supporting documents and data and their confidentiality status if applicable):

Item	**Description based on the submitted document(s)/data**	**Comments**
Consignments		
Origin		
Type of commodities		
Surveillance	(e.g. survey, commodity inspection, monitoring etc.)	
Level of infestation of plant material/product		
Quantity and size of commodities		
Means of transportation	(e.g. boats, planes, trains, tourism)	
Detection method of the pest in the plant material/product		
Place(s) of implementation	(e.g. truck, harbour)	
Sampling technique	(e.g. size, unit, number of samples)	
Type of detection method	(e.g. visual inspection, laboratory test)	
Accuracy	(e.g. sensitivity, specificity)	
Point(s) of entry	(e.g. city)	
Variable used to describe probability of pest entry	(e.g. entry rate, probability, score)	
Conclusion of the assessment		
Other relevant information		

1.5. Analysis of data from the documents submitted to the Panel

The checklist presented in section 2.2 was applied to seven assessments related to RROs that were submitted to the Panel. These assessments are discussed in detail by the Panel in its published opinions

(Table 1). Three of these assessments concerned the pinewood nematode (*Bursaphelenchus xylophilus*), one concerned a fungus (*Tilletia indica*) and three concerned insects (*Agrilus planipennis*, *Bemisia tabaci* and *Anoplophora chinensis*). Four of the seven proposed RROs were temperature treatments (Table 1).

Three of the proposed options were based on experimental assessments under laboratory conditions (Table 1). A statistical analysis was reported by the authors in only one of these experimental assessments. In the other two, conclusions were derived without any statistical analysis of the data. None of the proposed options was assessed under operational conditions. Although the effectiveness of the option in reducing the risk of pest entry was addressed in three cases, such risk was assessed quantitatively in only one of the submitted documents (*T. indica*) using a quantitative pathway analysis. Finally, only one type of assessment was reported in each submitted document (with one exception for *T. indica*). As a result, it was not possible to fully assess RROs based on the information in the submitted documents.

Table 1: Risk reduction option (RRO) assessment requests submitted to the Panel

Pest	RRO	Experimental assessment under laboratory/controlled conditions	Experimental assessment under operational conditions	Analysis of the applicability of the RRO	Assessment of the effectiveness of the option for reducing risk of pest entry
Bursaphelenchus xylophilus	Treatment of wood shavings at a high temperature (398 °C), for a short period of time (3 min)	Yes (no statistical analysis of the data by the authors)	No	No	No
Bursaphelenchus xylophilus and insects (species not specified)	Not specified. Authorities are looking for alternative to the existing requirements	No	No	No	No, but a protocol was proposed to carry out the assessment
Bemisia tabaci	A cold treatment for strawberry transplants at 28 °F (–2.2 °C) for 2 weeks	Yes (no statistical analysis of the data by the authors)	No	No	No
Tilletia indica	Detection of bunted wheat kernels	No	No	Yes (partly)	Yes (quantitative assessment)
Anoplophora chinensis	Reduction in number of inspections. Two alternative proposals were submitted : Alternative 1: to allow grafting of scions from outside the cage Alternative 2: to remove the net from the field cage during the winter months	No	No	No	Yes (partly, no quantitative assessment)
Bursaphelenchus xylophilus	Heat treatment (56 ºC for 30 min)	No	No	Yes	No
Agrilus planipennis	Heat treatment of wood (60 °C for 60 min)	Yes	No	No	No

Review of existing approaches, experimental design, observational design, statistical methods and quantitative methods for assessing the effectiveness of risk reduction options

1.6. Literature review

1.6.1. General description of the selected documents

Selection of the categories for different RROs was based on EU legislation (Council Directive 2000/29/EC, emergency measures in the plant health field and legislation concerning plant reproductive material), on relevant ISPMs (FAO, 2011) of the IPPC, as mentioned in section 1.2.2.1 (Review of existing guidance documents and of experimental assessments of RROs), and on the EFSA PLH guidance on a harmonised framework for pest risk assessment (EFSA Panel on Plant Health (PLH), 2010a). According to ISPM No 11 (FAO, 2004a) appropriate measures should be chosen based on their effectiveness in reducing the probability of the pest introduction, and they can be classified into broad categories related to the pest presence in the pathway.

Based on the above, the following RRO categories were identified for the literature review:

Options for consignments

1. Prohibition.
2. Pest freedom: inspection or testing.
3. Prohibition of parts of the host or of specific genotypes of the host.
4. Pre- or post-entry quarantine system.
5. Phytosanitary certificates and other compliance measures.
6. Preparation of the consignment.
7. Specified treatment of the consignment/reducing pest prevalence in the consignment.
8. Restriction on end use, distribution and periods of entry.

Options preventing or reducing infestation in the crop

1. Treatment of the crop, field or place of production in order to reduce pest prevalence.
2. Resistant or less susceptible varieties.
3. Growing plants under exclusion conditions (glasshouse, screen, isolation).
4. Harvesting of plants at a certain stage of maturity or during a specified time of year.
5. Certification scheme.

Options ensuring that the area, place or site of production, remains free from the pest

6. Maintaining a pest-free area (PFA).
7. Pest-free production site.
8. Inspections, surveillance.

Options for other types of pathways

9. Natural spread, spread by human activities (people movement, transport, machinery, trade), vectors, phoresy.

Other relevant information

10. Other relevant information.

After extensive search for each category using methodology described in section 1.2.2.1, the search yielded 358 publications, comprising 347 full papers and 11 abstracts. These were not subjected to a systematic evaluation but certain key papers were identified from their titles and abstracts as relevant. After further reviewing the full text of these potentially relevant publications, 192 documents on assessing the effectiveness of RROs were chosen for application in this guidance document (see Appendix B), most of which comprised peer-reviewed articles and guidance documents issued by different authorities. In addition, a large number of publications emerged from specific searches carried out by the experts who developed this opinion.

The table presented in Appendix B includes some examples of existing guidance documents and articles on experimental assessments illustrating relevant RROs in a comprehensive manner. Therefore, to find the relevant RROs for a country–commodity–pest association, it is necessary to recognise the categories of options that could be considered, starting from the time of production in the field, through harvest and post-harvest practices up to the import process.

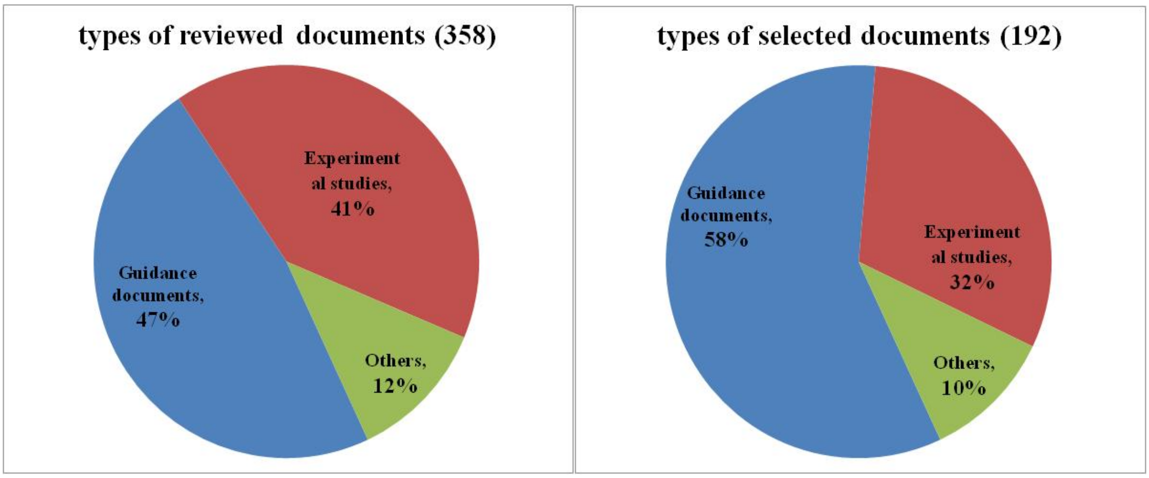
Examples of regulations from some countries were used as guidance for analysts in designing RRO recommendations that are compliant with the existing import requirements. However, the existing requirements stipulated in such regulations can be challenged according to Article 4 (Para 1) “Equivalence” of the Sanitary and Phytosanitary Agreement (SPS) of the World Trade Organization (WTO). In such cases, new options for reducing risk can be suggested if they are deemed to be equivalent in meeting countries’ appropriate level of protection (ALOP). The new options for such proposals can often be found in publications of an experimental nature, i.e. those testing survival of pests in commodities. Selecting guidance from publications based on experimental results found in research articles is not as straightforward as using adopted regulations. When assessing such publications it is important to examine the methodology for possible flaws, such as incomplete description of experimental design or inappropriate statistical methods used for data analysis (see sections 2.2, “A checklist for evaluating a proposed risk reduction option”, and section 3.2, “Experimental designs and statistical methods used for assessing risk reduction options” for specific guidance).

1.6.2. Results of the literature review

1.6.2.1. Summary of the results from the literature review

Of the 358 documents retrieved from the literature, 47 % were guidance documents, 41 % were documents presenting results of experimental assessment of RROs and 12 % were miscellaneous types of documents (mainly reviews) (Figure 1A).

Out of the 358 documents, only 192 relevant documents (55 %) were selected for further analysis (Figure 1). Of these, 58 % were guidance documents, whereas 32 % were experimental studies (Figure 1B).



A. B.

Figure 1: Typologies of reviewed and selected documents.

Figure 2 shows the proportion of selected documents in each RRO category. The distribution is rather uneven, with categories 7 and 18 being the largest and including 39 % and 19 % of the selected documents, respectively. Category 14, on the other hand, includes 7 % of the selected documents and categories 4 and 13 only 6 % each. Each of the remaining categories includes less than 5 % of the documents. Categories 5 and 12 do not include any documents.

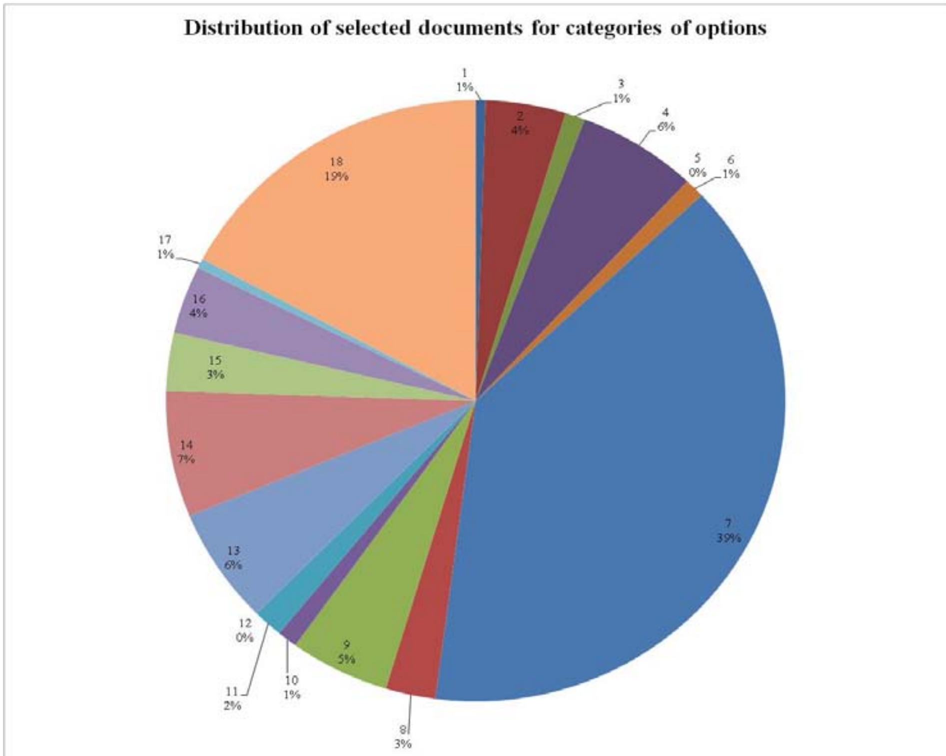
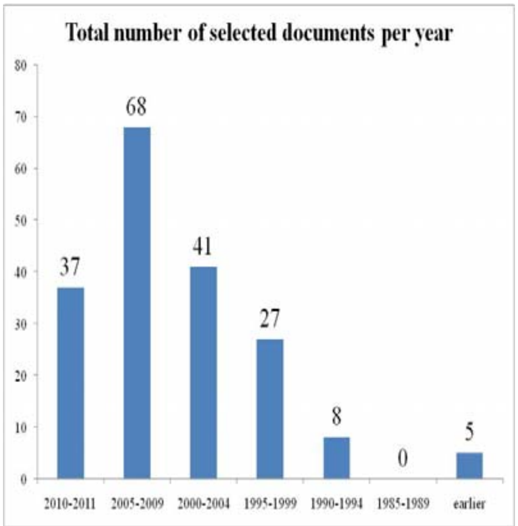
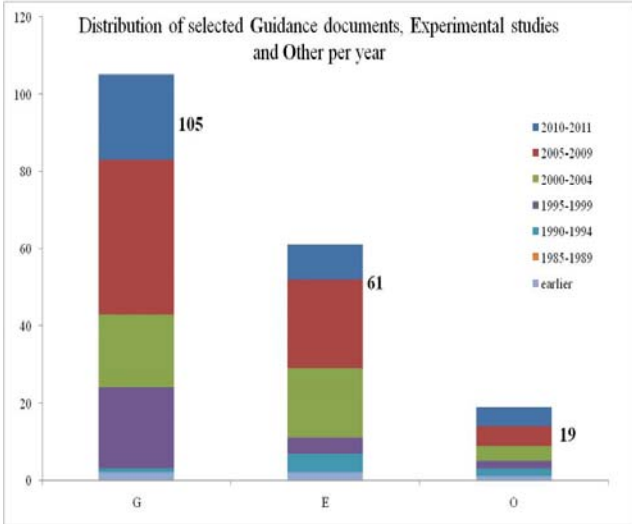


Figure 2: Proportions of papers allocated to the 18 risk reduction option categories.





A. B.

Figure 3: Distribution of the selected documents over time.

Figure 3 shows the distribution of the selected documents according to their year of publication. More than half of the selected documents (56 %) were published in the last 7 years, between 2005 and 2011 (Figure 3A). When classified in the three categories (guidance documents, experimental studies and others), the majority (57 %) of the selected documents were identified as guidance documents (Figure 3B). Among the guidance documents, the proportion of articles published since 2005 is higher than the general figure (59 %).

1.6.2.2. Detailed analysis for each category

- **Options for consignments**

Category 1: Prohibition

The most relevant guidance document within this category outlines the requirements for preventing the introduction into and spread within Canada of the emerald ash borer, *Agrilus planipennis* Fairmaire (CFIA, 2010). The document lists in detail all types of regulated articles that could harbour or sustain this pest throughout its life cycle, as well as the requirements for their domestic movement and importation from the continental United States. No experimental articles demonstrating effectiveness of the prohibition options were found within this group.

Category 2: Pest freedom, inspection or testing

Only 10 of the 25 reviewed documents were considered to adequately represent options for consignments that refer to pest freedom via inspection or testing. Six of the 10 selected documents are guidances and four are scientific articles presenting experimental results on inspection or testing. Among relevant examples is guidance on detection and surveillance for tomato leafminer, *Tuta absoluta*, using trapping (USDA APHIS, 2011b). Of interest are also measures (including inspection) for a group of pests in sweet oranges from Italy imported to Australia (Biosecurity Australia, 2005). Other relevant documents include sampling for detection of pine wood nematode in trees, wood and insects (Schröder et al., 2009) and analysis of probit 9 as a standard for quarantine security (Chew, 1996). Among the experimental articles demonstrating effectiveness of the inspection or testing, four documents were found relevant. Examples include Elmouttie et al. (2010) discussing the importance of choosing the most appropriate biological model when developing sampling methodologies for insect pests in stored grain and Vail et al. (1993) on a biological approach to decision making for selected hosts of codling moth.

Category 3: Prohibition of parts of the host or of specific genotypes of the host

This category includes only two examples: one guidance document from a regulatory agency (CFIA, 2008) and one concept document under the category "other" (Armstrong, 1994). The concept document is based on using infestation-resistant or non-host commodities, cultivars, stages of maturity and appropriate growing periods to achieve pest-free production. The regulatory document forms a basis for a Canadian barberry certification programme prohibiting the importation and movement of certain varieties of barberry nursery stock that are susceptible to rust.

Category 4: Pre-entry or post-entry quarantine systems

This group includes 10 relevant guidance documents and five experimental papers. Several USDA APHIS manuals provide guidance on specific methodologies for inspecting different types of quarantine commodities. Two protocols from Australia for quarantine detection of *T. indica* in wheat were also considered relevant. Among statistical guidance documents of interest is a publication emphasising binomial-, β-binomial- and hypergeometric-based sampling strategies relevant to quarantine inspections for exotic pests (Venette et al., 2002). Experimental articles on visual inspection include sampling for injury in quarantine protection of fruit (Yamamura and Katsumata, 1999) and detection of the nematode *B. xylophilus* in wood packaging material based on morphology and intergenic transcribed spacer restriction fragment length polymorphism (Gu et al., 2006). Also included is an article on polymerase chain reaction detection tools for phytoplasmas in fruit trees (Heinrich et al., 2001).

Category 5: Phytosanitary certificates and other compliance measures

A phytosanitary certificate is an attestation by the exporting country that the requirements of the importing country have been fulfilled. Although the use of phytosanitary certificates is implemented by IPPC members, no scientific publications were found in their support as a RRO.

Categories 6 and 7: Preparation of the consignment and specified treatment of the consignment/reducing pest prevalence in the consignment

Results from the systematic literature search for these two groups were numerous but overlapping and were thus combined for the purpose of this discussion. Many guidance documents from plant protection organisations (e.g. EPPO, USDA APHIS) represent treatments of consignments applied either as a single RRO or in combination with other measures in a systems approach. Examples include heat treatment, irradiation and chemical treatment and fumigation alternatives to methyl-bromide (USDA APHIS, 2011a). Many experimental studies were of dose–response relations for treatments of wood and wood packaging material (Mushrow et al., 2004; Myers et al., 2009). Some publications demonstrate the possible failure of ISPM No 15 requirements to eradicate pests (Encinas and Briceño, 2010; Goebel et al., 2010). Several papers describe experiments intended to develop methods for effective replacement of methyl-bromide fumigations (e.g. Gupta, 2001**)**. A number of papers discuss the feasibility and limitations of the probit 9 mortality standard (originally developed for eradication of fruit flies in fruit consignments) for other types of pests and commodities (e.g. Follett and Neven, 2006; Haack et al., 2011). A review of statistical methodology to assess the effectiveness of treatments in consignments is discussed in Mangan and Sharp (1994).

Category 8: Restriction on end use, distribution and periods of entry

We found no publications on experiments demonstrating the effectiveness of either of these options. An example of a restriction on the end use is the processing of imported commodities (e.g. juicing, slicing or peeling) instead of the consumption of unprocessed fresh fruit and vegetables. The processed commodities are allowed to enter without permit or phytosanitary certificate, thus meeting the ALOP for the United States. Limitations on the distribution of fresh commodities potentially infested with internal pests are requirements to enter exclusively through ports located north of 39° latitude and east of 104° longitude. This assumes that pest survival will be limited by environmental factors (suitable temperature and available hosts). Limitation can also relate to certain periods of the year, e.g. in some situations, entry is allowed from 1 December to 30 April only with additional safeguarding practices (i.e. using insect-proof material to cover the harvested commodity).

- **Options preventing or reducing infestation in the crop**

Category 9: Treatment of the crop, field, or place of production in order to reduce pest prevalence and possibly achieve areas of low pest prevalence

Differing from the establishment of PFAs (see category 14), this option, which is described in ISPM No 22 (FAO, 2005), aims at establishing areas of low pest prevalence (ALPPs) for regulated pests in an area and, to facilitate export, for pests regulated by an importing country only. These measures can be combined with other options such as categories 6–8. The relevant literature comprises reviews, guidance documents and experimental articles on control of quarantine pests in various crops (i.e. ornamentals, fruit trees, grapes and vegetables), including pest and disease management in the crop and post-harvest treatment (e.g. Jamieson et al., 2009; Jackson et al. 2010**)**. Some examples of relevant publications include but are not limited to testing treatment effectiveness of fumigation (Zettler et al., 2002) and biological control of pests with parasitoids (El-Wakeil et al., 2008**)**.

Category 10: Resistant or less susceptible species (varieties)

RROs using resistant or less susceptible species or varieties as a sole measure do not often prove to be effective enough to prevent the introduction of a quarantine pest. This might explain why only a few papers were found in support of this option. A relevant example by Badiger et al. (2011) describes an experiment in which cotton hybrids containing the Bt gene were successfully used against pink bollworm and tobacco caterpillar. Promising results were obtained by Zehnder et al. (1997) in a cucumber crop experiment studying the effect of resistance induced by growth-promoting rhizobacteria on the cucumber beetle. Research by Aluja et al. (2004) demonstrated that the commercially cultivated and marketed avocado cultivar Hass should not be considered a natural host for *Anastrepha ludens*, *A. striata*, *A. sermentina* and *A. obliqua* fruit flies in Mexico. This study formed the basis for the importation requirements of Hass avocado to the United States under a systems approach, without specific treatment against the above-mentioned *Anastrepha* spp. (USDA APHIS, 2011a; CFR, 2011a,b).

Category 11: Growing plants under exclusion conditions (glasshouse, screen, isolation)

Only three guidance-type documents were found relevant to this group, all of which were devoted to biological control. Albajes et al. (1999) authored a book that provides the basic strategies and tactics of integrated pest management, with special reference to greenhouse crops and a pre-eminence of biological control. The second publication (Mahr et al., 2001) was also a book reviewing biological control of pests in greenhouses. The third publication (Yano, 2006) reviewed the ecological bases for the biological control of aphids in a protected environment, evaluation of biological control agents, natural enemy release strategies and the effects of intraguild predation on biological control.

Category 12: Harvesting of plants at a certain age or a specified time of year

Only **a** few relevant documents were found for this group. Examples include regulations for the importation into the United States of green tomatoes from several regions (e.g. Central America, the Mediterranean) that are admissible without treatment, while tomatoes with pink or red fruit are subject to certain risk mitigation requirements, depending on the country of origin (CFR, 2011a; USDA APHIS, 2011a).

Category 13: Certification scheme

Options for preventing or reducing infestation by certification system are very common in quarantine practice everywhere in the world. Many papers were found from different countries, including the EPPO region, with certification schemes for various crops – seed potatoes, *Rubus* spp., rose, freesia, hyacinth, narcissus, petunia, kalanchoe, apple, pear, quince, cherries, almond, apricot, peach and plum. Usually this method is used against organisms that can be introduced or spread by planting material (e.g. viruses) and where other methods, i.e. chemical control, are not available. These options require systematic sampling and pathogen testing so that the certification system can guarantee healthy, pest-free planting material.

- **Options ensuring that the area, place or site of production or crop is free from the pest**

Category 14: Maintaining a pest-free area

The majority of selected documents are guidelines from different parts of the world. The relevant ISPMs (FAO, 2011) include Nos 4, 6, 8, 9, 10 and 26, of which No 4 on the establishment of PFAs is the most important. Among national plant protection organisation (NPPO) guidances, we note the guidelines for a fruit fly systems approach by USDA APHIS (2003), developed to prevent the risk of the introduction of fruit flies from Mexico to the United States via traded host commodities. A guidance document from India for tephritid fruit flies (PQOI, 2005) was also selected and describes the requirements for the establishment, maintenance and verification of fruit fly-free areas in the country. From the regional guidelines, we selected the EPPO standard PM 9/10(1) for containment and eradication of plant pests, which describes the generic elements for contingency plans (EPPO, 2009). Also of interest is Schröder et al. (2009**)** describing sampling for detection of the pine wood nematode in trees and wood, which is very important for establishing areas free from this pest. The experimental paper of Melifronidou-Pantelidou (2009) concerns the survey, delimitation of infested areas and establishment of PFAs for the red palm weevil, *Rhynchophorus ferrugineus*, in palm tree cropping. Sosnowski et al. (2009) present a review article on the eradication of various plant pathogens using burning, burying, pruning, composting, soil fumigation and biofumigation, solarisation, steam sterilisation and biological vector control.

Category 15: Pest-free production site
The most relevant documents retained for this option are in FAO (2011), the ISPMs No 4, 6, 8, 9 and 10, of which the most important is ISPM No 10 on the requirements for the establishment of pest-free places of production and pest-free production sites. As with RRO category 14, Schröder et al. (2009) is also relevant to the establishment of pest-free production sites.

Category 16: Inspections and surveillance
One of the most relevant documents for the assessment of surveillance and inspection as a RRO is guidance from Australia for the survey of plant pests in the Pacific area (McMaugh, 2005). This manual assists plant health scientists in devising surveillance programmes and transmitting specimens to the laboratory for identification and preservation. Of equal importance is the USDA (2011) post-entry manual for state inspectors for surveillance. Other publications of importance include Wardlaw et al. (2008), which compare different surveillance techniques for the assessment of disease and pest impact in forests and their limitations. Also of interest are the studies of Sigvald and Hulle (2004), which reports on two models that assist in monitoring and forecasting the spread of a virus in potato crops, and Dallot et al. (2004), which presents models for assessing the impact of a cultural technique on the spread and persistence of a plum pox virus.

- **Options for other types of pathways**

Category 17: Natural spread and spread by human activities (movement of people, transport, machinery), vectors and phoresy
Options preventing the introduction of pests by natural spread practically do not exist; consequently, no papers illustrating these options were found. Spread by human activities is a very important and common pathway. Trade can be regulated by legal methods (prohibition, specific requirements, etc.); this is already discussed in other categories for RROs. Some treatment and disinfection methods can be used to reduce the spread of pests by human activities. Some of the relevant examples are Heather et al. (1991) on the disinfestation of fruit flies in mango with gamma irradiation and Evans et al. (2007) on prevention of the spread of *B. xylophilus* from Portugal using an intensive monitoring system.

Category 18: Other relevant information
This group includes a significant number of relevant documents that cannot, however, be associated with a specific type of RRO identified above. Some of these documents present general principles ensuring the safety of commodities. Others deal with a wide range of options (e.g. pre-harvest treatment, post-harvest treatment, pest detection) and provide useful information about system approaches. Five of the selected documents allocated to this group describe quantitative risk models estimating the probability of the introduction of pests depending on the type of RROs implemented in

the pathway. Although these models were developed for specific pests, they can be adapted by the Panel to deal with pests other than those considered in the selected papers. Eight documents allocated to this group describe the phytosanitary requirements for importation of different commodities into New Zealand and the United States. This group also includes several manuals for inspection, monitoring and treatment of plant commodities and provide information about the practical implementation of several RROs.

1.6.2.3. Database including the references of the selected documents

After the literature review, a database of references of documents useful for Panel members when writing opinions on RROs was developed. The database is divided into 19 groups:

- The first group contains seven opinions on RROs (Table 1) and two guidance documents produced by the Panel before 2012.

- The next 18 categories include the documents ranged according to the type of RRO. These folders were divided into two subgroups each: one with guidance documents and the other with reports of an experimental nature.

The references of the selected documents are included in the summary table available in Appendix B.

1.7. Experimental designs and statistical methods used for assessing risk reduction options

The assessment of RROs depends on the nature of these options. Among the 18 categories deriving from ISPM No 11 (FAO, 2004a) which we considered above, all have to be operationally assessed by surveillance (surveys and sampling) in real time. In addition, six of these options must also be developed and assessed experimentally before and after practical implementation.

1.7.1. Experimental designs for assessment of risk reduction options

ISPM No 28 (FAO, 2007a) provides a series of annexes that define criteria for treating specific commodities.

The six categories of RROs described in ISPM No 11 (FAO, 2004a) that need to be experimentally developed and tested, and assessed after implementation, are described in Table 2.

Table 2: Risk reduction options that need experimental development prior to implementation and experimental assessment after implementation

Category	**Treatment**	**Experimental assessment**
Category 6 – Options for consignments – Preparation of the consignment	e.g. handling to prevent infestation or reinfestation	Experimental comparison of the prepared shipment with an unprepared control lot or with a control lot containing a known quantity of naturally or artificially contaminated material
Category 7 – Options for consignments – Specified treatment of the consignment/Reducing pest prevalence in the consignment	Such treatments are applied post-harvest and could include mechanical, chemical, irradiation, physical and controlled atmosphere treatments	Specific treatments to be tested on samples with material naturally or artificially contaminated with a known quantity of the pest
Category 9 – Options preventing or reducing infestation in the crop – Treatment of the crop, field or place of production in order to reduce pest prevalence and possibly achieve areas of low pest prevalence	Chemical control, cultural control, biological control	Experimental comparison of treated and untreated plots
Category 10 – Options preventing or reducing infestation in the crop	Resistant varieties, cultivars, species	Experimental comparison of pest prevalence on different varieties, cultivars or species

– Resistant or less susceptible varieties		
Category 11 – Options preventing or reducing infestation in the crop – Growing plants under exclusion conditions (glasshouse, screen, isolation)	Glasshouses, greenhouses, *in vitro* culture, plastic foil	Comparison of the levels of pest prevalence with or without exclusion conditions
Category 12 – Options preventing or reducing infestation in the crop – Harvesting of plants at a certain stage of maturity or during a specified time of year	Early or late planting or sowing, early or late harvesting	Comparison of the levels of pest prevalence under different conditions of planting/sowing or harvesting

A comprehensive analysis of the many experimental methods for testing RROs exceeds the scope of this mandate, and therefore the Panel restricted itself to specific treatments of consignments in view of reducing pest prevalence as addressed in category 7, above.

ISPM No 28 (FAO, 2007a) presents in its annexes phytosanitary treatments evaluated and adopted by the Commission on Phytosanitary Measures (CPM). It also describes the requirements for submission and evaluation of the effectiveness data and other relevant information on a phytosanitary treatment that can be used as a phytosanitary measure after adoption. National and regional plant protection organisations may "submit data and other information for the evaluation of effectiveness, feasibility and applicability of treatments. The information should include a detailed description of the treatment, including effectiveness data, the name of a contact person and the reason for the submission. Treatments that are eligible for evaluation include mechanical, chemical, irradiation, physical and controlled atmosphere treatments. The effectiveness data should be clear and should preferably include data on the treatment under laboratory or controlled conditions as well as under operational conditions."

These criteria are included in the checklists presented in sections 2.2.2 (Experimental assessment of the effectiveness of the option for reducing pest infestation in plant material/products under laboratory/controlled conditions) and 2.2.3 (Experimental assessment of the effectiveness of the option for reducing pest infestation in plant material/products under operational conditions). These checklists, however, have a larger coverage, including plant material information and pest information; the Panel checklist includes additional items such as factors influencing effectiveness not taken into account in the experiments, the methodology for monitoring critical parameters, the presentation of the data, the description of the statistical analysis and the conclusions of the experiment. A comparison between the criteria presented in ISPM No 28 (FAO, 2007a) and the checklists prepared by the Panel is presented in Appendix C.

ISPM No 28 presently provides 14 annexes (FAO, 2007a), all of which define criteria for post-harvest treatments of fruit crops for the following species: *Anastrepha ludens, A. obliqua, A. serpentina, Bactrocera jarvisi, B. tryoni, Cydia pomonella,* Tephritidae (generic), *Rhagoletis pomonella, Conotrachelus nenuphar* and *Grapholita molesta* by irradiation; and *Cylas formicarius elegantulus, Euscepes postfasciatus* and *Ceratitis capitata* under hypoxia. Minimal irradiation doses range from 60 to 232 Gy (1 Gy = 1 gray = 1 J/kg), with values for the effective dose (ED) ranging from 99.9921 to 99.9980 Gy at the 95 % confidence level. These annexes explicitly accept a certain level of extrapolation, which extends to all fruits and vegetables because dosimetry systems measure actual radiation dose absorbed by the target pest independent of host commodity. ISPM No 18 (FAO, 2003), "Guidelines for the use of irradiation as a phytosanitary measure", describes the procedures to be followed and criteria to respect for irradiation treatments. The NPPO of the importing country has the liberty to define the treatment effectiveness by providing a precise description of the required response and its expected statistical level.

Another commodity, wood packaging material, is regulated by ISPM No 15 (FAO, 2009b). As emphasised by Haack et al. (2011), the 2009 revision reduced the initial scope ("practically eliminate the risk for most quarantine pests and significantly reduce the risk from a number of other pests that may be associated with wood packaging material") to a less ambitious objective ("reduce significantly the risk of introduction and spread of most quarantine pests"). According to ISPM No 15, wood packaging material must be treated at the core to 56 °C for 30 minutes. This norm is based on two reports (EOLAS, 1991; Smith 1991) and one conference proceeding (Smith, 1992). It was originally established against the pine wood nematode, *B. xylophilus.* Alternative treatments that are more environmentally friendly are being pursued (FAO, 2010). For the establishment of these alternative treatments, precise criteria have been defined, based on two requirements:

(i) identification of the most treatment-resistant test organism and life stage and establishment of its susceptibility to the proposed treatment

(ii) detailed effectiveness testing of this most resistant species to provide confidence that treatment is effective against all pests.

Requirements for treating firewood against the emerald ash borer, *A. planipennis*, have been developed in the United States. In 2008, the United States authorities (USDA APHIS, 2008a) adopted a heat treatment schedule against the emerald ash borer in firewood of 71.1 °C for 75 minutes. This treatment, however, was initially developed to control basidiomycete fungi on Douglas fir poles (Newbill and Morrell, 1991). Based on a study by Myers et al. (2009), the modified temperature/time norm for the United States was reduced to 60 °C for 60 minutes (USDA APHIS, 2011c). The Panel questioned the effectiveness of this proposed treatment (EFSA Panel on Plant Health (PLH), 2011a) based on the data provided.

Based on the available literature, there is a considerable level of uncertainty regarding the effectiveness of these different treatments, because they were established against particular species that were not necessarily the most treatment-resistant test organisms or life stage which cannot be automatically extrapolated. Although the 56 °C for 30 minutes norm is considered acceptable against the pine wood nematode, *B. xylophilus* (ISPM No 15: FAO, 2009b), a higher norm (60 °C for 60 minutes) was established by Myers et al. (2009) to treat firewood against the emerald ash borer, *A. planipennis*, and was adopted by the United States authorities. To add to this uncertainty, this latter norm has been questioned since by one experimental study (Goebel et al., 2010) and one statistical re-analysis of the results of Myers et al. (2009) (EFSA Panel on Plant Health, 2011a). Another element of high uncertainty is the unpublished nature of the sources for the norm used in ISPM No 15 (EOLAS, 1991; Smith, 1991; Smith, 1992).

From the examples above, and referring again to its checklist, the Panel concluded that it is of the utmost importance for any experimental assessment that the objectives of a proposed RRO (e.g. expected infestation levels, pest incidence) are clearly established.

1.7.2. Surveillance

1.7.2.1. Surveillance and risk reduction options

Surveillance is an obligatory element of plant health risk reduction. Under the IPPC,

- NPPOs are obliged to perform:
    - the surveillance of growing plants, including both areas under cultivation (*inter alia* fields, plantations, nurseries, gardens, greenhouses and laboratories) and wild flora, and plants and plant products in storage or in transportation, particularly with the object of reporting the occurrence, outbreak and spread of pests, and of controlling those pests, (Art IV-2-b)
    - the protection of endangered areas and the designation, maintenance and surveillance of pest free areas and areas of low pest prevalence (Art IV-2-e)

and

- contracting parties shall, to the best of their ability:

- conduct surveillance for pests
- develop and maintain adequate information on pest status in order to support categorisation of pests, and for the development of appropriate phytosanitary measures. This information shall be made available to contracting parties, on request. (Art VII-2-j).

According to ISPM No 6 “Guidelines for surveillance” (FAO, 1997), surveillance may consist of any combination of “general surveillance: and “specific surveys”. General surveillance for plant health risk is the systematic collection, verification and compilation of qualitative and quantitative information from a wide range of sources on particular pests that are of concern for an area, so that it is available for use by the NPPO. Specific surveys for plant health risk are procedures by which NPPOs obtain information on pests of concern through structured, representative sampling on specific sites in an area over a defined period of time. ISPM No 6 serves as a reference for other ISPMs:

- Determination of pest status in an area in ISPM No 8 (FAO, 1998).
- Requirements for the establishment of pest free areas in ISPM No 4 (FAO, 1995).
- Requirements for the establishment of pest free places of production and pest free production sites in ISPM No 10 (FAO, 1999).
- Requirements for the establishment of areas of low pest prevalence in ISPM No 22 (FAO, 2005).
- Establishment of pest free areas for fruit flies (Tephritidae) in ISPM No 26 (FAO, 2006).
- Recognition of pest free areas and areas of low pest prevalence in ISPM No 29 (FAO, 2007b).
- Establishment of areas of low pest prevalence for fruit flies (Tephritidae) in ISPM No 30 (FAO, 2008a).

Several RROs require information from surveillance. Depending on the perceived risk of the pest, the current state of information on pest occurrence and the specific RRO, the emphasis may be on general surveillance or on specific surveys, as illustrated in Table 3.

Table 3: General surveillance and specific surveys

Risk component	Required surveillance
Maintenance of official pest list	In the importing country, general surveillance of cultivated and non-cultivated plants is required to maintain adequate information on pest status (ISPM No 6 in FAO (1997)), and may be required to support pest listing (ISPM No 20 in FAO (2004b))
Probability of entry	General surveillance in the exporting country, as required by the importing country, to demonstrate pest absence (ISPM No 4, 10 and 26 in FAO (1995, 1999, 2006) or low pest prevalence (ISPM No 22 and 30 in FAO (2005, 2008a)) in the area of origin of the commodity. This area of origin can be referred to as the country, an area within the country, a place of production or a production site. Additional requirements for the area may be formulated, e.g. a buffer zone, or the “immediate vicinity” of a place of production. Depending on the current distribution of the pest in or near the area of origin and the potential impacts of the pest in the importing country, the importing country may require a detailed plan for specific surveys (describing the power of the survey) and quantitative reports of specific surveys, including risk maps of the area.
Probability of establishment	The importing country may perform repeated, specific surveys at points of entry and at importing companies and their environments for early detection of pest presence and subsequent eradication
Probability of	The importing country may perform specific surveys to delimit the infested area in order to

spread	contain the pest within the boundaries of the infested area
Impact of pest occurrence	The importing country may perform general surveillance and specific surveys in order to monitor pest prevalence in the country as part of official control programmes

1.7.2.2. Quality criteria for general surveillance

In order to conclude on the absence or low prevalence of a pest, general surveillance reports must be based on systematic collection, verification and compilation of information on the pest in the area by plant health experts.

ISPM No 6 provides guidance on how to conduct systematic general surveillance, including the distribution of reports derived from surveillance, but does not provide details on the reports. In turn, ISPM No 8 provides guidance on good reporting practices that mostly concern the accuracy, timeliness and completeness of the reports, without indicating specific information that should be included to ensure such completeness. This is also not covered in ISPM No 17 (FAO, 2002), which provides guidance on reporting immediate or potential danger.

The Panel recommends that reports of general surveillance for the purpose of developing RROs by the NPPO or the NPPO's trading partners should include the following information:

- Identification of the pest of concern
- A description and clear demarcation of the area for which general surveillance is performed.
- A hypothesis on the presence or absence of the pest of concern in this area.
- A description and listing of data sources used in the general surveillance (e.g. NPPO pest records, communications with extension officers, producers and trading companies, reports from research institutes, trade data, etc.).
- An evaluation of the potential presence of the pest in the area of concern based on:
    - the current and recent distribution of the pest within and near the area
    - the climatic and other ecological conditions of the area for development of pest populations
    - the presence of host plants or other potential niches suitable for pest populations in the area
    - the import and trade rates of distinguished host plant products in the area.
- A discussion of the actual presence of the pest in the area, based on all information obtained.
- If the pest is present at low prevalence in the area, additional information needs to be presented characterising the nature the pest distribution in the area. The IPPC defines an ALPP as "an area, whether all of a country, part of a country, or all or parts of several countries, as identified by the competent authorities, in which a specific pest occurs at low levels and which is subject to effective surveillance, control or eradication measures". This definition is ambiguous. It covers situations in which many fields are infested but at a low incidence in each field as well as situations in which only a few fields in the area are infested but possibly at high incidence levels. In both cases, the pest would occur at low levels in the area. However, the different distributions may require different sources of information. As ALPPs may be established for different purposes, the size and description of the ALPP will depend on the purpose. Specified levels for the relevant pests should be established by the NPPO of the country in which the ALPP is located, with sufficient precision to allow

assessment of whether surveillance data and protocols are adequate to determine that pest prevalence is below these levels (ISPM No 22; FAO, 2005).

- A clear conclusion on the pest status (ISPM No 8; FAO, 1998) in the area of concern.

1.7.2.3. Quality criteria for specific surveys

Just as the inspection of a sample from a consignment of plants cannot give certainty about the absence of pests in the consignment, no survey can demonstrate the absence of a pest in an area with 100 % certainty. The level of uncertainty of the results of the survey or, inversely, the confidence level of the survey needs to be specified in order to recognise the value of its results. For that purpose, the area under investigation can be considered as a population of potential niches for the pest under investigation, in which each potential pest niche has the binary characteristic of either being infested or free from the pest. Depending on the target of the survey, a potential niche can be defined as a plant of a host species, a field planted with a host crop, a landscape element (a length of river shore or a natural stand with host plants), a storage facility for host plant products, etc. A survey to determine pest absence/presence can then be considered as a sample of inspected pest niches from the population of total potential niches in the area, and the number of presences follows a hyper-geometric distribution. When the number of potential pest niches is large relative to the number of observed niches in the survey, this distribution is approached by the binomial distribution. Hence, the statistical basis for these surveys is similar to that for the sampling of consignments to determine pest freedom (see ISPM No 31; FAO, 2008b), and the recommendations for design and analysis described in ISPM No 31 may be applied to surveys for determining pest absence. However, the definition of the potential pest niches may be difficult (e.g. in the case of polyphagous pests of ornamental plants), and a poor definition may decrease the value of the survey.

In statistics, the power of a statistical test is the probability of rejecting the null hypothesis when the null hypothesis is false (see, for example, EFSA Scientific Committee, 2011). For specific surveys with the purpose to demonstrate the absence or presence of a pest in an area, a null hypothesis may be formulated as “the pest is absent in the area”. Under the following assumptions the survey may be designed based on the binomial probability distribution (Venette, 2010):

- the total number of potential pest niches is large relative to the number of infested pest niches

- infested niches are randomly distributed in the area, and

- each observation is 100 % effective in detecting a pest if it is present.

The probability of a type II error (β) of the survey, i.e. concluding that the pest is absent when it is actually present (false absence), is calculated as $(1 - p)^n$, where n is the number of potential pest niches in the survey and p is the minimum fraction of infested niches in the area under investigation above which detection is required.

The power of the survey, or its confidence level, i.e. the probability of concluding that the pest is present when it is actually present (probability of true presence), then equals $1 - \beta$. The value of p is set arbitrarily in relation to the expected level of confidence.

Our capability to correctly conclude on a pest’s presence can be improved by increasing the number of surveyed potential pest niches, but it is reduced when the required level of detection is set to a lower value.

In reality the confidence level may be lower than the theoretical value, if:

- The distribution of the pest in the area is aggregated rather than random. The level of aggregation of the pest in the area is not known in advance of a survey, but it may be estimated from the biological characteristics of the pest. The survey may then be based on more complex statistical models, e.g. a β-binomial distribution (Venette et al., 2002) or the negative binomial distribution (Schomaker and Been, 1999; Binns et al., 2000).

- The effectiveness of each single observation is less than perfect (e.g. when individuals of the pest are hidden, or when the survey is performed at a time when the pest has not developed symptoms or visible life stages).

The confidence level may be increased by:

- timing the survey according to environmental conditions that are optimal for host plant growth, pest population development (in particular visible life stages) and symptom expression

- targeting the observations using knowledge of pest biology, area characteristics and the distribution of host plants and other potential pest niches in the area

- the use of traps and lures (extensively discussed in PRATIQUE (2011) final report)

- the training of inspectors

- laboratory testing of samples, where appropriate (ISPM No 6; FAO, 1997).

Several papers discuss methodologies for the optimisation of survey design. Probability-based designs such as (stratified) random sampling and cluster sampling have the advantage of producing unbiased estimates of proportions and variances (Snedecor and Cochran, 1980). Barron (2006) concluded that the results of random sampling, as opposed to those of cluster sampling, are not affected by aggregation of the pest at low incidence levels and, therefore, random sampling is preferred over cluster sampling when the level of aggregation is unknown. Huebner (2007) compared four sampling methods to detect and monitor invasive exotic plants and concluded that the timed-meander method performed best in detecting exotic invasive plant species, followed by stratified random sampling. Demon et al. (2011) also showed that random sampling may not yield the highest detection probabilities. They compared a modelling framework using simulated annealing with four other survey designs and found that simulated annealing, probability map sampling and distance-based sampling resulted in larger detection probabilities than (stratified) random sampling. However, the simulated annealing method requires epidemiological information, in particular the source of infestation, as well as detailed knowledge of the environment and the distribution of potential pest niches in the area, and hence may not be always applicable.

The Panel recommends that reports of specific surveys for use in plant health risk reduction meet the following qualifications:

- demarcation of the area for which the survey is performed and the year of the survey

- identification of the pest under survey and a description of its ecology and biology in relation to the environmental characteristics of the area, relevant to survey objectives

- quantitative information on host plants and other potential pest niches present in the area (number of fields/locations, area covered with host plants, etc.) and maps of their distribution

- formulation of a survey hypothesis (pest X is absent in the identified area)

- explanation of the applied mathematical background (e.g. binomial distribution, β-binomial distribution) and its justification

- sampling method (e.g. random sampling, stratified sampling, planned number and timing of observations, timing of observations)

- confidence level (the survey has 95 % confidence to detect the pest in the area if it is present at or above the level of p);

- the methodology and instruments for performing an individual observation, including the use of traps, lures and laboratory testing

- results of the survey, i.e. the list of observations, including for each observation the date, the geographical reference of the potential pest niche, the observation method and details and the result of the observation, as well as maps presenting the results of observed and total potential pest niches in the area)

- a clear conclusion of the survey and formulation of pest status according to the procedures described in ISPM No 8 (FAO, 1998).

1.7.2.4. Integrating general surveillance and specific surveys.

Martin et al. (2007) compared the strengths and weaknesses of general surveillance and specific surveys as tools for demonstrating the absence or presence of a pest. They presented a method based on scenario trees to integrate the information from both approaches in order to quantitatively estimate the probability that an area is free from a pest. Using all available data, Barrett et al. (2010) presented a remarkably similar approach to the design of surveillance systems using data from multiple sources and decision trees, although no reference to Martin et al. (2007) was made. In both papers the concept of "survey system component" (SSC) is introduced, whereby each SSC refers to a separate data source, with its specific sensitivity to detect a pest. Such SSCs may include results from general surveillance (e.g. collection and aggregation of data from literature, collection of records from farmers on pest occurrence) and results from specific surveys by NPPO experts. With this methodology all available information is integrated quantitatively to evaluate the pest occurrence in an area.

The Panel recommends the implementation of the methodology proposed by Martin et al. (2007) and Barrett et al. (2010) for those cases in which a clear conclusion on either the absence of the pest in the area or the demarcation of the presence of the pest in an area is difficult to reach.

1.7.3. Statistical methods for assessing option effectiveness to reduce pest infestation

In this section, several statistical methods are presented for:

- assessing the uncertainty of the effectiveness of RROs

- comparing the effectiveness of RROs with a threshold

- testing the equivalence of two RROs

- estimating the dose–effectiveness relationship.

1.7.3.1. Assessing the uncertainty of the effectiveness of risk reduction options

Uncertainty in pest detection and treatment effectiveness can be assessed in different ways. Several approaches are presented below.

- Assessing errors in detection

The application of a detection method for pest presence in plant material can lead to four possible outcomes (Swets, 1988): true positive, true negative, false positive or false negative (Table 4). True positives (A) occur when a positive detection corresponds to the actual presence of a pest in the tested material. False positives (B) occur when detection is positive, but the pest is not present. True negatives (C) occur when the pest is both not detected and not present in the tested material. False negatives (D) occur when the pest is not detected but present. Outcomes A and C will lead to correct decisions, whereas outcomes B and D will lead to erroneous decisions about pest presence or absence.

Table 4: Outcomes of a detection method

Detection result	**Actual condition**	
	Present	**Absent**
Positive	True positive (A)	False positive (B)
Negative	False negative (D)	True negative (C)

When outcomes for the method (i.e. positive or negative) are available for *n* different samples of plant material with known conditions (i.e. pest presence or absence), the results can be used to assess the accuracy of the considered detection method. This is achieved by computing relevant quantities such as sensitivity, specificity, likelihood ratio and overall accuracy (e.g. Swets, 1988; Smith et al., 1999; Venette et al., 2002), defined by:

$$Sensitivity = \frac{\text{Number of true positive (A)}}{\text{Number of true positive (A) + Number of false negative (D)}},$$

$$Specificity = \frac{\text{Number of true negative (C)}}{\text{Number of true negative (C) + Number of false positive (B)}},$$

$$Likelihood\ ratio = \frac{\text{Sensitivity}}{1 - \text{Specificity}},$$

$$Overall\ accuracy = \frac{\text{Number of true positive and of true negative (A+C)}}{\text{Total number of tested samples (A+B+C+D)}}$$

Sensitivity and specificity values range from zero to one. A good detection method is characterised by sensitivity and specificity values close to one. The likelihood ratio can be used to compare the probability of correctly detecting a pest's presence with the probability of incorrectly detecting a pest's presence. The ratio should thus be as high as possible. A ratio close to one indicates that the two probabilities are similar and that the detection method is not very useful. The overall accuracy ranges from 0 to 1: values approaching one indicate a high level of accuracy. If the pest prevalence is known, the sensitivity and specificity can also be used to calculate the probability of pest presence (or absence) as a function of the result of the detection method as follows:

$$\text{Prob. of pest presence in case of positive detection} =$$
$$\frac{\text{Sensitivity} \times \text{Pest prevalence in plant materials}}{\text{Sensitivity} \times \text{Pest prevalence in plant materials} + (1 - \text{Specificity}) \times (1 - \text{Pest prevalence in plant materials})}$$

Other criteria can be useful such as, for example, the area under the receiver operating characteristic curve (ROC) (Pepe, 2003).

Assume that $n = 150$ plant samples have been tested for the presence of a given pest using a given detection method (Table 5).

Table 5: Numerical example (total number of plants (n) = 150)

Detection result	**Actual condition**	
	Present **A + D = 20**	**Absent** **B + C = 130**
Positive **A + B = 72**	True positive A = 17	False positive B = 55
Negative **D + C = 78**	False negative D = 3	True negative C = 75

The sensitivity shows that 85 % (A/(A + D) = 17/20 = 0.85) of the actual infested plant samples were correctly tested as "positive". The specificity shows that 56 % (C/(C + D) = 55/130 = 0.56) of the not infested plant samples were correctly tested as "negative".

In the numerical example above, the considered detection method has a low specificity. A consequence is that a risk assessor using this method will have only a 1.92 higher probability of correctly detecting a pest's presence than of detecting it incorrectly:

$$\text{Likelihood Ratio} = \frac{\text{Sensitivity}}{1\text{- Specificity}} = \frac{85\,\%}{100\,\% - 56\,\%} = 1.92$$

This result shows that the detection method is not very useful for confirming pest presence. This is confirmed by the low positive predictive value of the method, defined by:

$$\frac{\text{Number of true positive (A)}}{\text{Number of true positive (A) + Number of false positive (B)}} = 17/72 = 24\%$$

On the contrary, the detection method is useful for confirming absence of the pest as shown by its high negative predictive value, defined by:

$$\frac{\text{Number of true negative (C)}}{\text{Number of true negative (C) + Number of false negative (D)}} = 75/78 = 96\%$$

The simple techniques presented above can be applied to different types of detection methods, such as symptomatic inspections, serological and molecular tests, and others. When several detection methods have been applied to the same set of n samples of plant material, it is possible to compare their sensitivity, specificity, likelihood ratio and overall accuracy using statistical tests in order to select the best one (Pepe, 2003). When the actual presence and absence are unknown, a gold standard (i.e. the best possible proxy variable) can be used to compute these quantities.

- Confidence and credible intervals of survival rate

The effectiveness of many treatments (e.g. temperature treatment, fumigation, pesticide application) is often assessed by estimating survival rates (or mortality rates) from experimental data (e.g. Follett and Sanxter, 2001; Powell, 2002; Follett, 2004). For example, assume that n insects were treated and that x survivors were found after treatment. The survival rate after the treatment can then be estimated by $\hat{\pi} = \frac{x}{n}$. It is important to note that this is not the true survival rate; it is an estimated rate for a sample size of n.

Uncertainty about survival rate estimates can be studied by computing confidence intervals with classic statistical methods or by computing credible intervals with Bayesian methods (Newcombe, 1998; Carlin and Louis, 2008). The width of these intervals (and so the level of uncertainty) depends on both the number of survival x and the sample size n. Several confidence intervals have been proposed for proportions (e.g. Newcombe, 1998); and the most familiar interval is based on asymptotic Gaussian approximation:

$$\hat{\pi} \pm z_{1-\alpha/2}\sqrt{\hat{\pi}(1-\hat{\pi})/n}$$

For example, if $x = 25$ and $n = 300$, the survival rate is 25/300 = 0.0833 (i.e. 8.33 % of survival after treatment) and the 95 % confidence interval is defined by the confidence limits 0.0521 and 0.1146.

This interval based on Gaussian approximation is not appropriate when dealing with small n or with very low and very high π values (survival rate close to 0 or 1. Other confidence intervals should be used in such cases, but all would have advantages and disadvantages (Newcombe, 1998). For example, the Pearson–Clopper confidence intervals [p_1–p_2] for the probability π can be used even for small n but are strictly conservative, which means sometimes too large. These intervals can be derived from F percentiles as follows:

$$p_1 = \frac{x \cdot F_{2x,2(n-x+1);\alpha/2}}{n - x + 1 + x \cdot F_{2x,2(n-x+1);\alpha/2}}$$

$$p_2 = \frac{(x+1) \cdot F_{2(x+1),2(n-x);1-\alpha/2}}{n - x + (x+1) \cdot F_{2(x+1),2(n-x);1-\alpha/2}}$$

and

$$p_1 = 0$$

$$p_2 = \frac{F_{2,2n;1-\alpha}}{n + \cdot F_{2,2n;1-\alpha}}$$, if $x = 0$

$$p_1 = \frac{x \cdot F_{2x,2;\alpha}}{1 + x \cdot F_{2x,2;\alpha}}$$

$$p_2 = 1$$, if $x = n$

An alternative is to compute a Bayesian credible interval using a Beta probability distribution given by

$$Beta\left(x+1, n-x+1\right)$$

(e.g. Carlin and Louis, 2008). This distribution corresponds to the posterior distribution for the survival rate obtained with x survivals out of n (i.e. distribution of survival rates conditionally to x) and with a uniform prior probability distribution for the survival rate (distribution of survival rates before the measure of x). A 95 % credible interval can be defined from the 2.5 % and 97.5 % percentiles of the posterior distribution. This approach can be implemented with any values of n and x, even when $x = 0$ (a common case in experimental studies of pest treatments). For example, Figure 4 shows the posterior distributions obtained in two experiments with a sample size equal to 1 000 and 5 000 respectively and with $x = 0$ in both cases (no survival after treatment). The corresponding credible intervals are [2.53×10^{-5} to 3.68×10^{-3}] if $n = 1\,000$ and [5.06×10^{-6} to 7.37×10^{-4}] if $n = 5\,000$. The survival rate is thus likely to be much lower in the second experiment than in the first one, although both experiments led to zero survival. This is due to the larger sample size used in the second experiment, which resulted in a strong reduction in the uncertainty.

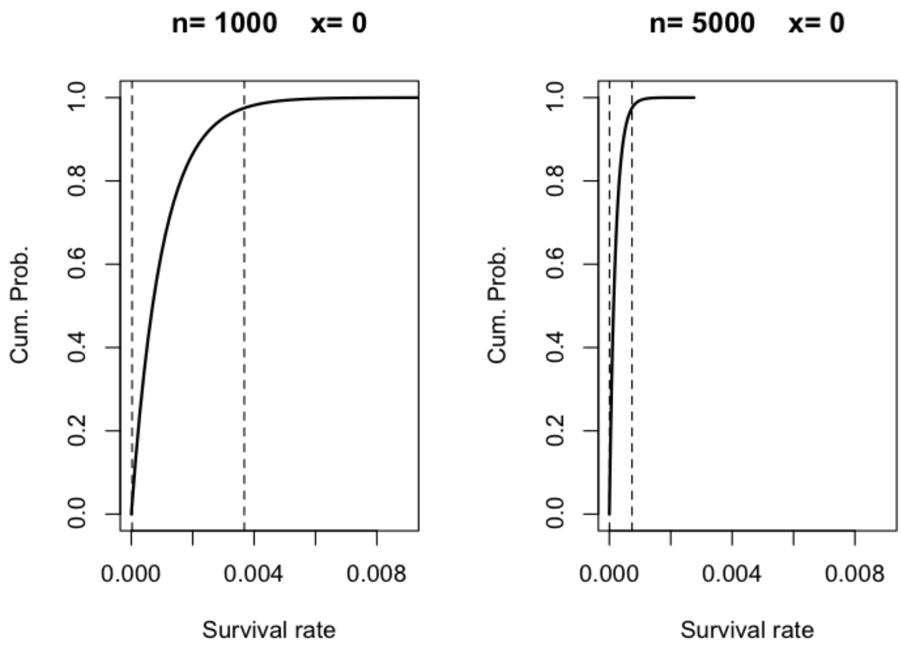


Figure 4: Cumulative probabilities for the survival rates estimated with $x = 0$, and $n = 1\,000$ or $n = 5\,000$. Dashed lines show the 95 % credible intervals.

While the estimation of a survival rate depends on the number of treated pests, the probability of having surviving pests in treated lots depends on the amount of plant material and the infestation before treatment (pest prevalence). When data about pest prevalence and lot size are available, prognosis intervals can be computed to calculate the probability of pest survival in the lot under consideration after the treatment.

1.7.3.2. Comparing the effectiveness of risk reduction options with a threshold

Survival rates (or mortality rates) need sometimes to be compared with a threshold in order to assess the degree of quarantine security associated with a given RRO. This approach can be formally defined as a test of the hypothesis H_0: « $\pi > \pi_0$ », where π is the survival rate after the application of a RRO and π_0 is the threshold (i.e. a low value of survival rate). This hypothesis can be tested by counting the number of survivors x in a sample of n individuals (e.g. insects) treated with the considered RRO.

The probability of zero survival among the n individuals is equal to $p(x = 0) < (1 - \pi)^n$.

If H_0 is true, $\pi > \pi_0$, and $p(x = 0) < (1 - \pi_0)^n$

If $x = 0$ and if the probability $p(x = 0)$ is low enough (e.g. 0.05), the hypothesis H_0: « $\pi > \pi_0$ » can be rejected with a low risk of error (type I error) and the risk assessor can conclude that the RRO leads to a survival rate lower than π_0.

For example, assuming that $n = 300$ insects have been treated (e.g. heat treatment), that no survival was found, and that a risk assessor would like to test H_0: « $\pi > 0.01$ » versus H_1: « $\pi \leq 0.01$ » (i.e. to test if the survival rate after treatment is higher than 1 % or not).

In this case, $p(x = 0) < (1 - 0.01)^{300}$ and $p(x = 0) < 0.049$.

Based on this result, H_0 is rejected (with a risk of type I error of 5 %) and the conclusion is that the survival rate is lower than 1 %.

The test will confirm the efficiency of the treatment when no survivor is observed. Based on the test result, the maximal survival probability (π) can be computed by:

$$\pi_0 = 1 - \sqrt[n]{\alpha}$$

This is an alternative approach to calculate the upper confidence limit for π, when the number of observed pests after treatment is zero. Finally, the same reasoning can be used to calculate how many pests are needed before the treatment to test its efficiency.

Table 6: Sample size needed to confirm different mortality rates by "no survivors" (with significance level α = 5 %)

Significance	α = 0.05		
probit	**Survival (π), %**	**Mortality ($q = 1 - \pi$), %**	**Sample size (n)**
	10.0000000	90.0000000	29
	1.0000000	99.0000000	299
	0.1000000	99.9000000	2 995
	0.0100000	99.9900000	29 956
	0.0010000	99.9990000	299 572
	0.0001000	99.9999000	2 995 731
1	15.8655254	84.1344746	18
2	2.2750132	97.7249868	131
3	0.1349898	99.8650102	2 218
4	0.0031671	99.9968329	94 587
5	0.0000287	99.9999713	10 450 778

The probability $p(x = 0)$ depends both on the chosen threshold π_0 and on the sample size n. The so-called "probit 9" (which is in fact probit 4; see Table 6) was a common mortality threshold in the past (Follett and Neven, 2006). It corresponds to 99.9968329 % mortality (i.e. 0.0031671 % survival) (Follett and Neven, 2006). However, the use of this threshold has been criticised (Follett and Neven, 2006; Haack et al., 2011; Schortemeyer et al., 2011). According to Schortemeyer et al. (2011), this threshold is arbitrary and may be too stringent for rarely infested commodities or a poor host. Indeed, the probability of entry of the pest depends on the mortality of the pest after treatment but also on the number of imported commodities and on the prevalence of the pest in these commodities. It is thus possible to have a low probability of entry with a mortality rate lower than probit 9 in the case of low prevalence and/or low quantities of imported commodities. Another issue is that a high number (n) of individuals need to be treated (n > 94 000) in order to conclude that the mortality rate is higher than probit 9 with a sufficient level of confidence (0.95) (Follett and Neven, 2006; Haack et al., 2011; Schortemeyer et al., 2011). This is difficult to achieve in practice.

The development of new RROs aiming at a mortality level of probit 9 is difficult to achieve under experimental conditions. Artificially infesting certain commodities (i.e. wood with wood-boring insects) is a cumbersome task and can also lead to increased mortality (Haack et al., 2011; Schortemeyer et al., 2011). Additional controls therefore would be required to compensate for this artefact, and mortality in these controls would have to be taken into account (Follett and Neven, 2006). For these reasons, the use of probit 9 as a systematic reference threshold for assessing the effectiveness of most RROs applied for controlling insects and nematodes is not recommended.

1.7.3.3. Testing the equivalence of risk reduction options

In the terms of reference provided by the European Commission, in some cases EFSA has been requested to determine whether an alternative RRO provides a comparable level of protection to the EU as those currently stipulated in the EC regulation. When a new RRO is proposed as an alternative to a standard RRO, it is useful to know whether the alternative RRO is at least as good as the standard (Sgrillo, 2002). Non-inferiority can be tested using a specific equivalence test called a *non-inferiority test* (Blackwelder, 1982; D'Agostino et al., 2003; Garrett, 1997, EFSA Scientific Committee, 2011). The null hypothesis of the non-inferiority test is that the standard RRO is more effective than the alternative RRO by at least some specified amount. This test puts the burden of proof on the experimenter to demonstrate that the alternative RRO is non-inferior compared with the standard RRO with a "reasonable" tolerance. Note that equivalence tests are considered as useful tools in other areas, e.g. to test equivalence between genetically modified crops and conventional crops (EFSA Panel on Genetically Modified Organisms (GMO), 2009).

Assuming that q_S and q_A are the mortality rates obtained with the standard and alternative RRO respectively. In a non-inferiority test, the tested hypotheses are:

H_0 : « $q_A \leq q_S - \delta$ » versus H_1 : « $q_A > q_S - \delta$ »

where $\delta > 0$ is a tolerance margin (a minimum difference of practical interest). Assuming a sufficiently large sample to justify normal approximation, we reject H_0 if the one-sided α-level confidence bound on $\hat{q}_A - \hat{q}_S$ is greater than $-\delta$ (Blackwelder, 1982). That is, we reject H_0 if

$$\hat{q}_A - \hat{q}_S - z_{1-\alpha}\sqrt{\hat{q}_A\left(1-\hat{q}_A\right)/n_A + \hat{q}_S(1-\hat{q}_S)/n_S} > -\delta$$

where $\hat{q}_A$ and $\hat{q}_S$ and are the measured mortality rates based on samples of sizes n_A and n_S and respectively.

For example, assume that a standard heat treatment applied on n_S = 110 insects led to a mortality rate of 0.82 and that an alternative heat treatment applied on n_A= 150 insects led to a mortality rate of 0.83, then the 95 % confidence bound is equal to:

$$\hat{q}_A - \hat{q}_S - z_{1-\alpha}\sqrt{\hat{q}_A\left(1-\hat{q}_A\right)/n_A + \hat{q}_S(1-\hat{q}_S)/n_S} = -0.06$$

This result shows that, although the estimated mortality rate was slightly higher (by 1 %) with the alternative RRO than with the standard RRO, we cannot exclude the possibility that the alternative RRO decreases the mortality rate by 6 % due to uncertainty in the estimated values. If we set $\delta = 0.05$ (i.e. if we accept a mortality rate reduction of 5 %), we do not reject the null hypothesis that the alternative RRO is less effective, and we cannot conclude that the alternative RRO is at least as good as the standard RRO. On the other hand, if we set $\delta = 0.1$ (i.e. if we accept a mortality rate reduction of 10 %), we reject the null hypothesis that the alternative RRO is less effective and we conclude that the alternative RRO is at least as good as the standard RRO.

A limitation of this method is that it relies on a Gaussian approximation that is not valid for small samples or for very high or very low mortality rates. An interesting alternative is to compute a credibility interval for the difference between q_S and q_A using a Bayesian approach and to compare this credibility interval with δ. Assuming a uniform prior distribution for the mortality rates, the posterior distributions for q_S and q_A are the Beta probability distributions $Beta\left(x_A+1, n_A-x_A+1\right)$ and $Beta\left(x_S+1, n_S-x_S+1\right)$ where x_S and x_A are the observed number of deaths with the standard and alternative RRO respectively. Credibility intervals can be derived from these two distributions by Monte Carlo simulation.

For example, assume that $x_A = n_A = 10$ insects, and $x_S = n_S = 50$ insects. In this case, the measured mortality rate is 100 % with both the standard and the alternative, but the number of tested insects is higher for the standard. The probability distribution of the difference between q_S and q_A is shown in Figure 5. The 5th percentile of this distribution is –0.22 (i.e. there is a 5 % chance of having more than a 22 % reduction in mortality rate with the alternative than with the standard). This strong reduction is due to the large uncertainty induced by the small sample sizes, especially for the alternative RRO ($n_A = 10$). Unless considering a very high tolerance threshold, it is not reasonable to conclude that the alternative is at least as good as the standard in this case.

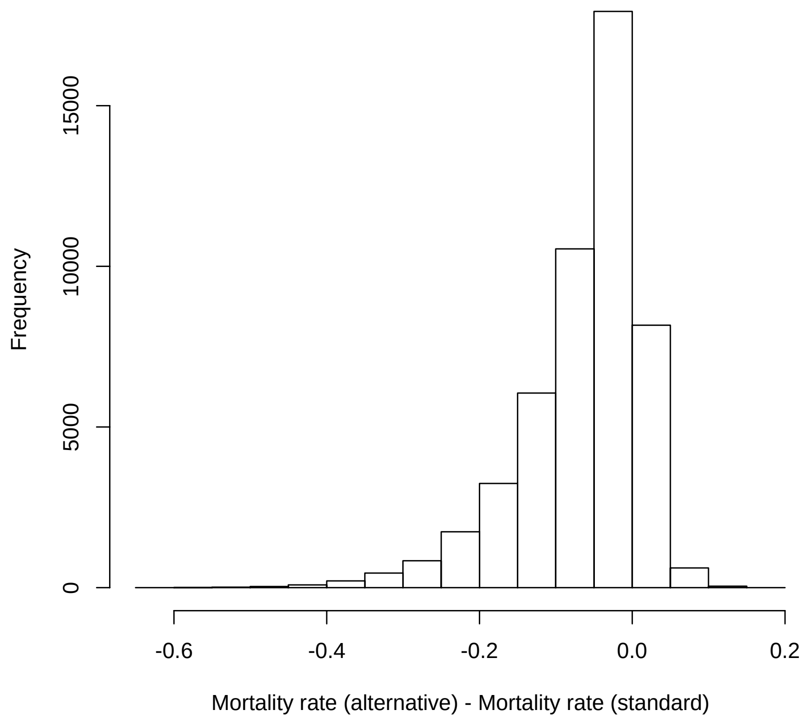


Figure 5: Probability distribution of the difference of mortality rates between a standard RRO and an alternative RRO when $x_A = n_A = 10$ insects, and $x_S = n_S = 50$ insects (50 000 Monte Carlo simulations).

The above analysis is insect oriented; however, for pathogens the guidance would be similar, using different variables.

1.7.3.4. Estimating the dose–effectiveness relationship

When the effectiveness of an option depends on the dose of the applied treatment, it is useful to estimate the relationship between dose (e.g. pesticide concentration, duration, temperature, etc.) and effectiveness to optimise the treatment dose. This is the case, for example, for pesticide treatment (its effectiveness depends on the quantity of applied pesticide), heat treatment (its effectiveness depends on temperature and duration) and for irradiation treatment (its effectiveness depends on the dose of irradiation).

Experimental data available for studying the dose–effectiveness relationship generally consists of a series of doses (e.g. several temperatures for heat treatment) applied to plant material for which pest survival after treatment has been measured. Pest survival is usually expressed either as survival (or mortality) rate (e.g. Follett and Sanxter, 2001, tables 1–3) or as a number of individuals found alive after treatment (e.g. Follett, 2004, table 2).

When appropriate, the dose–effectiveness relationship can be studied by fitting generalised linear models to such data, and the uncertainty can be assessed by computing confidence intervals for the fitted models (Agresti, 2003). The type of generalised linear model fitted to data must be chosen carefully depending on the nature of the available data. When survival or mortality rates have been measured, logit, probit or log–log regression models should be used. When count data are available (i.e. number of surviving individuals after treatment), the use of Poisson regression models (Figure 6) is advised, as shown in the EFSA Panel on Plant Health (PLH) (2011a) opinion on the effectiveness of heat treatment of *Agrilus planipennis*. It is not recommended to transform count data into survival or mortality rates because such transformation requires the estimation of the initial level of infestation of plant material and may increase uncertainty (EFSA Panel on Plant Health (PLH), 2011a). Several software packages are available to fit these models.

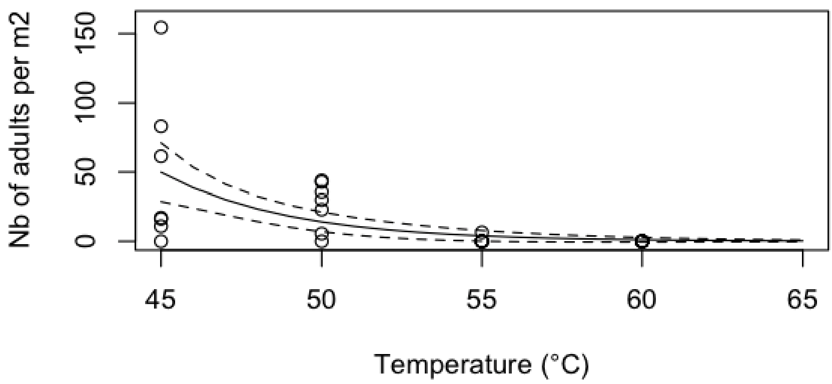


Figure 6: Number of surviving insects (emerald ash borer, *A. planipennis*) as a function of the temperature of the heat treatment (heat treatment duration 60 minutes). Points correspond to measurements obtained in an experiment (data from Myers et al., 2009), the continuous curve indicates the expected number of survivors derived from a Poisson regression model, and the dashed lines indicate the 95 % confidence intervals.

1.7.3.5. Recommendations

- Uncertainty about the effectiveness of RROs should be studied by computing confidence intervals with classic statistical methods or credibility intervals with Bayesian methods. According to the EFSA Scientific Committee (2011), more information can be presented in the estimate of the size of an effect and its uncertainty when described by a confidence interval than when expressed solely by the results of significance tests.

- The probit 9 threshold of mortality rate should not be systematically used as reference threshold for assessing the effectiveness of RROs. Instead of using a specific threshold for mortality rate, it is recommended that the risks of pest entry and establishment associated with the RRO under consideration are analysed.

- Although not frequently used in plant pathology, equivalence tests and, more specifically, non-inferiority tests are useful tools for comparing two RROs and testing whether an alternative RRO is at least as good as a standard RRO.

- Depending on the nature of the available experimental results, different types of generalised linear model can be fitted to data to study the relationship between the dose of a treatment and its effectiveness. Such models are commonly used in chemical risk assessment, but are also applicable in treatment effect assessment.

1.8. Qualitative assessment of risk reduction options

Qualitative assessment methods have proved to be useful for the Panel to assess a large number of RROs in a short period of time (EFSA Panel on Plant Health (PLH), 2010a, 2011b). Moreover, owing to the limited availability of data, the Panel often performs qualitative assessments supported by documentary evidence to evaluate the RROs, giving special attention to listing and rating the level of uncertainty.

Various schemes have been proposed to assess RROs (e.g. EFSA Panel on Plant Health (PLH), 2010a; EPPO, 2011; PRATIQUE, 2011). They consist of a series of questions that need to be answered by risk assessors using qualitative ratings (e.g. very low, low, moderate, high, and very high). A decision support system has been produced by the PRATIQUE EU-funded project for screening system approach measures (PRATIQUE, 2011). It can be used to quickly identify relevant combinations of RROs.

The guidance document on the harmonised framework for risk assessment (EFSA Panel on Plant Health, 2010a) defined one of the principles of transparency under section 3.1: "… Transparency requires that the scoring system to be used is described in advance. This includes the number of ratings, the description of each rating." Opinions of the Panel based on qualitative methods should thus always include rating descriptors to provide clear justification when a rating is given. Examples of descriptors are provided in risk assessments by the EFSA Panel on Plant Health (PLH) (2010c, 2010d).

A limitation of the qualitative approaches is that the individual scores cannot be easily combined in order to derive an overall risk level for a given RRO. It is thus difficult to compare the levels of effectiveness of different RROs using these approaches. Several techniques have been proposed for combining scores such as weighted sums, risk matrices, Bayesian belief networks, etc. (Holt, 2006; Cox, 2008; EFSA Panel on Plant Health (PLH), 2010a; PRATIQUE, 2011; Prima Phacie, 2011). Several studies showed that, at least in some cases, the final result depends on the chosen technique used for combining the individual scores (Holt, 2006; Cox, 2008; Makowski and Mittinty, 2010; Prima Phacie, 2011). The practical interests of the proposed score combination techniques still need to be evaluated.

1.9. Quantitative pathway analysis and other quantitative tools for assessing risk reduction options

Quantitative models have been used in several instances in published literature and in risk assessment to estimate the probabilities of introduction and spread of plant pests (for examples, see Roberts et al., 1998; Stansbury et al., 2002; Fowler et al., 2006; Harwood et al., 2009; Peterson et al., 2009; Yemshanov et al., 2009). These predictive models are used to estimate the probabilities of introduction and spread of plant pests under new or changed conditions. The Panel currently applies in its opinions quantitative methods for the assessment of climate suitability for establishment and spread of plant pests. With regard to the quantitative assessment of the probability of introduction, in the Panel (EFSA Panel on Plant Health (PLH), 2010b) has evaluated a quantitative pathway analysis of the likelihood of *T. indica* being introduced into the EU with imports of United States wheat (USDA APHIS, 2008b) (Figure 7). The Panel's review highlighted the key parameters of the quantitative pathway analysis model, identified through sensitivity analysis, and also showed that the proposed model did not consider the possibility of the pathogen being introduced through a single infected consignment.

Probabilistic pathway analyses can be used to evaluate quantitatively the probabilities of introduction of plant pests. This method is well known in assessment of the exposure of the human population to chemicals (Cullen and Frey, 1999) but needs to be adapted to the specific conditions and datasets for plant health risk assessment.

The main objective of a pathway model is to follow the "course of the pest from the source to the target" (compare IPCS, 2001). The start of the pathway is an infested area with known prevalence and number of host plants. The model should cover the pathway of the pest from the starting point of the pest to the end of the pathway (including isolation, re-exportation, elimination and reproduction) over a given period of time. The end of the pathway is a target area (e.g. an area cultivated with a given host plant in the EU).

Every pathway model has a spatial and a temporal component. The spatial resolution may correspond to a single potential niche, e.g. a plant, a field or a storage unit, or to a large area (e.g. regional, national). The temporal resolution may correspond to an hourly, daily, monthly or yearly time step or life cycle of plant products or pests.

Depending on the spatial and regional resolution, the quantification may have different interpretations from the probability of infestation of a single plant at a specific hour of one day to the total number of pests introduced into the EU within one year. The spatial and temporal resolutions should be chosen in accordance with the objective of the RRO.

To evaluate whether a RRO achieves its objective the model can be run without and with the RRO and the model output difference can be used to quantify the risk reduction induced by the option. The model can thus be used to calculate a reduction rate as well as the remaining amount of the pest reaching the end of a pathway.

Where quantitative elements are included, transparency requires that every element of the calculation or mathematical modelling is communicated and justified, with a clear description of the model used, its accuracy and the parameter estimation. For quantitative models it is recommended that an uncertainty and sensitivity analysis be performed in order to analyse the consequences of uncertainties in model parameter values. The result of such an analysis will correspond to a probabilistic pathway analysis and will allow risk assessors to assess the level of uncertainty associated with the estimated effect of the RRO. This method is therefore also applicable in situations where detailed information is missing or when the quality of input data is low.

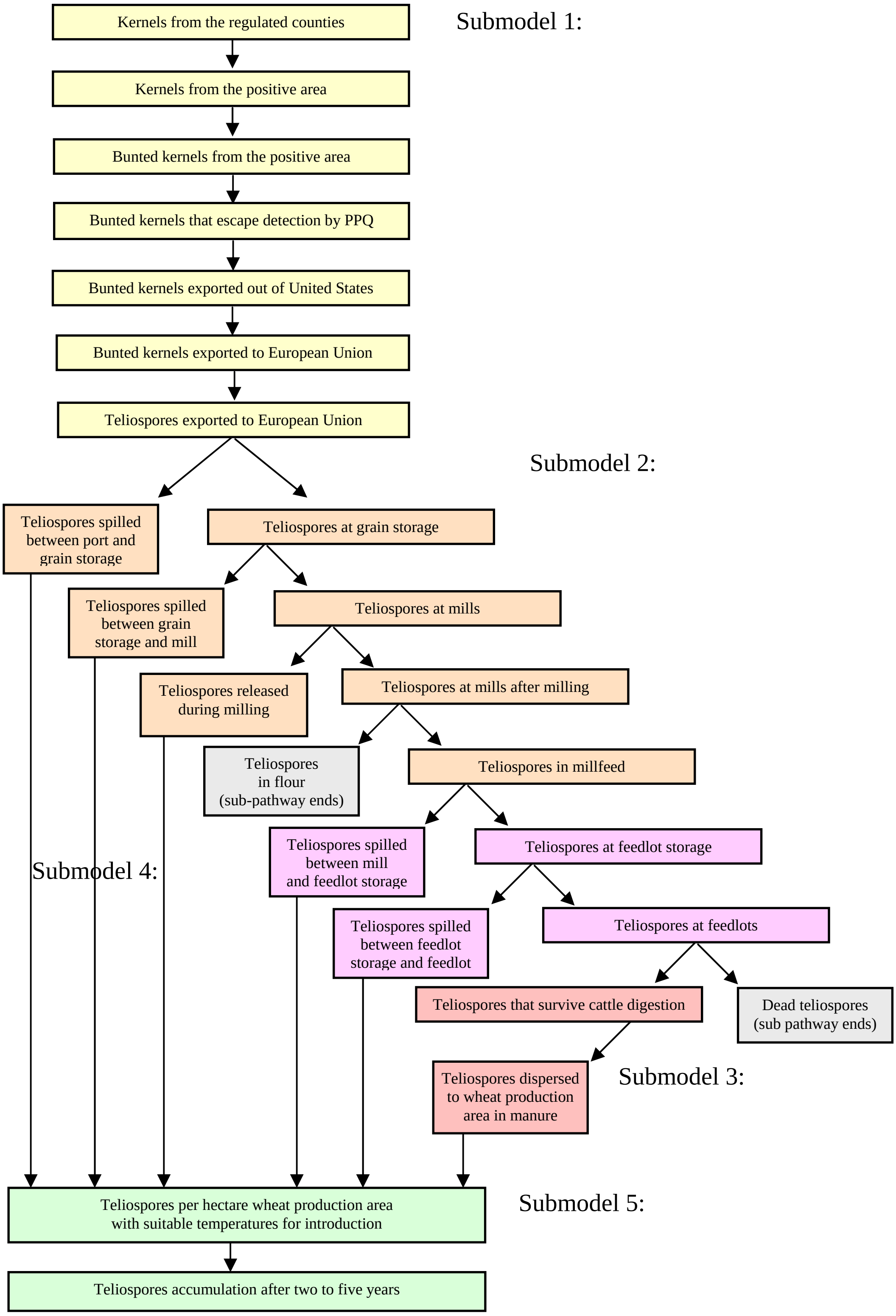


Figure 7: Example for a teliospore pathway model (from USDA APHIS, 2008b) discussed in EFSA opinion on *Tilletia indica* introduction into Europe (EFSA Panel on Plant Health (PLH), 2010b)

1.9.1. Quantitative pathway analysis

The main task of a pathway analysis is to model the total flow of infested material from the area of production to the endangered host plants in Europe. To achieve this task four key elements have to be defined:

- an estimation of the total amount of the pest to follow up through the pathway
- a description of the total pathway under consideration
- estimations of the proportions of material following each branch of the pathway
- estimations of survival and growth of the pest (or probability of infection of host plants) on each branch of the pathway.

Given these key elements the simplest structure of a pathway model is:

$$Y = X \cdot \left[p \cdot s_1 + (1-p) \cdot s_2 \right]$$

where:

X is the total amount of the pest at the beginning of the pathway (production side)

p is the proportion of material going into the first path of the pathway

s_1 is the survival rate of the pest on the first path

s_2 is the survival rate of the pest on the second path

Y is the resulting amount of the pest at the end points of the pathways.

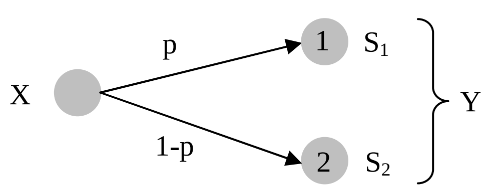


Figure 8: Graphical representation of a simple pathway model.

With a global view such a pathway model can been interpreted as weighted average of all survival rates of the pathogen on the different pathways, weighted with the proportion of the specific pathway on the total flow.

Typical extensions of this simple model are:

- incorporation of all possible paths
- use of infection rate instead of survival of the pathogen as the output variable
- stratification by regions, e.g. EU countries, etc.
- Stratification by time, e.g. month, year, etc.

Such extensions can be used to incorporate further differences in the path, i.e. in the behaviour of the pathogen, between EU countries and in the life cycle of the pest and the host plants. Additional data sources, such as climatic data, might be used to get more precise estimations of survival and infection rates.

All parameters can be defined as random variables in order to incorporate further variations within the paths and to analyse uncertainties in the estimation. With this approach, a distribution of values is generated for each model output instead of a single value (point estimator). The final calculation is obtained via simulation, choosing a random set of parameters for each calculation and iterating this procedure several times to get again a sample of possible output values, expressing the final distribution of possible outputs.

The main advantage of pathway models is that all assumptions are collected and documented in a transparent way. In some cases, it is also possible to evaluate (or calibrate) the model using real observations of pathogen occurrence at the end points.

When the total flow of the pathogen is included in the model, it is possible to assess a wide range of RROs using the model. Figure 9 shows a systematic assessment of RROs for entry, establishment, spread and impact. These options influence different parts of the pathway model (Table 7).

Table 7: Parameters influenced by risk reduction options

Risk component	Risk reduction option	Parameters influenced by the risk reduction options
Entry	Monitor prevalence in the field	Total amount of material/pest
	Reduce the infestation in the imported commodity	Total amount of material/pest
	Reduce the infestation at the production site	Total amount of material/pest
	Reduce the infestation during transport before import	Survival rate during transport
	Reduce infestation at the border	Survival rate at the boarder
Establishment	Restrict import to unfavourable regional/temporal conditions	
	• Restrict import to unfavourable climatic conditions	Infection rate in EU regions
	• Restrict import to regions without suitable host plants	Infection rate in EU regions
	• Restrict import to seasons without dangerous life stages	Infection rate in EU regions
	Avoid any release of material or pest during transportation	
	• Avoid any release during transport	Proportion of transportation loss
	• Avoid any release during storage	Proportion of storage loss
	• Avoid any release during processing	Proportion of production loss
	• Avoid any release by waste	Proportion of waste
	• Avoid any release during consumption	Proportion of consumption loss
	• Avoid any release to the environment (e.g. by planting)	Proportion of direct release
Spread	Monitor prevalence of the pest to avoid spread	Completeness of model
	Ensure pest-free buffer zones and isolation of infested plants	Infection rate at outbreak sites
	Apply eradication methods	Survival rate at outbreak sites
	Reduce rate of spread by removing means of transportation	Infection rate in EU
	Reduce rate of spread by changing agricultural practices	Infection rate in EU
	Reduce natural spread	Infection rate in EU
	Reduce spread by human activities	Infection rate in EU
Potential consequences	Reduce impact by use of resistant hosts	Infection rate in EU
	Reduce impact by changing agricultural practice	Infection rate in EU

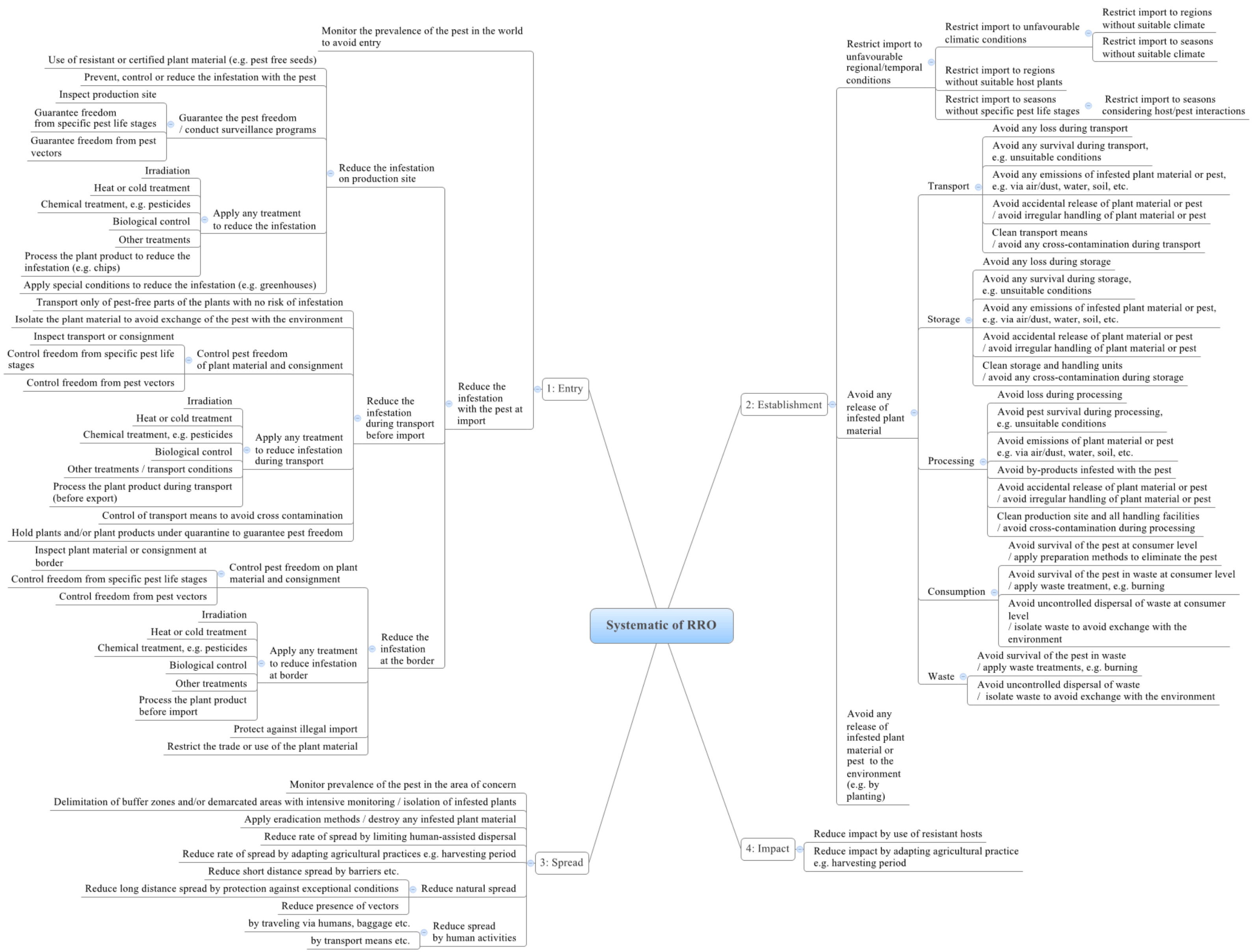


Figure 9: Systematic of risk reduction options on entry, establishment, spread and impact.

The development of a comprehensive pathway model has several advantages:

- It allows risk assessors to assess RROs at relevant scales.
- The model can be used to identify influential parameters and to identify the options that would strongly reduce the risk.
- Several RROs can be compared on a common scale using such a model.
- Several RROs can be combined and evaluated together in the comprehensive pathway model. Quantitative pathway models can thus be used to assess system approaches.

As with all models, quantitative pathway models have some limitations:

- Quantitative pathway models usually include many parameters, which might be uncertain.
- Calibration and evaluation against real measurements is generally missing, because this type of model is usually used to assess future risks.
- Quantitative models do not usually predict the complete absence of a pest. All results should therefore be compared with limits of acceptable infestation or risk of infection.

1.9.2. Spread models

Spread models can be seen as special cases of pathway models. They are used to model the flow of the pathogen from an infested plant, field or production site to the local environment. These models can take into account regional and temporal factors influencing pest spread, such as wind direction or average wind speed, host distribution, geographic barriers or the local soil composition.

Simple models estimate the velocity of spread; this is the average distance of spread per time unit (e.g. year). Without any additional information the spread will be concentric around the source of the pest.

Short distance models (Spijkerboer et al., 2002; Gilligan and van den Bosch, 2008; EFSA Panel on Plant Health (PLH), 2011b) include information on the plant, the local conditions and the natural means of spread, e.g. by air, rain, vectors, etc. Long-distance models include extreme weather conditions (Aylor, 1990, 2003), unintended transportation of the pest or uncontrolled movement of infested plant material (EFSA Panel on Plant Health (PLH), 2010d).

Spread models are typically calibrated against existing data, e.g. reports on infestations, detections, etc. The model parameters are estimated to give best fit to past situations.

A protocol has been recently developed in the PRATIQUE EU project for mapping endangered areas. This protocol summarises the information required to run the spread models and formulate recommendations for their use (Baker et al., 2011; PRATIQUE, 2011).

1.9.3. Quantitative tools used by other EFSA Panels

On April 2011 an internal mandate (M-2011-0173) was presented by EFSA to the Plant Health Unit to provide a review of EFSA outputs on biological hazards relevant to methodologies for the evaluation of RROs (Pautasso, 2012).

The purpose of the review was to identify and evaluate the quantitative tools applied at EFSA in scientific opinions published from 2004 to May 2011 by EFSA's scientific Panels dealing with biological hazards (AHAW (Animal Health and Welfare), BIOHAZ (Biological Hazards), CONTAM (Contaminants), GMO (Genetically Modified Organisms) and PLH (Plant Health)) when identifying and evaluating RROs. During the review, 323 scientific opinions were examined and a report was delivered.

A general result that can be extracted from that report concerns the low percentage of outputs, for each of the above mentioned panels, in which quantitative methodologies were applied. Nevertheless, when combining the data from all Panels, a temporal trend towards increased use of quantitative methods can be observed (from 5 % in 2004 to 22 % in 2010, increasing to 40 % in 2011, taking into account only the scientific opinions published up to May 2011).

CONCLUSIONS AND RECOMMENDATIONS

The European Food Safety Authority (EFSA) asked the Panel on Plant Health to deliver guidance on the methodology for evaluation of the effectiveness of options for reducing the risk of introduction and spread of organisms harmful to plant health in the European Union territory.

This guidance document was prepared by the Panel to address mainly the quantitative evaluation of the effectiveness of risk reduction options (RROs). When data and/or information are available, the quantitative methods described in this document can be applied. When only limited or no data and/or information are available, the Panel performs qualitative evaluations that are briefly described in this guidance document. The Panel developed this guidance document to be used for the assessment of RROs together with the guidance on a harmonised framework for risk assessment (EFSA Panel on Plant Health (PLH), 2010a) and the guidance on the evaluation of pest risk assessments and risk management options prepared to justify requests for phytosanitary measures under Council Directive 2000/29/EC (EFSA Panel on Plant Health (PLH), 2009). The guidance provided in this document complements and does not replace the two above-mentioned documents when responding to requests for scientific advice on issues related to the evaluation of the effectiveness of options for reducing the phytosanitary risks within the EU in order to support the decision-making process under Council Directive 2000/29/EC.

Two operational tools are presented in this guidance document:

- a checklist for evaluating a proposed RRO
- a database of references of scientific documents presenting recommendations on how to assess RROs and/or describing experimental assessments of RROs.

The two tools have different purposes. The checklist includes a series of items that can be used by the Panel to check whether all required information is provided to support a RRO. Four types of RRO assessments are distinguished in the proposed checklist according to their purposes and characteristics:

i. experimental assessment of the effectiveness of the option for reducing pest infestation in plant material/products under laboratory/controlled conditions

ii. experimental assessment of the effectiveness of the option for reducing pest infestation in plant material/products under operational conditions

iii. analysis of the applicability of the RRO

iv. assessment of the effectiveness of the option for reducing the risk of pest entry from an infested area to a pest-free area.

The checklist can be used by experts to make a preliminary assessment of documents and data submitted to EFSA to support a RRO (e.g. a temperature treatment of plant material) and, more specifically:

- to quickly describe the information provided to EFSA (i.e. report and experimental results) to support a proposed RRO
- to identify major gaps in data submitted to EFSA
- to organise the work of the Panel when evaluating a dossier.

This checklist could also be used by the author of the submitted dossier or by the author of a pest risk analysis to verify whether all the requested data have been provided.

The second tool is a database of references corresponding to published guidance documents or experimental assessments of RROs.
The content of these documents is summarised in a table presented in Appendix B. This database of references can be used by the Panel to find some specific experimental results on the effectiveness of a given RRO, or to find guidance documents for designing RROs. Although this database does not intend to include all existing references on RRO assessment, it may help the Panel experts to quickly retrieve the relevant experimental data and guidance documents for assessing a proposed RRO, or for assessing a range of options in a pest risk analysis. It can also be used to identify potential RROs for a given pest and/or plant material.

Finally, based on the literature review described in this guidance document and on its own experience, the Panel is able to formulate several recommendations on the use of quantitative methods for assessing the effectiveness of RROs.

Recommendations on surveillance (as defined in ISPM No 5, Glossary of phytosanitary terms)

- General surveillance should evaluate the possible occurrence of a pest in an area, using all relevant (quantitative and qualitative) information on the current pest distribution in and near the area, the ecological conditions of the area, the presence of host plants and other potential pest niches, and the import and trade rates of host plant products in the area. The conclusion of general surveillance and a discussion of the level of uncertainty should be presented along with all information used to reach the conclusion.

- Specific surveys should be conducted to test an explicitly formulated hypothesis on the occurrence of a pest in an area and/or on its incidence. They should be performed on a statistical basis, using relevant quantitative and qualitative information on the area, the pest, the host plants and other potential pest niches. They should provide a conclusion on pest occurrence and the uncertainty of the conclusion, expressed as the confidence level to detect the pest above the threshold prevalence of the survey.

- Methodology to integrate the results from general surveillance and specific surveys should be implemented in cases in which a conclusion on pest occurrence is difficult to reach.

Recommendations on the design of experiments

- The checklist provided herewith should be used prior to, and during, the experimentation.
- The information requested in the checklist and pertaining to the plant and to the pest should be first as complete and precise as possible.
- The objectives (e.g. mortality rates, maximal pest density acceptable) and confidence levels of the tests should be clearly stated and, when relevant, compared with the current standards.
- A complete description of the experimental or observational design should be provided, including: variables used to measure effectiveness; factors influencing effectiveness that were or were not taken into account in the experiments; description of facilities and equipment; description of treatments; methodology followed for monitoring critical parameters; description of experimental design; presentation of the data; and description of the statistical analysis.

The complete datasets produced by the experiment and/or the observations and used in the analyses should be kept available with a full definition of all the variables.

Recommendations on the use of statistical methods for assessing the effectiveness of options for reducing pest infestation

- Uncertainty about the effectiveness of RROs should be studied by computing confidence intervals with classic statistical methods or credibility intervals with Bayesian methods.

- The probit 9 threshold for mortality rate should not be systematically used as the reference threshold for assessing the effectiveness of RROs. Instead of using a specific threshold for mortality rate, it is recommended that the risks of pest entry and establishment associated with the RRO under consideration be analysed.

- Although not frequently used in plant pathology, equivalence tests and, more specifically, non-inferiority tests are useful tools for comparing two RROs and testing whether a proposed RRO is at least as good as a currently implemented RRO.

- Depending on the nature of the available experimental results, different types of generalised linear models can be fitted to data to study the relationship between the dose of a treatment and its effectiveness. Such models are commonly used in chemical risk assessment, but are also applicable in treatment effect assessment.

Recommendations on the use of quantitative pathway analysis and spread models

Quantitative pathway analysis and spread models have several advantages compared with experimental and/or observational studies:

- They allow risk assessors to quantify the effects of RROs, singly or in combination, on several variables such as probabilities of entry, establishment and spread, or magnitude of impact. They do not restrict the assessment of RROs to their capabilities for reducing pest infestation.

- Quantitative pathway analysis and spread models can address uncertainties and can be used to study the effect of different sources of uncertainty on the risk of entry, establishment, spread and impact.

- They enable to perform a sensitivity analysis to identify the most influential parameters in a model that define the most effective RRO.

These advantages make these quantitative tools attractive for assessing the effectiveness of different RROs. However, their application can be difficult in practice owing to the amount of data required to develop such models. In the case of missing data, the uncertainty associated with the model outputs could be high and decrease the ability of the model to discriminate between different RROs, thus diminishing the usefulness and value of the models.

REFERENCES

Agresti A, 2003. Frontmatter. In: Categorical Data Analysis, 2nd edition. John Wiley & Sons, Inc., Hoboken, NJ. doi: 10.1002/0471249688.fmatter.

Albajes R, Gullino ML and van Lenteren JC, 1999. Integrated Pest and Disease Management in Greenhouse Crops. Developments in Plant Pathology, Volume 14. Springer, Berlin, 221 pp.

Aluja MN, Diaz-Fleischer F and Arredondo J, 2004. Non host status of commercial *Persea americana* 'Hass' to *Anastrepha ludens*, *Anastrepha obliqua*, *Anastrepha serpentina*, and *Anastrepha striata* (Diptera: Tephritidae) in Mexico. Journal of Economic Entomology 97, 293–309.

Armstrong JW, 1994. Commodity resistance to infestation by quarantine pests. In: Sharp L and Hallman GJ (eds), Quarantine Treatments for Pests of Food Plants. Westview Press, Boulder, CO, 199–211.

Aylor DE, 1990. The role of intermittent wind in the dispersal of fungal pathogens. Annual Review of Phytopathology 28, 73–92.

Aylor DE, 2003. Spread of plant disease on a continental scale: role of aerial dispersal of pathogens. Ecology 84, 1989–1997.

Badiger HK, Patil SB, Udikeri SS, Biradar DP, Chattannavar SN, Mallapur CP and Patil BR, 2011. Comparative efficacy of interspecific cotton hybrids containing single and stacked Bt genes against pink bollworm, *Pectinophora gossypiella* (Saund.) and tobacco caterpillar, *Spodoptera litura* (Fab.)*. Karnataka Journal of Agricultural Science 24, 320–324.

Baker R, Benninga J, Bremmer J, Brunel S, Dupin M, Eyre D, Ilieva Z, Jarosik V, Kehlenbeck H, Kriticos D, Makowski D, Pergl J, Reynaud P, Robinet C, Soliman T, Van der Werf W and Worner S, 2011. Protocol for mapping endangered areas taking climate, climate change, biotic and abiotic factors, land use and economic impacts into account accessed via a hyperlink in a project web page and integrated into the web-based EPPO PRA scheme. Report.

Barrett S, Whittle P, Mengersen K and Stoklosa K, 2010. Biosecurity threats: the design of surveillance systems, based on power and risk. Environmental and Ecological Statistics 17, 503–519.

Barron MC, 2006. Effects of aggregation on the probability of detecting infestations in fresh produce consignments. New Zealand Plant Protection 59, 103–108.

Bartell SM and Nair SK, 2003. Establishment risks for invasive species. Risk Analysis 24, 833–845.

Binns MR, Nyrop JP and van der Werf W, 2000. Sampling and Monitoring in Crop Protection, the Theoretical Basis for Developing Practical Decision Guides. CABI Publishing, Wallingford, UK.

Biosecurity Australia, 2005. Draft Extension of Existing Policy for Sweet Oranges from Italy. Biosecurity Australia, Canberra, ACT, March 2005, 176 pp.

Blackwelder WC, 1982. «Proving the null hypothesis» in clinical trials. Controlled Clinical Trials 3, 345–353.

Carlin BP and Louis TA, 2008. Bayesian Methods for Data Analysis. Chapman & Hall/CRC, London.

CFIA (Canadian Food Inspection Agency), 2008. D-01–04: Plant protection import and domestic movement requirements for barberry (*Berberis*, *Mahoberberis* and *Mahonia* spp.) under the Canadian Barberry Certification Program, 2nd revision, 27 October 2008, 16 pp.

CFIA (Canadian Food Inspection Agency), 2010. Phytosanitary requirements to prevent the introduction into and spread within Canada of the emerald ash borer, *Agrilus planipennis* Fairmaire, 2nd revision, 30 pp.

CFR (Code of Federal Regulations), 2011a. US Code of Federal Regulations. Title 7 § 319.56–28 (for tomatoes).

CFR (Code of Federal Regulations), 2011b. US Code of Federal Regulations. Title 7 § 319.56–28 (for avocados).

Chew V, 1996. Probit analysis and probit 9 as a standard for quarantine security. In: Bartlett PW, Chaplin GR and van Velsen RJ (eds), Plant Quarantine Statistics: A Review. pp. 29–42.

Cox LA Jr, 2008. What's wrong with risk matrices? Risk analysis 28, 497–511.

Cullen AC and Frey HC, 1999. Probabilistic Techniques in Exposure Assessment: A Handbook for Dealing with Variability and Uncertainty in Models and Inputs. Plenum Press, New York. ISBN 0-306-45957-4.

D'Agostino RB, Massaro JM and Sullivan LM, 2003. Non-inferiority trials: design concepts and issues –the encounters of academic consultants in statistics. Statistics in Medicine 22, 169–186.

Dallot S, Gottwald T, Labonne G and Quiot JB, 2004. Factors Affecting the spread of plum pox virus strain m in peach orchards subjected to roguing in France. Phytopathology 94, 1390–1398.

Demon I, Cunniffe NJ, Marchant BP, Gilligan CA and van den Bosch F, 2011. Spatial sampling to detect an invasive pathogen outside of an eradication zone. Phytopathology 101, 725–731.

EFSA (European Food Safety Authority), 2010. Application of systematic review methodology to food and feed safety assessments to support decision making. EFSA Journal 8(6):1637, 90 pp.

EFSA (European Food Safety Authority), 2011. Submission of scientific peer-reviewed open literature for the approval of pesticide active substances under Regulation (EC) No 1107/2009. EFSA Journal 9(2):2092, 49 pp.

EFSA Panel on Genetically Modified Organisms (GMO), 2009. Statistical considerations for the safety evaluation of GMOs. EFSA Journal 8(1):1250, 59 pp.

EFSA Panel on Plant Health (PLH), 2009. Guidance of the Panel on Plant Health following a request from EFSA on the evaluation of pest risk assessments and risk management options prepared to justify requests for phytosanitary measures under Council Directive 2000/29/EC, EFSA Journal 1194, 18 pp.

EFSA Panel on Plant Health (PLH), 2010a. Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA. EFSA Journal 8(2):1495, 66 pp.

EFSA Panel on Plant Health (PLH), 2010b. Scientific opinion on a quantitative pathway analysis of the likelihood of *Tilletia indica* M. introduction into EU with importation of US wheat. EFSA Journal 8(6):1621, 88 pp.

EFSA Panel on Plant Health (PLH), 2010c. Risk assessment of *Gibberella circinata* for the EU territory and identification and evaluation of risk management options. EFSA Journal 8(6):1620, 93 pp.

EFSA Panel on Plant Health (PLH), 2010d. Risk assessment of the oriental chestnut gall wasp, *Dryocosmus kuriphilus* for the EU territory and identification and evaluation of risk management options. EFSA Journal 2010 8(6):1619, 114 pp.

EFSA Panel on Plant Health (PLH), 2011a. Scientific opinion on a technical file submitted by the US authorities to support a request to list a new option among the EU import requirements for wood of *Agrilus planipennis* host plants. EFSA Journal 9(7):2185, 51 pp.

EFSA Panel on Plant Health (PLH), 2011b. Pest risk assessment of *Monilinia fructicola* for the EU territory and identification and evaluation of risk management options. EFSA Journal 9(4):2119, 155 pp.

EFSA Scientific Committee, 2011. Statistical significance and biological relevance. EFSA Journal 9(9):2372, 17 pp.

Elmouttie D, Kiermeier A and Hamilton G, 2010. Improving detection probabilities for pests in stored grain. Pest Management Science 66, 1280–1286.

El-Wakeil NE, Awadallah KT, Farghaly HTh, Ibrahim AAM and Ragab ZA, 2008. Efficiency of the newly recorded pupal parasitoid *Pediobius furvus* (Gahan) for controlling *Sesamia cretica* (Led.) pupae in Egypt. Archives of Phytopathology and Plant Protection 41, 340–348.

Encinas O and Briceño I, 2010. Effect of moisture content in Caribbean pine wood used for packing wood subject to heat treatment, ISPM 15. Revista Forestal Venezolana 54, 21–27.

EOLAS (Irish Science and Technology Agency), 1991. The development of treatment schedules to ensure eradication in timber of the pinewood nematode (*Bursaphelenchus xylophilus*) and its insect vectors. Final Report. EOLAS, Glasnevin, Dublin, Ireland.

EPPO (European and Mediterranean Plant Protection Organization), 2009. Generic elements for contingency plans. EPPO/OEPP, PM 9/10(1), Bulletin OEPP/EPPO Bulletin 39, 471–474.

EPPO (European and Mediterranean Plant Protection Organization), 2011. Guidelines on pest risk analysis, decision-support scheme for quarantine pests. EPPO/OEPP, PM 5/3(5), Paris, 44 pp. Available from http://archives.eppo.int/EPPOStandards/pra.htm

Evans HF, Schröder T, Mota MM, Robertson L, Tomiczek C, Burgermeister W, Castagnone-Sereno P and de Sousa EMR, 2007. QLK5-CT-2002–00672: Development of improved pest risk analysis techniques for quarantine pests, using pinewood nematode, *Bursaphelenchus xylophilus*, in Portugal as a model system. PHRAME – Plant Health Risk And Monitoring Evaluation, 246 pp.

FAO (Food and Agriculture Organization of the United Nations), 1995. International Plant Protection Convention International standards for phytosanitary measures (ISPM) 04. Requirements for the establishment of pest free areas. FAO, Rome. Available from https://www.ippc.int/id/ispms

FAO (Food and Agriculture Organization of the United Nations), 1997. International Plant Protection Convention International standards for phytosanitary measures (ISPM) 06. Guidelines for surveillance. FAO, Rome. Available from https://www.ippc.int/id/ispms

FAO (Food and Agriculture Organization of the United Nations), 1998. International Plant Protection Convention International standards for phytosanitary measures (ISPM) 08. Determination of pest status in an area. FAO, Rome. Available from https://www.ippc.int/id/ispms

FAO (Food and Agriculture Organization of the United Nations), 1999. International Plant Protection Convention International standards for phytosanitary measures (ISPM) 10. Requirements for the establishment of pest free places of production and pest free production sites. FAO, Rome. Available from https://www.ippc.int/id/ispms

FAO (Food and Agriculture Organization of the United Nations), 2002. International Plant Protection Convention International standards for phytosanitary measures (ISPM) 17. Pest reporting. FAO, Rome. Available from https://www.ippc.int/id/ispms

FAO (Food and Agriculture Organization of the United Nations), 2003. International Plant Protection Convention International standards for phytosanitary measures (ISPM) 18. Guidelines for the use of irradiation as a phytosanitary measure. FAO, Rome. Available from https://www.ippc.int/id/ispms

FAO (Food and Agriculture Organization of the United Nations), 2004a. International Plant Protection Convention International standards for phytosanitary measures (ISPM) 11. Pest risk analysis for quarantine pests, including analysis of environmental risks and living modified organisms (originally adopted in 2001, with supplements integrated in 2003 and 2004). FAO, Rome. Available from https://www.ippc.int/id/ispms

FAO (Food and Agriculture Organization of the United Nations), 2004b. International Plant Protection Convention International standards for phytosanitary measures (ISPM) 20. Guidelines for a phytosanitary import regulatory system. FAO, Rome. Available from https://www.ippc.int/id/ispms

FAO (Food and Agriculture Organization of the United Nations), 2005. International Plant Protection Convention International standards for phytosanitary measures (ISPM) 22. Requirements for the establishment of areas of low pest prevalence. FAO, Rome. Available from https://www.ippc.int/id/ispms

FAO (Food and Agriculture Organization of the United Nations), 2006. International Plant Protection Convention International standards for phytosanitary measures (ISPM) 26. Establishment of pest free areas for fruit flies (*Tephritidae*). FAO, Rome. Available from https://www.ippc.int/id/ispms

FAO (Food and Agriculture Organization of the United Nations), 2007a. International Plant Protection Convention International standards for phytosanitary measures (ISPM) 28. Phytosanitary treatments for regulated pests. FAO, Rome. Available from https://www.ippc.int/id/ispms

FAO (Food and Agriculture Organization of the United Nations), 2007b. International Plant Protection Convention International standards for phytosanitary measures (ISPM) 29. Recognition of pest free areas and areas of low pest prevalence. FAO, Rome. Available from https://www.ippc.int/id/ispms

FAO (Food and Agriculture Organization of the United Nations), 2008a. International Plant Protection Convention International standards for phytosanitary measures (ISPM) 30. Establishment of areas of low pest prevalence for fruit flies (*Tephritidae*). FAO, Rome. Available from https://www.ippc.int/id/ispms

FAO (Food and Agriculture Organization of the United Nations), 2008b. International Plant Protection Convention International standards for phytosanitary measures (ISPM) 31. Methodologies for sampling of consignments. FAO, Rome. Available from https://www.ippc.int/id/ispms

FAO (Food and Agriculture Organization of the United Nations), 2009a. Checklist for evaluating treatment submissions. Submitted to and discussed at TPPT December 2007, additional information submitted in October 2009.

FAO (Food and Agriculture Organization of the United Nations), 2009b. International Plant Protection Convention International standards for phytosanitary measures (ISPM) 15. Regulation of wood packaging material in international trade (originally adopted in 2002, revised in 2009). FAO, Rome. Available from https://www.ippc.int/id/ispms

FAO (Food and Agriculture Organization of the United Nations), 2010. International Plant Protection Convention International Standards for Phytosanitary Measures – Draft Appendix to ISPM 15: 2009. Submission of New Treatments for Inclusion in ISPM 15, 6 pp. Available from http://www.aphis.usda.gov/import_export/plants/plant_exports/downloads/criteria_for_treatments_ISPM_15_.pdf

FAO (Food and Agriculture Organization of the United Nations), 2011. International Plant Protection Convention. International standards for phytosanitary measures 1 to 34. Available from https://www.ippc.int/id/ispms

Follett PA, 2004. Irradiation to control insects in fruits and vegetables for export from Hawaii. Radiation Physics and Chemistry 71, 161–164.

Follett PA and Neven LG, 2006. Current trends in quarantine entomology. Annual Review of Entomology 51, 359–385.

Follett PA and Sanxter SS, 2001. Hot water immersion to ensure quarantine security for *Cryptophlebia* spp. in lychee and longan exported from Hawaii. Journal of Economic Entomology 94, 1292–1295.

Fowler G, Caton B, Jackson L, Neeley A, Bunce L, Borchert D and McDowell R, 2006. Quantitative pathway initiated pest risk assessment: risks to the Southern United States associated with pine shoot beetle, *Tomicus piniperda* (Linnaeus), (Coleoptera: Scolytidae), on pine bark nuggets, logs and lumber with bark and stumps from the United States quarantined area. United States Department of Agriculture Animal and Plant Health Inspection Service, Raleigh, NC, June 2006, 96 pp. Available from http://www.aphis.usda.gov/plant_health/plant_pest_info/psb/downloads/southtimberpra.pdf

Garrett KA, 1997. Use of statistical tests of equivalence (bioequivalence tests) in plant pathology. Phytopathology 87, 372–374.

Gilligan CA and van den Bosch F, 2008. Epidemiological models for invasion and persistence of pathogens. Annual Review of Phytopathology 46, 385–418.

Goebel PC, Bumgardner MS, Herms DA and Sabula A, 2010. Failure to phytosanitize ash firewood infested with emerald ash borer in a small dry kiln using ISPM-15 standards. Journal of Economic Entomology 103, 597–602.

Gu J, Braasch H, Burgermeister W and Zhang J, 2006. Records of *Bursaphelenchus* spp. intercepted in imported packaging wood at Ningbo, China. Forest Pathology 36, 323–333

Gupta SC, 2001. Irradiation as an alternative treatment to methyl bromide for insect control. In: Loaharanu P and Thomas P (eds), Irradiation for Food Safety and Quality. International Atomic Energy Agency, Technomic Publishing Co., Lancaster, PA, pp. 39–49.

Haack R, Uzunovic A, Hoover K and Cook JA, 2011. Seeking alternatives to probit 9 when developing treatments for wood packaging materials under ISPM No. 15. Bulletin OEPP/EPPO Bulletin 41, 39–45.

Harwood TD, Xu X, Pautasso M, Jeger MJ and Shaw MW, 2009. Epidemiological risk assessment using linked network and grid based modelling: *Phytophthora ramorum* and *Phytophthora kernoviae* in the UK. Ecological Modelling 220, 3353–3361.

Heather NW, Corcoran, RJ and Banos C, 1991. Disinfestation of mangoes with gamma irradiation against two Australian fruit flies (Diptera: Tephritidae). Journal of Economic Entomology 84, 1304–1307.

Heinrich M, Botti S, Caprara L, Arthofer W, Strommer S, Hanzer V, Katinger H, Bertaccini A and da Câmara Machado ML, 2001. Improved detection methods for fruit tree phytoplasmas. Plant Molecular Biology Reporter 19, 169–179.

Holt J, 2006. Score averaging for alien species risk assessment: a probabilistic alternative. Journal of Environmental Management 81, 58–62.

Huebner CD, 2007. Strategic management of five deciduous forest invaders using *Microstegium vimineum* as a model species. In: Cavender N (ed.), Proceedings of the Ohio Invasive Plants Research Conference: Continuing Partnerships for Invasive Plant Management. Ohio Biological Survey, Columbus, OH, 19–28.

IPCS (International Programme on Chemical Safety), 2001. Harmonization of Approaches to the Assessment of Risk from Exposure to Chemicals: Glossary Of Exposure Assessment-related Terms: A Compilation. Harmonization of Approaches to the Assessment of Risk from Exposure to Chemicals. Geneva, WHO, 2001.

Jackson M, Bohac JR, Dalip KM, McComie L, Rhode L, Chung P, Seal D, Clarke-Harris D, Aseidu F and McDonald FD, 2010. Integrated pest management of major pests affecting sweetpotato, *Ipomoea batatas*, in the Caribbean. USAID Resources Management and Development Portal, 21pp. Available from: http://rmportal.net/library/content/nric/963.pdf/view?searchterm=health

Jamieson LE, Meier X, Page B, Zulhendri F, Page-Weir N, Brash D, McDonald RM, Stanley J and Woolf AB, 2009. A review of postharvest disinfestation technologies for selected fruits and vegetables. The New Zealand Institute for Plant and Food Research Ltd, Wellington, 36 pp.

Mahr SER, Cloyd RA, Mahr DL and Sadof CS, 2001. Biological control of insects and other pests of greenhouses crops. University of Wisconsin-Extension, Cooperative Extension, 108 pp.

Makowski D and Mittinty M, 2010. Comparison of scoring systems for invasive pests using ROC analysis and Monte Carlo simulations. Risk Analysis 30, 906–915.

Mangan RL and Sharp JL, 1994. Combination and multiple treatments. In: Sharp JL and Hallman GL (eds), Quarantine Treatments for Pests of Food Plants. Westview Press, Boulder, CO, pp. 239–247

Martin PAJ, Cameron AR and Greiner M, 2007. Demonstrating freedom from disease using multiple complex data sources. 1: A new methodology based on scenario trees. Preventive Veterinary Medicine 79, 71–97.

McMaugh T, 2005. Guidelines for surveillance for plant pests in Asia and the Pacific. Australian Centre for International Agricultural Research, Bruce, ACT, 55pp.

Melifronidou-Pantelidou A, 2009. Eradication campaign for *Rhynchophorus ferrugineus* in Cyprus. Bulletin OEPP/EPPO Bulletin 39, 155–160.

Mushrow L, Morrison A, Sweeney J and Quiring D, 2004. Heat as a phytosanitary treatment for the brown spruce longhorn beetle. The Forestry Chronicle 80, 224–228.

Myers SW, Fraser I and Mastro VC, 2009. Evaluation of heat treatment schedules for emerald ash borer (Coleoptera: Buprestidae). Journal of Economic Entomology 102, 2048–2055.

Newbill MA and Morrell JJ, 1991. Effect of elevated temperatures on survival of Basidiomycetes that colonize untreated Douglas-fir poles. Forest Products Journal 41(6), 31–33.

Newcombe RG, 1998. Two-sided confidence intervals for the single proportion: comparison of seven methods. Statistics in Medicine 17, 857–872.

Pautasso M, 2012. Review of quantitative assessment of risk reduction options applied in the EFSA outputs on biological hazards, in support of a guidance document of the EFSA Panel on Plant Health. Supporting Publications 2012:EN-251, 168 pp.

Pepe MS, 2003. The statistical evaluation of medical tests for classification and prediction. Oxford Statistical Series 28. Oxford University Press, Oxford, UK.

Peterson GL, Whitaker TB, Stefanski RJ, Podleckis EV, Phillips JG, Wu JS and Martinez WH, 2009. A risk assessment model for importation of United States milling wheat containing *Tilletia contraversa*. Plant Disease 93, 560–573.

Powell MR, 2002. A model for probabilistic assessment of phytosanitary risk reduction measures. Plant Disease 86, 552–557.

PQOI (Plant Quarantine Organization of India), 2005. Requirements for establishment of pest free areas for Tephritid fruit flies. NSPM-14, Directorate of Plant Protection, Quarantine and Storage (Dte of PPQS), Faridabad, 29pp.

PRATIQUE, 2011. Enhancement of pest risk assessment. Project final report, 67pp. Available from https://secure.fera.defra.gov.uk/pratique/publications.cfm

Prima Phacie, 2011. Pest risk assessment for the European Community Plant Health: a comparative approach with case studies – (acronym Prima Phacie), EFSA Art 36 project. Interim report 3.

Roberts RG, Haleb CN, van der Zwetc T, Millerd CE and Redlin SC, 1998. The potential for spread of *Erwinia amylovora* and fire blight via commercial apple fruit; a critical review and risk assessment. Crop Protection 17, 19–28.

Schomaker CH and Been TH, 1999. A model for infestation foci of potato cyst nematodes *Globodera rostochiensis* and *G. pallida*. Phytopathology 89, 583–590.

Schortemeyer M, Thomas K, Haack RA, Uzunovic A, Hoover K, Simpson J and Grgurinovic CA, 2011. Appropriateness of probit 9 in the development of quarantine treatments for timber and timber commodities. Journal of Economic Entomology 104, 717–731.

Schröder T, McNamara DG and Gaar V, 2009. Guidance on sampling to detect pine wood nematode *Bursaphelenchus xylophilus* in trees, wood and insects. Bulletin OEPP/EPPO Bulletin 39, 179–188.

Sgrillo R, 2002. Efficacy and equivalence of phytosanitary measures. IPPC Expert Working Group on the Efficacy of Phytosanitary Measures, Imperial College, London, UK, 2–4 July 2002.

Sigvald R and Hulle M, 2004. Aphid-vector management in seed potatoes: monitoring and forecasting. 12th EAPR Virology Section Meeting, Rennes, France, pp. 8–11.

Smith RS, 1991. The Use of heat treatment in the eradication of the pinewood nematode and its vectors in softwood lumber. Report of the task force on pasteurization of softwood lumber. Forintek Canada Corporation, Vancouver, BC.

Smith RS, 1992. Eradication of pinewood nematodes in softwood lumber. Proceedings of 13th Annual Meeting of Canadian Wood Preservation Association, pp. 185–206.

Smith CS, Lonsdale WM and Fortune J, 1999. When to ignore advice: invasion predictions and decision theory. Biological Invasions 1, 89–96.

Snedecor GW and Cochran WG, 1980. Statistical Methods, 7th edition. The Iowa State University Press, Ames, IA, 507 pp.

Sosnowski MR, Fletcher JD, Daly AM, Rodoni BC and Viljanen-Rollinson SLH, 2009. Techniques for the treatment, removal and disposal of host material during programmes for plant pathogen eradication. Plant Pathology 58, 621–635

Spijkerboer HP, Beniers JP, Jaspers D, Schouten HJ, Goudriaan J, Rabbinge R and van der Werf W, 2002. Ability of the Gaussian plume model to predict and describe spore dispersal over a potato crop. Ecological Modelling 15, 1–18.

Stansbury CD, McKirdy SJ, Diggle AJ and Riley IT, 2002. Modelling the risk of entry, establishment, spread, containment, and economic impact of *Tilletia indica*, the cause of karnal bunt of wheat, using an Australian context. Phytopathology 92, 321–331.

Swets JA, 1988. Measuring the accuracy of diagnostic systems. Science 240, 1285–1293.

USDA APHIS (United States Department of Agriculture, Animal and Plant Health Inspection Service), 2003. Guidelines for Fruit Fly Systems Approach to Support the Movement of Regulated Articles between Mexico and the United States. Draft Document, 5 June 2003, 26 pp.

USDA APHIS (United States Department of Agriculture, Animal and Plant Health Inspection Service), 2008a. New Pest Response Guidelines for the Emerald Ash Borer, *Agrilus planipennis* (Fairmaire) USDA–APHIS–PPQ–Emergency and Domestic Programs–Emergency Planning, Riverdale, MD.

USDA APHIS (United States Department of Agriculture, Animal and Plant Health Inspection Service), 2008b. Quantitative pathway analysis: likelihood of karnal bunt, (*Tilletia indica* M.), introduction as a result of the importation of United States wheat for grain into the European Union and desert durum wheat for grain into Italy. United States Department of Agriculture– Animal and Plant Health Inspection Service, 105 pp.

USDA APHIS (United States Department of Agriculture, Animal and Plant Health Inspection Service), 2011a. Fresh Fruits and Vegetables Import Manual, 612 pp.

USDA APHIS (United States Department of Agriculture Animal and Plant Health Inspection Service), 2011b. Federal Import Quarantine Order for Host Materials of Tomato Leafminer, *Tuta absoluta* (Meyrick). Federal order, 5 May 2011, 6 pp.

USDA APHIS (United States Department of Agriculture, Animal and Plant Health Inspection Service), 2011c. Treatment manual 01/2011–53 PPQ. Treatment Schedules T300: Schedules for miscellaneous plants. T314: Logs and firewood. T314-a: Regulated Wood Articles, including Fraxinus (Ash Logs and Firewood) and all Hardwood Firewood from Emerald Ash Borer quarantine areas. 5–4-38. Available from: http://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/treatment_pdf/05_04_t300schedules.pdf

Vail PV, Tebbets JS, Mackey BE and Curtis CE, 1993. Quarantine treatments: a biological approach to decision-making for selected hosts of codling moth (Lepidoptera: Tortricidae). Journal of Economic Entomology 86, 70–75.

Venette RC, 2010. Pine commodity-based survey guidelines, July 2008, Revised 2010. Northern Research Station, USDA Forest Service, St Paul, MN.

Venette RC, Moon RD and Hutchison WD, 2002. Strategies and statistics of sampling for rare individuals. Annual Review of Entomology 47, 143–174.

Wardlaw T, Bashford R, Wotherspoon K, Wylie R and Elliot H, 2008. Effectiveness of routine forest health surveillance in detecting pest and disease damage in eucalypt plantations. New Zealand Journal of Forestry Science 38, 253–269.

Yamamura K and H Katsumata, 1999. Efficiency of export plant quarantine inspection by using injury marks. Journal of Economic Entomology 92, 974–980.

Yano E, 2006. Ecological considerations for biological control of aphids in protected culture. Population Ecology 48, 333–339.

Yemshanov D, Koch FH, McKenney DW, Downing MC and Sapio F, 2009. Mapping invasive species risks with stochastic models: a cross border United States Canada application for *Sirex noctilio* Fabricius. Risk Analysis 29, 868–884.

Zehnder G, Kloepper J, Tuzun S, Yao C, Wei G, Chambliss O and Shelby R, 1997. Insect feeding on cucumber mediated by rhizobacteria-induced plant resistance. Entomologia Experimentalis et Applicata 83: 81–85.

Zettler JL, Follett PA and Gill RF, 2002. Susceptibility of *Maconellicoccus hirsutus* (Homoptera: Pseudococcidae) to methyl bromide. Journal of Economic Entomology 95, 1169–1173.

APPENDICES

A. KEY WORDS AND STRINGS USED FOR THE LITERATURE SEARCH IN THE ISI WEB OF KNOWLEDGE

1. Options for consignments – Prohibition.
   - Key words:
     Prohibition of import, illegal import, prohibitions of commodities (plants/crops)
   - String:
     Topic=(prohibition SAME import*) AND Topic=(plant* OR commodit* OR crop$)

2. Options for consignments – Pest freedom: inspection or testing.
   - Key words:
     Sample (size/method/procedure & equipment), pest freedom, inspection, laboratory testing, pest free area, low pest prevalence
   - String:
     Topic=((sample$ (size OR method$ OR procedure$ OR equipment$)) AND (pest free area$)) AND Topic=(plant pest*)
     Topic=(sample$ method*) AND Topic=((pest free area$) AND (plant pest*)) AND Topic=(inspection*)
     Topic=(pest SAME ((free area*) OR prevalence)) AND Topic=(plant pest*) AND Topic=((inspection$ OR (laboratory test*)))

3. Options for consignments – Prohibition of parts of the host or of specific genotypes of the host.
   - Key words:
     Resistant varieties, cultivars, plants, plant parts, species, prohibition of import, illegal import, prohibitions of commodities (plants/crops)
   - String:
     Topic=(prohibition SAME (import* OR commodit* OR crop$)) AND Topic=(Resistant SAME (variet* OR cultivar$ OR plant*))

4. Options for consignments – Pre-entry or post-entry quarantine system.
   - Key words:
     Inspection, testing, detectability, consignment, laboratory, detection, method, plants
   - String:
     Topic=(consignment$ AND (inspection$ OR test* OR detect*)) AND Topic=(pest$ AND (plant* OR crop*)) AND Topic=(laboratory OR (detection method*))

5. Options for consignments – Phytosanitary certificates and other compliance measures.
   - Key words:
     Plant passport, phytosanitary certificate, Europe
   - String:
     Topic=(phytosanitary certificate)

6. Options for consignments – Preparation of the consignment.
   - Key words:
     Handling, debarking, wood processing, treatment, consignment, plant material
   - String:
     Topic=((handl* OR debark* OR process* OR treat*)) AND Topic=(plant* SAME pest$) AND Topic=(wood* SAME consignment$)
     Topic=((handl* OR debark* OR process* OR treat*) SAME wood*) AND Topic=(phytosanitary)
     Topic=((handl* OR debark* OR process* OR treat*) SAME wood*) AND Topic=(phytosanitary) AND Topic=(import* OR export*)

7. Options for consignments – Specified treatment of the consignment/Reducing pest prevalence in the consignment.
   - Key words:
     Chemical treatment, fumigation, chemical pressure impregnation, suppression of germination thermal treatment, vapour heat treatment, heat treatment, cold treatment, hot water treatment, quick freeze treatment/drench, chemical pressure impregnation, suppression of germination, solarisation, compostation, sterilisation, irradiation, suppression of germination, waxing, seed coating, brushing, (protection against reinfestation)
   - String:
     Topic=((chemical treatment$) OR (pressure impregnation) OR fumigation OR (suppression of germination) OR (thermal treatment$) OR (vapour heat treatment$) OR (heat treatment$) OR (cold treatment$) OR (hot water treatment$) OR (quick freeze treatment$) OR drench* OR (chemical pressure impregnation) OR (suppression of germination) OR solarisation OR compostation OR sterilisation OR irradiation OR waxing OR (seed coating) OR brushing OR (protection against reinfestation)) AND Topic=((crop$ OR plant$) SAME pest$) AND Topic=(consignment$ OR inspection$ OR border$)

8. Options for consignments – Restriction on end use, distribution and periods of entry.
   - Key words:
     Restriction/limitation of use, intended use, end use, period of consignment
   - String:
     Topic=(((restriction of use) OR (limitation of use) OR (intended use) OR (end use)) OR (period of consignment)) AND Topic=((crop$ OR plant$) SAME pest$) AND Topic=(consignment$ OR inspection$ OR border$)

9. Options preventing or reducing infestation in the crop – Treatment of the crop, field, or place of production in order to reduce pest prevalence.
   - Key words:
     Spraying, control
   - String:
     A specific string was not defined, because, considering the amount of available publications on this field, only some examples were included.

10. Options preventing or reducing infestation in the crop – Resistant or less susceptible varieties.
    - Key words:
      Resistant varieties, cultivars, plants, species
    - String:
      See point 3.
11. Options preventing or reducing infestation in the crop – Growing plants under exclusion conditions (glasshouse, screen, isolation).

    - Key words:
      Protected conditions (glasshouse, isolation), greenhouse, in-vitro culture, plastic foil.
    - String:
      Topic=((protected condition$) AND (glasshouse$ OR greenhouse$ OR invitro OR in vitro OR (plastic foil$))) AND Topic=(plant$ SAME pest$) AND Topic=(restriction$)
      Topic=((protected condition$) AND (glasshouse$ OR greenhouse$ OR invitro OR in vitro OR (plastic foil$))) AND Topic=(plant$ SAME pest$) AND Topic=(guideline$ OR guidance$)

12. Options preventing or reducing infestation in the commodity – Harvesting of plants at a certain stage of maturity or during a specified time of year.

- Key words:
  Early harvest, harvesting period, trap crops
- String:
  Topic=(((early harvest) OR (harvesting period)) AND (trap crops)) AND Topic=(plant$ SAME pest$) AND Topic=(infest*)

13. Options preventing or reducing infestation in the crop – Certification scheme.
    - Key words:
      Certification system/scheme, virus, pathogens
    - String:
      Topic=(certification$ SAME (system$ OR scheme$)) AND Topic=(plant$ AND (virus* OR pathogen$ OR pest$)) AND Topic=(guidance OR guideline$)

14. Options ensuring that the area, place or site of production, remains free from the pest – Pest free area.
    - Key words:
      Control, containment, eradication, surveillance, survey, demarcated zones, (method), protected zone, Europe
    - String:
      Topic=(eradication$ AND (pest$ SAME plant$)) AND Topic=(surveillance$ OR survey$) AND Topic=(demarcated OR protected)

15. Options ensuring that the area, place or site of production or crop is free from the pest – Pest free production site
    - Key words:
      Pest free production site, pest free place of production
    - String:
      Topic=((pest free production site) OR (pest free place of production)) AND Topic=(crop$ OR plant$)

16. Options ensuring that the area, place or site of production or crop is free from the pest – Inspections, surveillance.
    - Key words:
      Inspections, surveillance, testing, survey, latent infestation/infection
    - String:
    Topic=(latent SAME (infestation$ OR infection$)) AND Topic=(crop$ OR plant$) AND Topic=(inspection$ OR surveillance$ OR testing$ OR survey$)

17. Options for other types of pathways – Natural spread, spread by human activities (people movement, transport, machinery, trade), vectors, phoresy.
    - Key words:
    Cleaning, disinfestations, fines, incentives, inspection, publicity, tourist, travellers, vector control, soil contamination, irrigation water
    - String
    Topic=((tourist$ OR traveller$ OR incentive$ OR vector$) AND pathway$) AND Topic=((crop$ OR plant$) SAME pest$) AND Topic=(control* OR inspection$)

18. Other relevant information.
    - This group includes a significant number of relevant documents that cannot however be associated with a specific type of RRO identified above. This groups results from the screening of the publications from the other 17 groups not retained in the specific groups but of general relevance.

B. DATABASE OF REFERENCES SELECTED FROM THE LITERATURE SEARCH (COMPILED IN SEPTEMBER 2011)

Ref No	Type of Documents (G)uidance (E)xperiment (O)ther	Reference	Relevant part (Page, section, chapter paragraph etc.)	Risk reduction option	Plants and plant product	Pest(s)	Comments
Group 1: Options for consignments – Prohibition (pest risk assessment step: Entry)							
1.	G	CFIA (Canadian Food Inspection Agency), 2010. Phytosanitary requirements to prevent the introduction into and spread within Canada of the Emerald Ash Borer, *Agrilus planipennis* Fairmaire. 2nd revision, 30 pp.	Whole document	Prohibition of movement from regulated to non regulated areas or from regulated areas to regulated areas transiting a non-regulated Area or between adjacent regulated areas	Logs, trees, wood, wood and bark chips, nursery stock, stand alone wood packaging materials, and other articles in the genus *Fraxinus* and firewood of all species	*Agrilus planipennis*	The document contains phytosanitary requirements to prevent the entry and spread within Canada; conditions for authorisation of movement of regulated articles within Canada are described requirements for imported regulated articles are also presented
Group 2: Options for consignments – Pest freedom: inspection or testing (pest risk assessment step: Entry)							
2.	G	Biosecurity Australia (2005). Draft Extension of Existing Policy for Sweet Oranges from Italy. Canberra, ACT. March 2005, 176 pp.	Relevant part: Stage 3: Pest Risk Management: pages 58-64	Various risk management measures are recognised to manage the risks associated with sweet oranges: cold treatment or PFA for Mediterranean fruit fly; inspection and remedial action for citrophilus mealybug, citrus pyralid and citrus flower moth; and operational	Sweet oranges (*Citrus sinensis*) from Italy	*Ceratitis capitata*, *Pseudococcus calceolariae*, *Cryptoblabes gnidiella* and *Prays citri*	

				systems for the maintenance and verification of the phytosanitary status of sweet oranges			
3.	G	Chew V, 1996. Probit analysis and probit 9 as a standard for quarantine security. In: Bartlett PW, Chaplin GR and van Velsen RJ, Plant Quarantine Statistics: A Review, 29–42.	Whole document	Probit 9			Probit analyses and probit 9 as a standard for quarantine security is discussed.
4.	E	Elmouttie D, Kiermeier A and Hamilton G, 2010. Improving detection probabilities for pests in stored grain. Pest Management Science 2010; 66, 1280–1286.	Whole document	Sampling programme, detection for pests in stored grain	Stored grain	Grain pests (e.g. *Rhyzopertha dominica*, *Cryptolestes* spp. *Sitophilus oryzae*	The study underlines the importance of considering an appropriate biological model when developing sampling methodologies for insect pests.
5.	G	MAF (Ministry of Agriculture and Forestry) Biosecurity Authority, 2003. Sea Container Review. MAF Discussion Paper No: 35, 116 pp.	Partly relevant: pages 11-13	Guidance on sampling	Sea containers arriving to New Zealand	Miscellaneous	Methods for surveying ports (including number of containers to be surveyed and container selection procedure) are described. Facilities and procedures that exist for on-wharf external inspection and treatment, such as CCTV, X-ray machines, auto-washing and new treatments. Containers are listed and brefly described (not in detail).
6.	G	Schröder T, McNamara DG and Gaar V, 2009. Guidance on sampling to detect pine wood nematode *Bursaphelenchus xylophilus* in trees, wood and insects. Bulletin OEPP/ EPPO bulletin 39, 179–188.	Whole document	Guidance on sampling	Trees, wood and insects	*Bursaphelenchus xylophilus*	Guidance on sampling to detect pine wood nematode (PWN) in trees, wood and insects are described: Detection of PWN in standing and cut trees; detection by the use of trap trees; sampling in sawmills and timber yards; extraction of nematodes from wood samples; detection of PWN in ⁄on insects
7.	G	USDA (United States Department of Agriculture) APHIS (Animal and Plant Health Inspection Service), 2007. Nursery Stock	Page 6	Sampling procedures	Nursery stock (*Chaenomeles*,	Miscellaneous	The entry status of regulated plant materials capable of and

		Restrictions, 432 pp.			*Cydonia*, *Malus*, *Prunus*, and *Pyrus*)		intended for propagation (nursery stock) is presented
8.	G	USDA APHIS (Animal and Plant Health Inspection Service), 2011. Federal Import Quarantine Order for Host Materials of Tomato Leafminer, *Tuta absoluta* (Meyrick). Federal order, 5 May 2011, 6 pp.	Relevant part: pages 4-6	Detection and surveillance for tomato leafminer, *Tuta absoluta* is demonstrated (five traps is sufficient to detect T. Absoluta - this is indicated by new research)	Tomato; plants for planting of *Solanum* spp., *Datura* spp. and *Nicotiana* spp , which are also hosts of *T. absoluta*, from all affected countries	*Tuta absoluta*	Beside prescription of five traps for detection and surveillance of *T. absoluta*, additional import requirements are listed
9.	E	Vail PV, Tebbets JS, Mackey BE and Curtis CE, 1993. Quarantine treatments: a biological approach to decision-making for selected hosts of codling moth (Lepidoptera: Tortricidae). Journal of Economic Entomology 86(1), 70–75.	Whole document	Systems approaches to quarantine	Cherry, nectarine, wallnut (*Prunus* spp.)	*Cydia pomonella*	Biological approach to decision making for selected hosts of Codling moth is discussed. Systems approaches to quarantine include development of more qualitative biology data, modification of shipment volume, arrival times and the distribution of the commodity upon arrival. It is suggested that quarantine treatment should be based on survival and that, in number of situations, treatment is not needed at all.
Group 3: Options for consignments – Prohibition of parts of the host or of specific genotypes of the host (pest risk assessment step: Entry)							
10.	O	Armstrong JW, 1994. Commodity resistance to infestation by quarantine pests. In Sharp L and Hallman GJ [eds.], Quarantine treatments for pests of food plants. 1994. Westview, Boulder, CO., 199–211.	Whole document	Commodity resistance	Exaples on quarantine hosts	Examples on *Ceratitis capitata*, *Cryptorhynchus mangiferae*, *Bactrocera* spp., *Anastrepha* spp.	Review
11.	G	CFIA (Canadian Food Inspection Agency), 2008. D-01-04: Plant protection import and domestic movement requirements for barberry (*Berberis*, *Mahoberberis* and *Mahonia* spp.) under the Canadian Barberry Certification Program. 2nd revision, October 27, 2008, 16 pp.	All 16 pp	Many options	Plants for planting *Berberis*, *Mahoberberis*, *Mahonia* spp.	*Puccinia graminis*	Full guidance doc for Canada; relevant to most of the groups

Group 4: Options for consignments – Pre-entry or post-entry quarantine system (pest risk assessment step: Entry)							
12.	G	Abbreviated hypergeometric tables for risk-based sampling in commodity inspection.	Whole document	Inspection methodology for plant quarantine	NA	NA	Statistical tables for the hypergeometric distribution
13.	G	APHIS (Animal and Plant Health Inspection Service) AQIM (Agriculture Quarantine Inspection Monitoring), 2003. AQIM sampling process. AQIM handbook 06/2003-1 PPQ, 10 pp.	Whole document	Inspection methodology for plant quarantine	NA	NA	USDA Agricultural Quarantine Inspection Monitoring handbook
14.	E	Asaad S and Abang MM, 2009. Seed-borne pathogens detected in consignments of cereal seeds received by the International Center for Agricultural Research in the Dry Areas (ICARDA), Syria. International Journal of Pest Management 55(1), 69–77.	Whole document	Detection of seed pathogens in seed consignments	Cereals	Tilletia caries; *T. foetida*; *T. controversa*; *Ustilago tritici*; *T. indica*; *Fusarium* spp.; *Helminthospori um* spp.; *Ustilago* spp.; *Urocystis agropyri*; *Anguina tritici*; *Ustilago hordei*	Survey made in 1995-2004, in Syria
15.	G	Griffin R, 1997. Inspection methodology for plant quarantine. Arab Journal of Plant Protection 15, 140–143.	Whole document	Inspection methodology for plant quarantine	NA	NA	FAO-Review
16.	E	Gu J, Braasch H, Burgermeister W and Zhang J, 2006. Records of Bursaphelenchus spp. intercepted in imported packaging wood at Ningbo, China. Forest Pathology 36, 323–333.	Whole document	Detection, interception	Wood packaging material	*Bursaphelenchu s* spp.	Morphology, ITS-RFLP
17.	E	Heinrich M, Botti S, Caprara L, Arthofer W, Strommer S, Hanzer V, Katinger H, Bertaccini A and da Câmara Machado ML, 2001. Improved detection methods for fruit tree phytoplasmas. Plant Molecular Biology Reporter 19, 169–179.	Whole document	Detection method	Micropropagated fruit trees (*Malus domestica* and *Pyrus* sp.)	Phytoplasma	
18.	G	Tan MK and Wright D, 2009. Enhancing the detection of *Tilletia indica*, the cause of Karnal bunt. CRC20004 – Final Report. Cooperative Research Centre for National Plant Biosecurity, 30 June 2009, 64 pp.	Whole document	Protocol for quarantine detection of *Tilletia indica*	*Triticum* spp.	*Tilletia indica*	Detection protocol, Australia
19.	G	Tan MK, Brennan JP, Wright D and Murray GM, 2010. An enhanced protocol for the quarantine detection of *Tilletia indica* and	Whole document	Protocol for quarantine detection	*Triticum* spp.	*Tilletia indica*	A protocol developed in Australia and involving a highly

		economic comparison with the current standard. Australasian Plant Pathology 39, 334–342.		of *Tilletia indica*			sensitive one-tube molecular assay
20.	G	USDA (United States Department of Agriculture) APHIS (Animal and Plant Health Inspection Service), 2011. Cut flowers and greenery import manual, 158 pp.	Whole document	Inspection methodology for plant quarantine	NA	NA	USDA - A manual concerning the importation of cut flowers and greenery
21.	G	USDA (United States Department of Agriculture) APHIS (Animal and Plant Health Inspection Service), 2011. Fresh fruits and vegetables import manual, 610 pp.	Whole document	Inspection methodology for plant quarantine	NA	NA	USDA-a listing of fruits and vegetables that have been approved for entry into the United States from foreign countries
22.	G	Venette RC, Moon RD and Hutchison WD, 2002. Strategies and statistics of sampling for rare individuals. Annual Review of . Entomology 47, 143–174.	Whole document	Sampling strategies for rare individuals	NA	NA	Binomial-, β-binomial-, and hypergeometric-based sampling strategies.
23.	E	Vilardi Tenente RC, Costa Manso ES and Figueira Filho ES, 1996. Inspeção e detecção de fitonematóides em introduções de germoplasma no Brasil no período de 1992-1994. Nematologia Brasileira 20(2), 68–73.	English summary p 65	Detection, thermal treatment, chemical treatment	Plant germplasm	Nematodes	
Group 6: Options for consignments – Preparation of the consignment (pest risk assessment step: Entry)							
24.	G	FAO (Food and Agriculture Organization of the United Nations), 2009b. International Plant Protection Convention International standards for phytosanitary measures (ISPM) 15. Regulation of wood packaging material in international trade (originally adopted in 2002, revised in 2009). FAO, Rome. Available from https://www.ippc.int/id/ispms	All pages	Methyl bromide, heat	Wood packaging material		
25.	O	Haack RA, Uzunovic A, Hoover K and Cook JA, 2011. Seeking alternatives to probit 9 when developing treatments for wood packaging materials under ISPM No. 15. Bulletin OEPP/ EPPO bulletin 41, 39–45.	Whole document	Treatment of consignment	Wood packaging material		Proposal for alternatives for probit-9
26.	G	Ibach RE, 1999. Wood preservation. In: Wood Handbook – Wood as an Engineering Material. Gen. Tech. Rep. FPL-GTR-113. US Department of Agriculture, Forest Service, Forest Products Laboratory. Madison, WI, 463 pp.	Whole document	Chemical preservation of wood	Wood		Broad and detailed coverage of methods
Group 7: Options for consignments – Specified treatment of the consignment/ Reducing pest prevalence in the consignment (pest risk assessment step: Entry)							
27.	G	USDA (United States Department of Agriculture) APHIS (Animal and Plant Health Inspection Service), 2011. Treatment manual, 90 pp.	All pages	Various treatments (methyl bromide, heat, radiation, etc)	Fruit, nuts and vegetables	Many species	USDA Treatment manual

28.	G	APHIS (Animal and Plant Health Inspection Service) AQIM (Agriculture Quarantine Inspection Monitoring), 2008. AQIS Heat Treatment Standard – Treatments and Fumigants – Version 1, 18 pp.	All pages	Dry heat treatment	Many species	Many species	Australia treatment manual
29.	E	Araya JE, Curkovic T and Zárate H, 2007. Mortality of *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) by gamma irradiation. Agricultura Técnica (Chile) 67(2), 196–200.	All	Irradiation	Not specified	*Frankliniella occidentalis*	Dose-response
30.	E	Arcinas AC, 2002. Hot water drench treatments for the control of burrowing nematode, *Radopholus similis*, in tropical ornamentals. Thesis (Master) in Botanical Sciences (Plant Pathology), University of Hawaii, 80 pp.	All	Hot water drenching	Palm species, *Anthurium* spp.	*Radopholus similis*	Dose-response
31.	O	Armstrong JW and Mangan RL, 1998. Commercial quarantine heat treatments. In: Tang J et al. (eds), Heat Treatments for Postharvest Pest Control. CAB International, Wallingford, UK, 311–340.	All pages	Heat treatment	Many species	Many species	Book chapter, review of methods
32.	O	Baker AC, 1939. The basis for treatment of products where fruitflies are involved as a condition for entry into the United States. Circular No 551, December 1939, United States Department of Agriculture, 8 pp.	All	Various	Fruit and vegetables	*Bactrocera cucurbitae*, *Ceratitis capitata*	Probit 9 approach
33.	E	Barak AV, Wang X, Yuan P, Jin X, Liu Y, Lou S and Hamilton B, 2006. Container fumigation as a quarantine treatment for *Anoplophora glabripennis* (Coleoptera: Cerambycidae) in regulated wood packing material. Journal of Economic Entomology 99(3), 664–670.	All pages	Fumigation	Wood packaging material	*Anoplophora glabripennis*	
34.	E	Bi J, Ballmer G and Toscano NC, 2009. Evaluation of strawberry nursery plant cold treatments on survival of the whitefly, *Bemisia tabaci*. 4 pp.	All	Cold treatment	*Fragaria* spp.	*Bemisia tabaci*	Effective treatment
35.	E	Birla SL, Wang S, Tang J and Hallman G, 2004. Improving heating uniformity of fresh fruit in radio frequency treatments for pest control. Postharvest Biology and Technology 33, 205–217.	All	Radio frequency with temperature	*Citrus paradise*, *Citrus sinensis* and other citrus, *Malus domestica*	*Anastrepha ludens*, *Anastrepha suspensa*, *Cydia pommonella* and other insects of fruit	Comparison of treatments
36.	G	Bond EJ, 2007. Manual of fumigation for insect control. FAO Plant Production and Protection Paper 54, 364 pp.	All especially	Fumigation	Many species	Many species	FAO Manual

			Ch 13,				
37.	E	Brcka C, McSorley R and Frederick J, 2000. Effect of hot water treatments on root-knot nematodes and caladium tubers. Proceedings of Florida State Horticultural Society 113, 158–161.	All	Hot water treatment	Caladium (*Caladium × hortulanum*)	*Meloidogyne incognita*	Comparison of treatments
38.	E	Drake SR and Neven LG, 1997. Irradiation as an alternative to methyl bromide for quarantine treatment of stone fruits. Journal of Food Quality 22, 529–538.	All	Irradiation	Stone fruit	None	Dose- response of fruit quality
39.	O	EFSA Plant Health (PLH) Panel, 2009. Scientific Opinion of the Panel on PLH on a request from the European Commission on mortality verification of pinewood nematode from high temperature treatment of shavings. EFSA Journal 1055, 1–19.	All	Heat treatment	Wood shavings	*Bursaphelenchus xylophilus*	Exclusion of treatment in evaluation of experimental papers
40.	E	Encinas O and Briceño I, 2010. Effect of moisture content in Caribbean pine wood used for packing wood subject to heat treatment, ISPM 15. Revista Forestal Venezolana 54(1), 21–27.	All	Heat treatment of wood packaging material	Wood packaging material	Wood fungi	Shortcomings of ISPM 15 requirements
41.	G	EPA (Environmental Protection Agency, United States), 2010. MeBr alternatives for applicators, commodity owners, shippers, and their agents. 68 pp.	All	Various	Many species	Many species	Alternatives to replace methyl-bromide fumigation
42.	G	EPPO (European and Mediterranean Plant Protection Organization), 2009. Hot water treatment of *Dracaena* And *Yucca* cuttings against *Opogona sacchari*. PM 10/2 (1). Bulletin OEPP/ EPPO bulletin 39, 28.	All	Hot water treatment	Cuttings of Yucca and Dracaena	*Opogona sacchari*	EPPO Standard
43.	G	EPPO (European and Mediterranean Plant Protection Organization), 2009. Sulfuryl fluoride fumigation of dried fruits and nuts to control various stored product insects. PM 10/4 (1). Bulletin OEPP/EPPO bulletin 39, 29–30.	All	Sulfuryl fluoride fumigation	Dried fruits and nuts	Stored products insects	EPPO Standard
44.	G	EPPO (European and Mediterranean Plant Protection Organization), 2009. Heat treatment of wood to control insects and wood-borne nematodes. PM 10/6 (1). Bulletin OEPP/EPPO bulletin 39, 31.	All	Heat treatment	Wood	Wood related insects, *Bursaphelenchus* spp.	EPPO Standard
45.	G	EPPO (European and Mediterranean Plant Protection Organization), 2009. Methyl bromide fumigation of wood to control insects. PM 10/7 (1). Bulletin OEPP/EPPO bulletin 39, 32–33.	All	Methyl-Bromide fumigation	Wood	Wood related insect pests, e.g. Scolytidae, Buprestidae and Cerambycidae	EPPO Standard
46.	G	EPPO (European and Mediterranean Plant	All	Ionizing radiation	Round and sawn	Many species	EPPO Standard

		Protection Organization), 2009. Disinfestation of wood with ionizing radiation. PM 10/8 (1). Bulletin OEPP/EPPO bulletin 39, 34–35.			wood		
47.	G	EPPO (European and Mediterranean Plant Protection Organization), 2009. Low energy electron treatment of cereal seed against fungi. PM 10/9 (1). Bulletin OEPP/EPPO bulletin 39, 36.	All	Low energy electron treatment of seed surface	Seed of *Triticum aestivum* and *Secale cereale*	*Tilletia* caries, *Urocystis occulta*	EPPO Standard
48.	G	EPPO (European and Mediterranean Plant Protection Organization), 2009. Irradiation of stored products to control stored-product insects in general. PM 10/10 (1). Bulletin OEPP/EPPO bulletin 39, 37–38.	All	Irradiation	Stored products	Insects	EPPO Standard
49.	G	EPPO (European and Mediterranean Plant Protection Organization), 2009. Fumigation of cut flowers to control insects and mites. PM 10/12 (1). Bulletin OEPP/EPPO bulletin 39, 39.	All	Fumigation	Cut flowers	Insects and mites	EPPO Standard
50.	G	EPPO (European and Mediterranean Plant Protection Organization), 2006. Disinfection procedures in potato production. PM 10/1 (1). Bulletin OEPP/EPPO bulletin 36, 463–466.	All	cleaning and disinfection procedures	*Solanum tuberosum*	*Clavibacter michiganensis* subsp. *sepedonicus*, *Ralstonia solanacearum*	EPPO Standard
51.	G	EPPO (European and Mediterranean Plant Protection Organization), 2009. Disinfestation of production site against *Bemisia tabaci*. PM 10/13 Bulletin OEPP/EPPO bulletin 39, 478–479.	All	Insecticides	Ornamental and vegetable crops	*Bemisia tabaci*	EPPO Standard
52.	G	EPPO (European and Mediterranean Plant Protection Organization), 2009. Disinfestation of production site against *Liriomyza sativae*. PM 10/14 (1). Bulletin OEPP/EPPO bulletin 39, 480–481.	All	Insecticides	Ornamental and vegetable crops	*Liriomyza sativae*	EPPO Standard
53.	G	EPPO (European and Mediterranean Plant Protection Organization), 2009. Disinfestation of production site against *Thrips palmi*. PM 10/15. Bulletin OEPP/EPPO bulletin 39, 482–483.	All	Insecticides	Ornamental and vegetable crops	*Thrips palmi*	EPPO Standard
54.	E	Evans HF and Fielding NJ, 2002. Alternatives to Methyl Bromide for control of quarantine pests: can composting of bark provide consistent lethal heat accumulation? Proceedings: 2002 U.S. Department of Agriculture Interagency Research Forum GTR-	All	Composting	Bark, wood chips	Many species	Heat inside compost heap is not sufficient

		NE-300, 20–22.					
55.	G	FAO/WHO Food Standards, 1983. General standard for irradiated foods. CODEX STAN 106-1983, REV.1-2003, 3 pp.	All	Irradiation	Many species	Many species	
56.	E	Ferriss RS, 1984. Effects of microwave oven treatment on microorganisms in soil. The American Phytopathological Society 74(1), 121–126.	All	Microwave	Soil	Fungi, nematodes	Dose-response, microwaving is effective
57.	O	Fields PG and White NDG, 2002. Alternatives to Methyl Bromide treatments for stored-product and quarantine insects. Annual Review of Entomology 47, 331–359.	All	Various	Many species	Many species	Review of alternatives to methyl-bromide
58.	E	Fleming MR, Janowiak JJ, Kimmel JD, Halbrendt JM, Bauer LS, Miller DL and Hoover K, 2005a. Efficacy of commercial microwave equipment for eradication of pine wood nematodes and cerambycid larvae infesting red pine. Forest Products Journal 55(12), 226–232.	All	Microwaves	Wood	*Bursaphelenchus xylophilus*, beetles	Microwaving can be effective
59.	E	Fleming MR, Janowiak JJ, Halbrendt JM, Bauer LS, Miller DL and Hoover K, 2005b. Feasibility of eradicating cerambycid larvae and pinewood nematodes infesting lumber with commercial 2.45 GHz microwave equipment. Forest Products Journal 55(12), 227–232.	Whole document	Heat treatment (microwaves)	Pine wood	*Bursaphelenchus xylophilus*	Effectiveness of commercial microwave equipement
60.	E	Follett PA, 2004. Irradiation to control insects in fruits and vegetables for export from Hawaii. Radiation Physics and Chemistry 71, 161–164.	All	Irradiation	*Ipomoea batatas*	*Ceratitis capitata*, *Bactrocera dorsalis*, *B. curcurbitae*, *B. latifrons* and other	Dose-response, confirmation of generic dose
61.	O	Follett PA, 2009. Generic radiation quarantine treatments: the next steps. Journal of Economic Entomology 102(4), 1399–1406.	All	Irradiation	Fresh horticultural commodities	Insects	Further research needs on irradiation
62.	O	Follett PA and McQuate GT, 2001. Accelerated development of quarantine treatments for insects on poor hosts. Journal of Economic EntomologyJ 94(5), 1005–1011.	All	Various	Fruit	Fruit flies	Probit 9 discussion
63.	O	Follett PA and Neven LG, 2006. Current trends in quarantine entomology. Annual Review of Entomology 51, 359–85.	All	Generic	Generic	Generic	Probit 9 alternatives for phytosanitary measures
64.	G	Forestry Commission, 2003. Verification of heat treatment facilities and authorisation of the use of the DB-HT mark to comply with the international standard for phytosanitary	All	Various treatments of wood packaging material	Wood packaging material	Wood related insects, *Bursaphelenchu*	Verification of facilities, authorisation of the ISPM No 15 Mark

		measures ISPM 15, 8pp.				*s* spp	
65.	E	Goebel PC, Bumgardner MS, Herms DA and Sabula A, 2010. Failure to phytosanitize ash firewood infested with emerald ash borer in a small dry kiln using ISPM-15 Standards. Journal of Economic Entomology 103(3), 597–602.	All	Kiln drying	Ash firewood	*Agrilus planipennis*	Failure of ISPM No 15 treatment
66.	O	Gupta, SC, 2001. Irradiation as an alternative treatment to methyl bromide for insect control. In: Loaharanu P and Thomas P (eds), Irradiation for Food Safety and Quality. International Atomic Energy Agency, Technomic Publishing Co., Lancaster, PA, 39–49.	All	Various alternatives for methyl-bromide	Many species	Many species	Review of alternatives to methyl-bromide
67.	E	Haack RA and Petrice TR, 2009. Bark- and wood-borer colonization of logs and lumber after heat treatment to ISPM 15 specifications: The Role of Residual Bark. Journal of Economic Entomology 102(3), 1075–1084.	All	Heat treatment	Wood packaging material	Wood insects	Failure of ISPM 15 treatment
68.	O	Haack RA, Uzunovic A, Hoover K and Cook JA, 2011. Seeking alternatives to probit 9 when developing treatments for wood packaging materials under ISPM No. 15. Bulletin OEPP/ EPPO bulletin 41, 39–45.	All	Various treatments of wood packaging material	Wood packaging material	Wood related insects, *Bursaphelenchus* spp.	Probit 9 alternatives for wood treatments
69.	O	Hallman GJ, 2011. Phytosanitary applications of irradiation. Comprehensive Reviews in Food Science and Food Safety, 10, 143–151.	All	Irradiation	Generic	Generic	Review of irradiation for phytosanitary purposes
70.	E	Hughs SE, Armijo CB and Staten RT, 2006. Boll weevil kill rates by gin processing and bale compression. American Society of Agricultural and Biological Engineers 22(1), 45–50.	All	Gin processing and bale compression	*Gossypium* spp.	*Anthonomus grandis grandis*	Routine processing of cotton
71.	E	IAEA (International Atomic Energy Agency), 1999. Irradiation as a quarantine treatment of arthropod pests. Proceedings of the final meeting held in Honolulu, Hawaii, 3-7 November 1997, 170 pp.	All	Irradiation	Many species	Many species	Various experimental papers
72.	E	IAEA (International Atomic Energy Agency), 2002. Irradiation as a phytosanitary treatment of food and agricultural commodities. Proceedings of a final research coordination meeting, 189 pp.	All	Irradiation	Many species	Many species	Various experimental papers
73.	E	Jagdale GB and Grewal PS, 2004. Effectiveness of a hot water drench for the control of foliar nematodes *Aphelenchoides fragariae* in floriculture. Journal of Nematology 36(1), 49–53.	All	Hot water drench	*Hosta* sp. And *Matteuccia pensylvanica*	*Aphelenchoides fragariae*	Dose-response

74.	E	Jang EB, Chan HT, Nishijima KA, Nagata JT, McKenney MP, Carvalho LA and Schneider EL, 2001. Effect of heat shock and quarantine cold treatment with a warm temperature spike on survival of Mediterranean fruit fly eggs and fruit quality in Hawaii-grown 'Sharwil' avocado. Postharvest Biology and Technology 21, 311–320.	All	Cold treatment + transient warm spike	*Persea americana*	*Ceratitis capitata*	Confirmation of effectiveness of method
75.	E	Jones, 2009. Mortality verification of pinewood nematode from high temperature treatment of shavings. Annex 1 of the Request letter from DG SANCO to EFSA Executive Director sent on 17/02/2009, as documentation provided to EFSA for the preparation of the scientific opinion "Mortality verification of pinewood nematode from high temperature treatment of shavings" of the PLH Panel.	All	High temperature treatment	Wood shavings	*Bursaphelenchus xylophilus*	Negatively evaluated by the Panel
76.	O	Lurie S, 1998. Postharvest heat treatments. Postharvest Biology and Technology 14, 257–269.	All	Heat treatment	Harvested products	Many species	Review of heat treatments
77.	O	Mangan RL and Hallman GJ, 1998. Temperature treatments for quarantine security: new approaches for fresh commodities. In: Hallman GL and Denlinger DL (eds), Temperature Sensitivity in Insects and Application in Integrated Pest Management. Westview Press, Boulder, CO, 201–236.	All	Temperature treatment	Many species	Many species	Review of temperature treatments
78.	E	Mangan RL and Sharp JL, 1994. Combination and multiple treatments. In: Sharp JL and Hallman GL (eds), Quarantine Treatments for Pests of Food Plants. Westview Press, Boulder, CO, 239–247.	All	Multiple treatments	Not specified	Not specified	Statistical evaluation of effectiveness of multiple treatments
79.	E	MCCullough DG, Poland TM, Cappaert D, Clark EL, Fraser I, Mastro V, Smith S and Pell C, 2007. Effects of chipping, grinding, and heat on survival of emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae), in chips. Journal of Economic Entomology 100(4), 1304–1315.	All	Chipping, grinding and heat treatment	*Fraxinus* wood	*Agrilus planipennis*	Failure of ISPM 15
80.	E	Mirić M and Willeitner H, 1984. Lethal temperature for some wood-destroying fungi with respect to eradication by heat treatment. The International Research Group on Wood Preservation. 8pp.	All	Heat treatment	Wood	*Serpula lacrymans*, *Coniophora puteana*, *Poria monticola*, *Paxillus*	Dose-response, MSc thesis

						panuoides, Gloeophyllum trabeum, G. sepiarium	
81.	E	Moy JH and Wong L, 2002. The efficacy and progress in using radiation as a quarantine treatment of tropical fruits – a case study in Hawaii. Radiation Physics and Chemistry 63, 397–401.	All	Irradiation	Tropical fruits	Insects	Effective dose, routine application
82.	E	Mushrow L, Morrison A, Sweeney J and Quiring D, 2004. Heat as a phytosanitary treatment for the brown spruce longhorn beetle. The Forestry Chronicle, 80(2), 224–228.	All	Heat treatment	Spruce wood	*Tetropium fuscum*	Dose-response, effective treatment
83.	E	Myers SW, Fraser I and Mastro VC, 2009. Evaluation of heat treatment schedules for emerald ash borer (Coleoptera: Buprestidae). Journal of Economic Entomology 102(6), 2048–2055.	All	Heat treatment	*Fraxinus* wood	*Agrilus planipennis*	Dose-response, effective treatment
84.	G	NAPPO (North American Plant Protection Organization), 2009. TP No. 01 – Thermotherapy or Thermaltherapy, 5pp.	All	Heat treatment of greenhouse crops	Citrus	Citrus viruses and graft transmissible agents	NAPPO treatment protocol
85.	E	Newbill MA and Morrell JJ, 1991. Effect of elevated temperatures on survival of Basidiomycetes that colonize untreated Douglas-fir poles. Forest Products Journal 41(6), 31–33.	All	Heat treatment	*Pseudotsuga menziesii* poles	*Stereum sanguinolentum, Peniophora* spp.	Dose-response, effective treatment
86.	E	Nzokou P, Tourtellot S and Kamdem DP, 2008. Kiln and microwave heat treatment of logs infested by the emerald ash borer (*Agrilus planipennis* Fairmaire) (Coleoptera: Buprestidae). Forest Products Journal 58(7/8), 68–72.	All	Kiln and microwave heat treatment	*Fraxinus* wood	*Agrilus planipennis*	Dose-response, microwave less effective than kiln
87.	E	Pawson SM and Watt MS, 2009. An experimental test of a visual-based push-pull strategy for control of wood boring phytosanitary pests. Agricultural and Forest Entomology 11(3), 239–245.	All	Multiple light traps	Wood	Cerambycidae	Potential alternative to fumigants
88.	O	Powell MR, 2002. A model for probabilistic assessment of phytosanitary risk reduction measures. Plant Disease 86, 552–557.	All	Heat treatment as example	Wood as example	Fungi as example	Statistical model to assess effectiveness of phytosanitary measures
89.	E	Prasad JS and Varaprasad KS, 1992. Elimination of white-tip nematode, *Aphelenchoides besseyi*, from rice seed.	All	Chemical seed treatment (soaking)	Rice seeds	*Aphelenchoides besseyi*	Effective method

		Fundamental and Applied Nematology 15(4), 305–308.					
90.	E	Ramsfield T D, Ball RD, Gardner JF and Dick MA, 2010. Temperature and time combinations required to cause mortality of a range of fungi colonizing wood. Canadian Journal of Plant Pathology 32(3), 368–375.	All	Heat treatment	Wood	Fungi	Failure of ISPM15
91.	O	Robertson JL, Preisler HK and Frampton ER, 1994. Statistical concept and minimum threshold. In: Paull RE and Armstrong JW (eds), Insect pests and fresh horticultural products treatments and responses, 47–65.	All	Various	Many species	Many species	Review of statistical methods to assess effectiveness of phytosanitary measures
92.	O	Schortemeyer M, Thomas K, Haack RA, Uzunovic A, Hoover K, Simpson JA and Grgurinovic CA, 2011. Appropriateness of Probit-9 in the development of quarantine treatments for timber and timber commodities. Journal of Economic Entomology 104(3), 717–731.	All	Various treatments of wood packaging material	Wood, wood packaging material	Wood related insects, *Bursaphelenchus* spp.	Probit 9 discussion
93.	E	Sobek S, Rajamohan A, Dillon D, Cumming RC and Sinclair BJ, 2011. High temperature tolerance and thermal plasticity in emerald ash borer *Agrilus planipennis*. Agricultural and Forest Entomology, 8 pp.	All	Heat treatment	Wood	*Agrilus planipennis*	Failure of ISPM No. 15
94.	E	Tsang MMC, Hara AH and Sipes B, 2003. Hot-water treatments of potted palms to control the burrowing nematode, *Radopholus similis*. Crop Protection 22, 589–593.	All	Hot water drench and dipping	*Chamaedorea seifrizii* and *Caryota mitis*	*Radopholus similis*	effective dos-response
95.	E	Tsang MMC, Hara AH and Sipes B, 2004. Efficacy of hot water drenches of *Anthurium andraeanum* plants against the burrowing nematode *Radopholus similis* and plant thermotolerance. Annals of Applied Biology, 145:309-316	All	Hot water drench and dipping	*Anthurium andraeanum*	*Radopholus similis*	Effective dose-response
96.	O	UNEP (United Nations Environment Program), 2010. 2010 Report of the methyl bromide. Technical Options Committee. 2010 assessment. 396 pp.	Pages 195-326	Alternatives to methyl-bromide	Many species	Many species	Review of alternative methods to methyl-bromide fumigation
97.	G	USDA (United States Department of Agriculture) APHIS (Animal and Plant Health Inspection Service), 2008. Nonchemical treatments, 4 pp.	All	Dry heat treatment	*Guizotia abyssinica*	Weed seeds	APHIS treatment manual
98.	O/G	USDA (United States Department of Agriculture) APHIS (Animal and Plant Health Inspection Service), 2009. Methyl bromide quarantine and preshipment interim national management strategy submission by the United States of America. October 30, 33pp.	All	Methyl bromide alternative	Many species	Many species	Extensive review of methyl-bromide and alternative treatments

99.	G	USDA (United States Department of Agriculture) APHIS (Animal and Plant Health Inspection Service), 2011. Treatment manual. T300 - Schedules for Miscellaneous Plant Products. 01/2011-53 PPQ, 40 pp.	All	Many	Many species	Many species	
100.	E	Uzunovic A and Khadempour L, 2007. Heat disinfestation of mountain pine beetle-affected wood. Mountain Pine Beetle Initiative Working Paper 2007-14, 33 pp.	All	Heat treatment	Wood	Fungi associated with mountain pine beetle	Dose-response, effective treatment
101.	E	Wang X, Bergman R, Simpson WT, Verrill S and Mace T, 2009. Heat-treatment options and heating times for ash firewood. USDA, General Technical Report FPL–GTR–187, 31 pp.	All	Heat treatment	*Fraxinus* spp.	*Agrilus planipennis*	Dose-response, extrapolation of lab-scale to practical scale, but no test with infested material
Group 8: Options for consignments – Restriction on end use, distribution and periods of entry (pest risk assessment step: Entry)							
102.	G	e-CFR (Electronic Code of Federal Regulations), webpage. Available from: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=446e2e3a8627eeda6f4802db874c91dc&tpl=/ecfrbrowse/Title07/7cfr319_main_02.tpl Additional info on APHIS FAVIR (Fruits and Vegetables Import Requirements) Database, webpage. Available from: https://epermits.aphis.usda.gov/manual/index.cfm?action=pubHome	§ 319.56-31	Entry from December 1 through April 30	*Capsicum* spp. from greenhouses (Almeria or Alicante provinces of Spain)	*Ceratitis capitata*	Safeguarding from harvest to export using insect proof material
103.	G	e-CFR (Electronic Code of Federal Regulations), webpage. Available from: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=446e2e3a8627eeda6f4802db874c91dc&tpl=/ecfrbrowse/Title07/7cfr319_main_02.tpl Additional info on APHIS FAVIR (Fruits and Vegetables Import Requirements) Database, webpage. Available from: https://epermits.aphis.usda.gov/manual/index.cfm?action=pubHome	§ 319.56-34	Entry at ports located north of 39° latitude and east of 104° longitude or At ports that have approved cold treatment facilities	*Citrus reticulata* from Spain	*Ceratitis capitata*	These restrictions are applied if the commodity treatment has not been completed or fails
104.	G	e-CFR (Electronic Code of Federal Regulations), webpage. Available from: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=446e2e3a8627eeda6f4802db874c91dc&tpl=/ecfrbrowse/Title07/7cfr319_main_02.tpl Additional info on APHIS FAVIR (Fruits and Vegetables Import Requirements) Database, webpage. Available from: https://epermits.aphis.usda.gov/manual/index.cfm?action=pubHome	§ 319.56-3	Entry at ports located north of 39° latitude and east of 104° longitude or at ports that have approved cold treatment facilities	*Vitis vinifera* (fruit, or cluster of fruit) from Italy into North Atlantic (NA) ports	Any plant pest or noxious weed	These restrictions are applied if the commodity treatment has not been completed or fails

105.	G	e-CFR (Electronic Code of Federal Regulations), webpage. Available from: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=446e2e3a8627eeda6f4802db874c91dc&tpl=/ecfrbrowse/Title07/7cfr319_main_02.tpl Additional info on APHIS FAVIR (Fruits and Vegetables Import Requirements) Database, webpage. Available from: https://epermits.aphis.usda.gov/manual/index.cfm?action=pubHome	§ 319.56-3	Dry bulb only	*Allium* spp. from France	Any plant pest or noxious weed	Except garlic *A. sativum*
106.	G	e-CFR (Electronic Code of Federal Regulations), webpage. Available from: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=446e2e3a8627eeda6f4802db874c91dc&tpl=/ecfrbrowse/Title07/7cfr319_main_02.tpl Additional info on APHIS FAVIR (Fruits and Vegetables Import Requirements) Database, webpage. Available from: https://epermits.aphis.usda.gov/manual/index.cfm?action=pubHome	§ 319.56-11	Dried, cured or processed fruits and vegetables, including cured figs and dates, raisins, nuts and dried beans and peas, may be imported without permit, phytosanitary certificate or other compliance with this subpart, except as specifically provided otherwise in this section or elsewhere in this part	Dried, cured or processed fruits and vegetables, including cured figs and dates, raisins, nuts and dried beans and peas from all Countries	Any plant pest or noxious weed	Except frozen fruits and vegetables and acorns and chestnuts from countries other than Canada and Mexico – treatment required
Group 9: Options preventing or reducing infestation in the crop – Treatment of the crop, field, or place of production in order to reduce pest prevalence (pest risk assessment step: Entry and Establishment/Spread/Impact)							
107.	G	Christie AW, 1959. Nursery tree certification insurance against root-rot. California Avocado Society 1959 Yearbook 43, 73–74.	Whole document	Fumigation; soil treatments	*Persea americana*	*Phytophthora cinnamomi*	
108.	G	Daughtrey ML and Benson DM, 2005. Principles of plant health management of ornamental plants. Annual Review of Phytopathology 43, 141–169.	Whole document	All treatments	Ornamental plants	Many species	Review
109.	E	El-Wakeil NE, Awadallah KT, Farghaly HTh, Ibrahim AAM and Ragab ZA, 2008. Efficiency of the newly recorded pupal parasitoid *Pediobius furvus* (Gahan) for controlling *Sesamia cretica* (Led.) pupae in Egypt. Archives Of Phytopathology And Plant Protection 41(5), 340–348.	Whole document	Biological control agents	*Zea mays*, *Sorghum* sp.	*Sesamia cretica*	Efficiency of the pupal parasitoid *Pediobius furvus* to control *Sesamia cretica* was studied
110.	G	Evans HF, McNamara DG, Braasch H, Chadoeuf J and Magnusson C, 1996. Pest Risk	Whole	In the forest; during	Plants for planting,	*Bursaphelenchu*	Review

		Analysis (PRA) for the territories of the European Union (as PRA area) on *Bursaphelenchus xylophilus* and its vectors in the genus *Monochamus*. Bulletin OEPP/ EPPO bulletin 26, 199–249.	document	processing; during transportation; end use Inspection for holes Heat Chemical	timber, sawn wood, packaging material, chips, sawdust	*s xylophilus*; *Monochamus* spp.	
111.	G	Hara AH, 2002. Preventing alien species invasion by pre-shipment disinfestations treatments. Micronesica Supplement 6, 111–121.	Whole document	Pre-shipment treatments; controlled atmosphere; heat treatment; irradiation; combinations of treatments	Cut flowers, plants for planting	Many species	Review
112.	E	Hata TY, Hara AH, Jang EB, Imaino LS, Hu BKS and Tenbrink VL, 1992. Pest management before harvest and insecticidal dip after harvest as a systems approach to quarantine security for red ginger. Journal of Economic Entomology 85(6), 2310–2316.	Whole document	Chemical treatments	*Alpinia purpurata*	Many species	Hawaii
113.	E	Jackson M, Bohac JR, Dalip KM, McComie L, Rhode L, Chung P, Seal D, Clarke-Harris D, Aseidu F and McDonald FD, 2010. Integrated pest management of major pests affecting sweetpotato, Ipomoea batatas, in the Caribbean. USAID Resources Management and Development Portal. 21pp. Available from: http://rmportal.net/library/content/nric/963.pdf/view?searchterm=health	Whole document	IPM	Miscellaneous (soil insect pests, including sweetpotato weevils, sweetpotato leaf beetles, flea beetles, and Wireworm-*Diabrotica-Systena*) complex	*Ipomoea batatas*	The potential of resistant varieties, insect growth regulators and botanical insecticides for managing sweetpotato weevils and grubs of the sweetpotato leaf beetle was evaluated
114.	G	Jamieson LE, Meier X, Page B, Zulhendri F, Page-Weir N, Brash D, McDonald RM, Stanley J and Woolf AB, 2009. A review of postharvest disinfestation technologies for selected fruits and vegetables. The New Zealand Institute for Plant and Food Research Ltd, Wellington 36 pp.	Whole document	Physical/chemical treatments; segregation	Many species	Many species	New Zealand – a review of postharvest disinfestation technologies for selected fruits and vegetables
115.	G	Quinlan MM, 2004. Trends in international phytosanitary standards: potential impact on fruit fly control. Proceedings of 6th International Fruit Fly Symposium 6–10 May 2002, Stellenbosch, South Africa, 195–200.	Whole document	Many options	Fruit	Fruit flies	Review of existing options
116.	E	Zettler JL, Follett PA and Gill RF, 2002.	Whole	Fumigation	Many species	*Maconellicoccu*	Methyl bromide

		Susceptibility of *Maconellicoccus hirsutus* (Homoptera: Pseudococcidae) to methyl bromide. Journal of Economic Entomology 95(6), 1169–1173.	document			*s hirsutus*	
Group 10: Options preventing or reducing infestation in the crop – Resistant or less susceptible species/varieties (pest risk assessment step: Entry and Establishment/Spread/Impact)							
117.	E	Badiger HK, Patil SB, Udikeri SS, Biradar DP, Chattannavar SN, Mallapur CP and Patil BR, 2011. Comparative efficacy of interspecific cotton hybrids containing single and stacked Bt genes against pink bollworm, *Pectinophora gossypiella* (Saund.) and tobacco caterpillar, *Spodoptera litura* (Fab.)*. Karnataka ournal of Agricultural Science 24(3), 320–324.	Whole document	Genetically modified crop	*Gossypium* spp.	*Pectinophora gossypiella* and *Spodoptera litura*	Hybrids containing Bt genes
118.	E	Zehnder G, Kloepper J, Tuzun S, Yao C, Wei G, Chambliss O and Shelby R, 1997. Insect feeding on cucumber mediated by rhizobacteria-induced plant resistance. Entomologia Experimentalis et Applicata 83, 81–85.	Whole document (Pages 81-85)	Induced resistance	*Cucumus sativus*	*Erwinia tracheiphila, Diabrotica undecimpunctat a howardi*	
Group 11: Options preventing or reducing infestation in the crop – Growing plants under exclusion conditions (glasshouse, screen, isolation) (pest risk assessment step: Entry and Establishment/Spread/Impact)							
119.	G	Albajes R, Gullino ML and van Lenteren JC, 1999. Integrated pest and disease management in greenhouse crops. Volume 14: Developments in plant pathology, 221 pp.	Parts 3, 4, 5	Biological control	Plants in greenhouses	Pests and diseases of greenhouse crops.	
120.	G	Mahr SER, Cloyd RA, Mahr DL and Sadof CS, 2001. Biological control of insects and other pests of greenhouses crops. University of Wisconsin-Extension, Cooperative Extension. 108 pp.	Whole document	Biological control	Plants in greenhouses	Pests of greenhouse crops	
121.	G	Yano E, 2006. Ecological considerations for biological control of aphids in protected culture. Population Ecology 48, 333–339.	Whole document	Biological control	Plants in greenhouses	Aphids	
Group 13: Options preventing or reducing infestation in the crop – Certification scheme (pest risk assessment step: Entry and Establishment/Spread/Impact)							
122.	G	AQIS (Australian Quarantine and Inspection Service), 2006. Phytosanitary Certificate Completion (Exports). Plant Program, 29 pp.	Whole document	Certification scheme	Many species	Many species	Instruction on phytosanitary certificate completion
123.	G	AUSVEG, 2007. Australian National Standard Certification of Seed Potato. 26 pp.	Whole document	Certification scheme	Seed potatoes (*Solanum tuberosum*)	Fungal, bacterial, viral and virus –like potato pathogens;	Australian national standard

						potato cyst and root knot nematodes; insect pests	
124.	G	EPPO (European and Mediterranean Plant Protection Organization), 1997. Certification scheme – Pathogen-tested material of rose. PM 4/21 (1). Bulletin OEPP/ EPPO bulletin 27, 621–640.	Whole document	Certification scheme	*Rosa* spp. and hybrids	Many species	Standard on pathogen-tested material of rose
125.	G	EPPO (European and Mediterranean Plant Protection Organization), 1998. EPPO Standards – Certification schemes. PM 4/22-26. Bulletin OEPP/ EPPO bulletin 28, 221–225.	Whole document	Guidance for certification scheme	Many species	Not specific	
126.	G	EPPO (European and Mediterranean Plant Protection Organization), 1998. Certification scheme for freesia. PM 4/22 (1). Bulletin OEPP/ EPPO bulletin 28, 227–234.	Whole document	Classification scheme	*Freesia* spp.	Fungal and viral pathogens	Scheme for general sequence for the production of classified, vegetatively propagated plants
127.	G	EPPO (European and Mediterranean Plant Protection Organization), 1998. Certification scheme – classification scheme for hyacinth PM 4/23 (1). Bulletin OEPP/ EPPO bulletin 28, 235–241.	Whole document	Classification system for hyacinth	*Hyacinthus orientalis*	HyaMV, TRV, *Xanthomonas hyacinthi*, *Ditylenchus* spp., not true types	Certification system
128.	G	EPPO (European and Mediterranean Plant Protection Organization), 1998. Certification scheme – classification scheme for narcissus. PM 4/24 (1). Bulletin OEPP/ EPPO bulletin 28, 243–250.	Whole document	classification scheme for narcissus	*Narcissus* spp.	viruses affecting narcissus, *Ditylenchus dipsaci*, visible off-types, plants rogued	Certification system
129.	G	EPPO (European and Mediterranean Plant Protection Organization), 1998. Certification scheme – Pathogen-tested material of kalanchoe. PM 4/25 (1). Bulletin OEPP/ EPPO bulletin 28, 251–262.	Whole document	Certification scheme for kalanchoe	Cultivars of *Kalanchoe blossfeldiana*	KMV, TSWV, INSV, KLV, SYNV	Pathogen tested material of kalanchoe
130.	G	EPPO (European and Mediterranean Plant Protection Organization), 1998. Certification scheme – Pathogen-tested material of petunia. PM 4/26 (1). Bulletin OEPP/ EPPO bulletin 28, 263–278.	Whole document	Certification scheme for petunia	*Petunia* spp.	AMV, CMV, TAV, ToMV, TMV, INSV, TSWV, BBWV, TRSV, TBRV, ToRSV, PVX,	Pathogen tested material of petunia

						PVCV	
131.	G	EPPO (European and Mediterranean Plant Protection Organization), 2001. Certification scheme for *Malus*, *Pyrus* and *Cydonia*. PM 4/27 (supplement). Bulletin OEPP/ EPPO bulletin 31, 445–446.	Whole document	Supplement to the certification system for *Malus domestica*, *Pyrus* spp. and *Cydonia oblonga*.	*Malus domestica*, *Pyrus* spp. and *Cydonia oblonga*	-	An added figure on the certification scheme
132.	G	EPPO (European and Mediterranean Plant Protection Organization), 2001. Certification scheme for cherry. PM 4/29. Bulletin OEPP/ EPPO bulletin 31, 447–461.	Whole document	Certification scheme for cherry	*Prunus avium*, *Prunus cerasus* and their rootstocks	ACLSV, ApMV, ArMV, PAMV, CIRV, CGRMV, CLRV, LChV-1, LChV-2, ChMLV, PDV, PNRSV, RpRSV, SLRSV, TBRV	Scheme for production of healthy plants for planting
133.	G	EPPO (European and Mediterranean Plant Protection Organization), 2009. Certification scheme for Rubus. PM 4/10 (2). Bulletin OEPP/ EPPO bulletin 39, 271–277.	Whole document	Certification scheme	*Rubus* spp.	Many pathogens	Scheme for the production of healthy plants for planting
Group 14: Options ensuring that the area, place or site of production or crop is free from the pest – Pest free area (pest risk assessment step: Entry and Establishment/Spread/Impact)							
134.	G	EPPO (European and Mediterranean Plant Protection Organization), 2009. Generic elements for contingency plans. PM 9/10. Bulletin OEPP/ EPPO bulletin 39, 471–474.	Whole document	Guidance for containment and eradication of plant pests	Not specific	Not specific	Generic elements for contingency plans
135.	G	FAO (Food and Agriculture Organization of the United Nations), 1997. ISPM (International Standards for Phytosanitary Measures) No 6. Guidelines for surveillance. 15 pp.	Whole document	Guidelines for surveillance	Not specific	Not specific	
136.	G	FAO (Food and Agriculture Organization of the United Nations), 1998. ISPM (International Standards for Phytosanitary Measures) No 8. Determination of pest status in an area. 12 pp.	Whole document	Determination of pest status (presence, absence, low prevalence etc.)	Not specific	Not specific	
137.	G	FAO (Food and Agriculture Organization of the United Nations), 1998. ISPM (International Standards for Phytosanitary Measures) No 9. Guidelines for pest eradication programmes. 10 pp.	Whole document	Guidance for eradication	Not specific	Not specific	
138.	G	FAO (Food and Agriculture Organization of the United Nations), 1999. ISPM (International	Whole	Establishment of pest	Not specific	Not specific	

		Standards for Phytosanitary Measures) No 10. Establishment of pest free places of production and pest free production sites. 16 pp.	document	free places of production and pest free production sites			
139.	G	FAO (Food and Agriculture Organization of the United Nations), 2006. ISPM (International Standards for Phytosanitary Measures) No 26. Establishment of pest free areas for fruit flies (Tephritidae). 15 pp.	Whole document	Establishment of pest free areas for fruit flies (Tephritidae)	Fruits, fruit trees	Fruit flies *Anastrepha*, *Bactrocera*, *Ceratitis*, *Dacus*, *Rhagoletis* and *Toxotrypana*.	Surveillance - trapping and fruit sampling, official control
140.	G	Glocke P and Hall B, 2010. Biosecure packaging for the transport of emergency plant pest samples. Cooperative Research Centre for National Plant Biosecurity, 26 pp.	Whole document	Development of protocols for packaging standards for transport of plants, soil and insect samples	Item for diagnostic laboratories – soil, seed, woody stems, herbaceous plants, soft and hard fruit or vegetables, fluid with seed and culture plates with agar	Emergency Plant Pests	Suitable packaging materials for different items are identified. Guidelines for transport of Emergency Plant Pests consistent with United Nations regulations are formulated
141.	E	Melifronidou-Pantelidou A, 2009. Eradication campaign for *Rhynchophorus ferrugineus* in Cyprus. Bulletin OEPP/ EPPO bulletin 39, 155–160.	Whole document	Eradication	Palm trees (*Phoenix canariensis*, *Phoenix dactylifera* and *Washingtonia* spp.)	*Rhynchophorus ferrugineus* (red palm weevil)	Surveys, delimitation of infested areas and establishment of pest free areas; measures in the demarcated areas
142.	G	Narayanasamy P, 2007. Postharvest pathogens and disease management. John Wiley & Sons, Inc., Hoboken, NJ, 584 pp.	Part 3, “Principles and practices of postharvest disease manageme nt” Pages 253-537	Cultural practices - reduction in sources of infection, crop sanitation, crop sequences, application of organic manures and mulches, irrigation systems and using resistant cultivars ; physical practices- ultraviolet- C (UV-C), different forms of heat, and	Many species	Fungal, bacterial and viral pathogens at pre- and post-harvest stages of crop production	Detailed book (578 pp.) on post-harvest pathogens – rapid detection and identification and disease management

				modification of storage atmosphere; chemical and biological control methods.			
143.	G	PQOI (Plant Quarantine Organization of India), 2005. Requirements for establishment of pest free areas for Tephritid fruit flies. NSPM-14, Directorate of Plant protection, Quarantine and Storage (Dte of PPQS), Faridabad, 29pp.	Whole document	Establishment of PFA for Tephritid fruit flies	Fruits, fruit trees	*Anastrepha* spp., *Bactrocera* spp., *Ceratitis capitata* and *Ceratitis rosae*	Guidance and requirements for establishment, maintenance and verification of pest free areas
144.	G	Schröder T, McNamara DG and Gaar V, 2009. Guidance on sampling to detect pine wood nematode *Bursaphelenchus xylophilus* in trees, wood and insects. Bulletin OEPP/ EPPO bulletin 39, 179–188.	Whole document	Definition of pest free area	Trees, woods	*Bursaphelenchu s xylophilus*	Guidance on sampling
145.	E	Sosnowski MR, Fletcher JD,Daly AM, Rodoni BC and Viljanen-Rollinson SLH, 2009. Techniques for the treatment, removal and disposal of host material during programmes for plant pathogen eradication. Plant Pathology 58, 621–635	Whole document review article	Eradication of plant pathogen using burning, burying, pruning, composting, soil and biofumigation, solarisation, steam sterilisation and biological vector control	Many species	Fungal, bacterial and viral pathogens: *Mycosphaerella fijiensis*, *Venturia inaequalis*, *Ustilago maydis*, *Erwinia amylovora*, *Xanthomonas smithii* subsp. *c itri* and PPV	Techniques for the treatment, removal and disposal of affected host plants are described
146.	G	USDA (United States Department of Agriculture) APHIS (Animal and Plant Health Inspection Service), 2003. Guidelines for fruit fly systems approach to support the movement of regulated articles between Mexico and the United States. Draft Document, 5 June 2003, 26 pp.	Whole document	Mitigation the risk for the introduction of fruit flies from Mexico to the United States	Fruits and fruit trees	Fruit flies, Tephritidae	Determination of places of production and buffer zones; pest detection and trapping programme; control measures; sterile insect technique
Group 15: Options ensuring that the area, place or site of production or crop is free from the pest – Pest free production site (pest risk assessment step: Entry and Establishment/Spread/Impact)							
147.	G	FAO (Food and Agriculture Organization of the United Nations), 1995. ISPM (International Standards for Phytosanitary Measures) No 4.	Whole document	Establishment of pest free area	Not specific	Not specific	

		Requirements for the establishment of pest free areas. 8 pp.					
148.	G	FAO (Food and Agriculture Organization of the United Nations), 1997. ISPM (International Standards for Phytosanitary Measures) No 6. Guidelines for surveillance. 15 pp.	Whole document	Guidelines for surveillance	Not specific	Not specific	
149.	G	FAO (Food and Agriculture Organization of the United Nations), 1998. ISPM (International Standards for Phytosanitary Measures) No 8. Determination of pest status in an area. 12 pp.	Whole document	Determination of pest status (presence, absence, low prevalence etc.)	Not specific	Not specific	
150.	G	FAO (Food and Agriculture Organization of the United Nations), 1998. ISPM (International Standards for Phytosanitary Measures) No 9. Guidelines for pest eradication programmes. 10 pp.	Whole document	Guidance for eradication	Not specific	Not specific	
151.	G	FAO (Food and Agriculture Organization of the United Nations), 1999. ISPM (International Standards for Phytosanitary Measures) No 10. Requirements for the establishment of pest free places of production and pest free production sites. 16 pp.	Whole document	Establishment of pest free places of production and pest free production sites	Not specific	Not specific	
152.	G	Schröder T, McNamara DG and Gaar V, 2009. Guidance on sampling to detect pine wood nematode *Bursaphelenchus xylophilus* in trees, wood and insects. Bulletin OEPP/ EPPO bulletin 39, 179–188.	Whole document	Definition of PFA	Trees, woods	*Bursaphelenchus xylophilus*	Guidance on sampling
Group 16: Options ensuring that the area, place or site of production or crop is free from the pest – Inspections, Surveillance (pest risk assessment step: Entry and Establishment/Spread/Impact)							
153.	E	Dallot S, Gottwald T, Labonne G and Quiot JB, 2004. Factors affecting the spread of plum pox virus strain M in peach orchards Subjected to Roguing in France. Phytopathology 94(12), 1390–1398.	Whole document	Rouging, field control	*Prunus persica*	PPV-M	Modelling of disease reduction option
154.	O	Gupta A, 2010. Emerald ash borer first detector: a volunteer early detection programme. New Zealand Journal of Forestry Science 40, 123–132.	Whole document	Survey, surveillance	*Fraxinus* spp.	*Agrilus planipennis*	Volunteer inspector network
155.	G	Martin RR, 2000. Appendix I – Recommended procedures for detection of viruses of small fruit crops. USDA-ARS-HCRL, 14 pp.	Whole document	Inspection, detection	*Fragaria*, *Humulus*, *Ribes*, *Rubus* and *Vaccinium* genera	Viruses	Definition of standards and procedures to validate reagents and protocols of detection
156.	G	McMaugh T, 2005. Guidelines for surveillance for plant pests in Asia and the Pacific. Australian Centre for International Agricultural Research, Bruce, ACT, 55pp.	Whole document	Survey	All crops	Pest	Australian official Guidance for survey of plant pest in pacific area
157.	E	Sigvald R and Hulle M, 2004. Aphid-vector	Whole	Surveillance	Potato tuber	Aphis species	Model to monitoring and

		management in seed potatoes: monitoring and forecasting. 12th EAPR Virology Section Meeting Rennes, France, 2004, 8–11.	document		(*Solanum tuberosum*)		forcasting
158.	G	USDA (United States Department of Agriculture) APHIS (Animal and Plant Health Inspection Service), 2011. Postentry quarantine manual for State inspectors. 1/2011-2 PPQ. 334pp.	Whole document	Inspection	All crops	Pest and disease	United States post-entry manual for State inspectors
159.	E	Wardlaw T, Bashford R, Wotherspoon K, Wylie R and Elliot H, 2008. Effectiveness of routine forest health surveillance in detecting pest and disease damage in eucalypt plantations. New Zealand Journal of Forestry Science 38(2/3), 253–269.	Whole document	Inspection	Forest tree	Many species	Comparison of surveillance techniques to assess the impact of diseases and pests in forests
Group 17: Options for other types of pathways – Natural spread, by human activities (people movement, transports, machineries...), vectors, phoresy (pest risk assessment step: Entry and Spread)							
160.	O	Evans HF, Schröder T, Mota MM, Robertson L, Tomiczek C, Burgermeister W, Castagnone-Sereno P and de Sousa EMR, 2007. QLK5-CT-2002-00672: Development of improved pest risk analysis techniques for quarantine pests, using pinewood nematode, *Bursaphelenchus xylophilus*, in Portugal as a model system. PHRAME – Plant Health Risk And Monitoring Evaluation. 246 pp.	Pages 128-135 Pages 180-217	Insecticides, nematicides, traps and lures Modelling of ecoclimatic risk factors		*Bursaphelenchus xylophilus*	Project for Portugal, Spain and the Iberian peninsula
Group 18: Other relevant information							
161.	G	Addobediako A, Baharnu T, Jackai LEN and Bonsi CK, 2007. Assessment of Risk of Introduction of *Cylas formicarius elegantulus* (Coleoptera: Brentidae) into Weevil-Free Areas in the Southern United States Journal of Economic Entomology 100(2), 315–321.	Whole document	Reduction of introduction	Sweet potato, *Ipomoea batatas*	Sweet potato weevil (*Cylas formicarius elegantulus)*	Quantitative risk model to estimate the probability of introduction
162.	G	Bartell SM and Nair SK, 2003. Establishment Risks for Invasive Species. Risk Analysis 24(4), 833–845.	Whole document	Reduction of entry	Not specific	Not specific	Quantitative approach based on a population model
163.	E	Bogich T and Shea K, 2008. A state-dependent model for the optimal management of an invasive metapopulation. Ecological Applications, 18(3), 748–761.	Whole document	Not specific	Not specific	Not specific	Model for assessing RRO
164.	E	Bogich TL, Liebhold AM and Shea K, 2008. To sample or eradicate? A cost minimization model for monitoring and managing an invasive species. Journal of Applied Ecology 45, 1134–1142.	Whole document	Detection and eradication	Many species	*Lymantria dispar*	Simulation study
165.	G	EFSA Panel on Plant Health (PLH), 2010a. Guidance on a harmonised framework for pest risk assessment and the identification and	Section 4	Not specific	Not specific	Not specific	Harmonised framework

		evaluation of pest risk management options by EFSA. EFSA Journal 2010; 8(2):1495, 66 pp.					
166.	E	EFSA Panel on Plant Health (PLH), 2010b. Risk assessment of the oriental chestnut gall wasp, *Dryocosmus kuriphilus* for the EU territory on request from the European Commission. EFSA Journal 2010; 8(6):1619, 114 pp.	Section 3	Not specific	*Castanea sativa*	*Dryocosmus kuriphilus*	
167.	G	FAO (Food and Agriculture Organization of the United Nations), 2011. Guide to implementation of phytosanitary standards in forestry. FAO Forestry Paper 164, 118 pp.	Chapters 3 and 4	Reduction of spread	Forest	Not specific	
168.	G	Follet PA and Vick KW, 2002. Desarrollo de estrategias de manejo integrado de plagas para eliminar las barreras sanitarias que restringen la exportación de productos agrícolas. Manejo Integrado de Plagas y Agroecolog.a (Costa Rica) 65, 43–49.	Whole document	System approach	Not specific	Not specific	In Spanish
169.	G	IOBC/WPRS (International Organization for Biological and Integrated Control of Noxious Animals and Plants, West Palearctic Regional Section), 2002. Guidelines for integrated production of olives. IOBC-WPRS Bulletin 25(4), 11pp.	the whole document	Technical guidelines for integrated production of olives	*Olea europaea*	Not specific	healthy growing and integrated management methods
170.	G	IOBC (International Organization for Biological and Integrated Control of Noxious Animals and Plants), 2002. Guidelines for integrated production of pome fruits. IOBC-WPRS Bulletin 25(8), 11pp.	the whole document	Technical guidelines for integrated production of pomefruits	Pomefruits	Not specific	healthy growing and integrated management methods
171.	G	IOBC (International Organization for Biological and Integrated Control of Noxious Animals and Plants), 2003. Guidelines for integrated production of stone fruits. IOBC-WPRS Bulletin 26, 10pp.	the whole document	Technical guidelines for integrated production of stone fruits	Stone fruits (peach, nectarine, apricot, plum and cherry)	Not specific	healthy growing and integrated management methods
172.	G	IOBC/WPRS (International Organization for Biological and Integrated Control of Noxious Animals and Plants, West Palearctic Regional Section), 2005. Guidelines for integrated production of citrus. IOBC-WPRS Bulletin 28, 10pp.	the whole document	Technical guidelines for integrated citrus production	Rutaceae	Not specific	healthy growing and integrated management methods
173.	G	MAF (Ministry of Agriculture and Forestry) Biosecurity New Zealand, 2002a. MAF Biosecurity Authority (Plants) Standard 155.02.04: import health standard for cut flowers and foliage. 19 pp.	Whole document	Reduction of entry	Cut flowers and foliage	Not specific	Phytosanitary requirements for importation/clearance in NZ (e.g. sampling)
174.	G	MAF (Ministry of Agriculture and Forestry) Biosecurity New Zealand, 2002b. MAF Biosecurity Authority (Plants) Standard	Whole document	Reduction of entry	Cut flowers and foliage	Not specific	Phytosanitary requirements for importation/clearance in NZ

		155.09.05: clearance of fresh cut flowers and foliage. 25 pp.					(e.g. sampling)
175.	G	MAF (Ministry of Agriculture and Forestry) Biosecurity New Zealand, 2003. Import Health Standard for Bark from All Countries, 14 pp.	Whole document	Reduction of entry	Bark	Not specific	Phytosanitary requirements for clearance in NZ (e.g. fumigation, heat treatment)
176.	G	MAF (Ministry of Agriculture and Forestry) Biosecurity New Zealand, 2009. Wood packaging material from all countries. 9pp.	Whole document	Reduction of entry	Wood packaging	Not specific	Phytosanitary requirements for clearance in NZ (e.g. fumigation, heat treatment)
177.	G	MAF (Ministry of Agriculture and Forestry) Biosecurity New Zealand, 2010. MAF Biosecurity New Zealand import health standard 155.02.05: importation of seed for sowing. 158 pp.	Whole document	Reduction of entry	Seed	Not specific	Phytosanitary requirements for importation in NZ (e.g. sampling)
178.	G	MAF (Ministry of Agriculture and Forestry) Biosecurity New Zealand, 2011a. MAF Biosecurity New Zealand Standard: 152.02: importation and clearance of fresh fruit and vegetables into New Zealand. 414 pp.	Whole document	Reduction of entry	Fruit and vegetables	Not specific	Phytosanitary requirements for importation/clearance in NZ (e.g. sampling)
179.	G	MAF (Ministry of Agriculture and Forestry) Biosecurity New Zealand, 2011b. BNZ-NPP-HUMAN Standard. Importation of Stored Plant Products for Human Consumption into New Zealand. 39 pp.	Whole document	Reduction of entry	Stored plant products	Not specific	Phytosanitary requirements for importation in NZ (e.g. sampling)
180.	E	Mastro V, Lance D, Reardon R and Parra G, 2007. Emerald ash borer – Research and development meeting. October 23-24, 2007 Pittsburgh, PA, 136 pp.	P38-86	Not specific	Wood	*Agrilus planipennis*	Proceedings
181.	G	Merriman P and McKirdy S, 2005. Technical guidelines for development of pest specific response plans. Plant Health Australia, 42 pp.	Whole document	Reduction of entry, establishment and spread	Not specific	Not specific	
182.	E	Powell MR, 2002. A model for probabilistic assessment of phytosanitary risk reduction measures. Plant Dis. 86, 552–557.	Whole document	Heat treatment	Wood	Not specific	Optimisation of temperature and duration
183.	G	Quinlan MM and Ikin R, 2009. A review of the application of Systems Approach to risk management in plant health. EU Framework 7 Research Project, PRATIQUE (Enhancements of Pest Risk Analysis Techniques). Deliverable number: 4.2 Date: 30/10/2009, 58 pp.	Whole document	System approach	Not specific	Not specific	Review of the application of systems approach and best practices
184.	E	Stansbury CD, McKirdy SJ, Diggle Aj and Riley IT, 2002. Modeling the risk of entry, establishment, spread, containment, and impact of *Tilletia indica*, the cause of karnal bunt of wheat, using an Australian context. Phytopathology 92(3), 321–331.	Whole document	Not specific	*Triticum* spp.	*Tilletia indica*	Model for assessing RRO

185.	G	USDA (United States Department of Agriculture) APHIS (Animal and Plant Health Inspection Service), 2010a. Fresh fruits and vegetables import manual. 01/2010-93 PPQ, 608 pp.	Whole document	Reduction of entry	Fruit and vegetables	Not specific	Phytosanitary requirements for importation
186.	G	USDA (United States Department of Agriculture) APHIS (Animal and Plant Health Inspection Service), 2010b. Agricultural Quarantine Inspection Monitoring (AQIM) Handbook. 07/2010-11 PPQ, 209 pp.	Whole document	Reduction of entry	Not specific	Not specific	Inspection monitoring handbook
187.	G	USDA (United States Department of Agriculture) APHIS (Animal and Plant Health Inspection Service), 2010c. Seeds not for planting. 11/2010-33 PPQ, 134 pp.	Whole document	Reduction of entry	Seed not for planting	Not specific	Inspection monitoring handbook
188.	G	USDA (United States Department of Agriculture) APHIS (Animal and Plant Health Inspection Service), 2011a. Treatment manual. 10/2010-50 PPQ, 853 pp.	Whole document	Redusction of entry, establishment and spread	Not specific	Not specific	Treatment manual
189.	G	USDA (United States Department of Agriculture) APHIS (Animal and Plant Health Inspection Service), 2011b. Cut flowers and greenery import manual. 05/2011-39 PPQ, 198 pp.	Whole document	Reduction of entry	Cut flowers and greenery	Not specific	Import manual
190.	G	USDA (United States Department of Agriculture) APHIS (Animal and Plant Health Inspection Service), 2011c. Miscellaneous and processed products. 01/2011-07 PPQ, 324 pp.	Whole document	Reduction of entry	Miscellaneous and processed products	Not specific	Import manual
191.	G	USDA (United States Department of Agriculture) APHIS (Animal and Plant Health Inspection Service), 2011d. Plants for planting manual. Interim edition PPQ, 610 pp	Whole document	Reduction of entry	Plants for planting	Not specific	Import manual
192.	G	Vickery J, webpage. Integrated Fruit Production (IFP): An overview of programmes. Available from http://www.pmac.net/intefrt.htm	the whole document	Overview of guidelines for integrated fruit production	Fruits, grapes	General	list of references with comment
193.	G	Webber J, 2010. Pest risk analysis and invasion pathways for plant pathogens. New Zealand Journal of Forestry Science 40 suppl., S45–S56.	Whole document	Reduction of introduction		Plant pathogens	Overview article Risk presented by the import of plants for planting; genetic change and adaptationof the pathogens in new environments

C. Comparison between the criteria presented in ISPM No 28 and the checklists in sections 2.2. 2 and 2.2.3 of this document

ISPM 28 Phytosanitary treatments for regulated pests (FAO, 2007)

PT 1: 2009 – Irradiation treatment for *Anastrepha ludens*
PT 2: 2009 – Irradiation treatment for *Anastrepha obliqua*
PT 3: 2009 – Irradiation treatment for *Anastrepha serpentina*
PT 4: 2009 – Irradiation treatment for *Bactrocera jarvisi*
PT 5: 2009 – Irradiation treatment for *Bactrocera tryoni*
PT 6: 2009 – Irradiation treatment for *Cydia pomonella*
PT 7: 2009 – Irradiation treatment for fruit flies of the family Tephritidae (generic)
PT 8: 2009 – Irradiation treatment for *Rhagoletis pomonella*
PT 9: 2010 – Irradiation treatment for *Conotrachelus nenuphar*
PT 10: 2010 – Irradiation treatment for *Grapholita molesta*
PT 11: 2010 – Irradiation treatment for *Grapholita molesta* under hypoxia
PT 12: 2011 – Irradiation treatment for *Cylas formicarius elegantulus*
PT 13: 2011 – Irradiation treatment for *Euscepes postfasciatus*
PT 14: 2011 – Irradiation treatment for *Ceratitis capitata*

Checklists in sections 2.2.2 and 2.2.3	ISPM No 28
Plant material information	
Type of plant material/product used in the experiment	
Plant identity (e.g. botanical name, variety)	
Conditions under which plant materials/products are managed	
Conditions of the plant commodity (e.g. degree of ripeness, presence of bark, etc.)	
Pest information	
Identity (species, strains, biotypes if applicable)	
Conditions under which the pests are cultured, reared or grown	
Method of infestation	
Level of infestation	
Stage of the pest that is most resistant to the treatment (refer to research data if relevant)	
Was the most resistant stage used in the experiment?	
Potential development of resistance to the option	

Checklists in sections 2.2.2 and 2.2.3	ISPM No 28
Experiment(s) description and analysis	
Objectives (maximal pest density acceptable) For example, ISPM No 15 presently relies on the probit 9 norm (100 % mortality of at least 93 613 test organisms, at a reliability of 0.99994) regarding the prevalence of pine wood nematodes (*Bursaphelenchus xylophilus*) in wood packaging material (IPPC, 2009). See also section 3.2.3.2 for a discussion on the use of probit 9	
Level of confidence of laboratory or field test	Level of confidence of laboratory tests
Variables used to measure effectiveness (e.g. mortality rate, count)	Methodology to measure the effectiveness of the treatment (e.g. whether mortality is the proper parameter, whether the end-point mortality was assessed at the correct time, the mortality or sterility of the treated and control groups)
Factors influencing effectiveness that were taken into account in the experiment (e.g. wood humidity)	Monitoring of critical parameters (e.g. exposure time, dose, temperature of regulated article and ambient air, relative humidity)
Factors influencing effectiveness that were **not** taken into account in the experiment (e.g. wood humidity)	
Description of facilities and equipment	Experimental facilities and equipment
Description of treatment (e.g. temperature/duration, chemicals, concentration)	Experimental conditions (e.g. temperature, relative humidity, diurnal cycle)
Methodology followed for monitoring critical parameters (e.g. number and placement of temperature sensors)	
	Determination of effectiveness over a range of critical parameters, where appropriate, such as exposure time, dose, temperature, relative humidity and water content, size and density
Description of experimental design (e.g. randomisation, blocks, number of replicates)	Experimental design
Presentation of the data	
Description of the statistical analysis (e.g. analysis of variance, regression, test)	
Conclusions of the experiment	
Other relevant information	Methodology to measure phytotoxicity, when appropriate; dosimetry system, calibration and accuracy of measurements, if using irradiation

ABBREVIATIONS

ALOP: appropriate level of protection

ALPP: areas of low pest prevalence

CPM: Commission on Phytosanitary Measures

ED: effective dose

EFSA: European Food Safety Authority

EPPO: European and Mediterranean Plant Protection Organization

EU: European Union

IPPC: International Plant Protection Convention

ISPM: International Standard for Phytosanitary Measures

NPPO: national plant protection organisation

PFA: pest-free area

PLH: plant health

RRO: risk reduction option

SPS: Sanitary and Phytosanitary Agreement

SSC: survey system component

WTO: World Trade Organization