



HAL
open science

Proposal of a ranking methodology for plant threats in the EU

Christine Tayeh, Maria Rosaria Mannino, Olaf Mosbach-schulz, Giuseppe Stancanelli, Sara Tramontini, Emmanuel Gachet, Thierry T. Candresse, Josep Anton Jaques Miret, Michael John Jeger

► To cite this version:

Christine Tayeh, Maria Rosaria Mannino, Olaf Mosbach-schulz, Giuseppe Stancanelli, Sara Tramontini, et al.. Proposal of a ranking methodology for plant threats in the EU. *EFSA Journal*, 2022, 20 (1), pp.e07025. 10.2903/j.efsa.2022.7025 . hal-03580503

HAL Id: hal-03580503

<https://hal.inrae.fr/hal-03580503>

Submitted on 18 Feb 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NoDerivatives 4.0 International License

APPROVED: 26 November 2021

doi: 10.2903/j.efsa.2022.7025

Proposal of a ranking methodology for plant threats in the EU

European Food Safety Authority (EFSA),
Christine Tayeh, Maria Rosaria Mannino, Olaf Mosbach-Schulz, Giuseppe Stancanelli,
Sara Tramontini, Emmanuel Gachet, Thierry Candresse, Josep Anton Jaques Miret and
Michael John Jeger

Abstract

Following a request of the European Commission, EFSA and ANSES, beneficiary of the EFSA tasking grant on horizon scanning for plant pests (GP/EFSA/ALPHA/2017/02), developed a methodology to order by risk non-regulated pests recently identified through the monitoring of media and scientific literature. The ranking methodology proposed at the end of the pilot phase was based on the scoring of pests under evaluation following 16 criteria related to the steps of the pest risk assessment scheme. The multicriteria matrix of scores obtained was then submitted to the multicriteria analysis method PROMETHEE. The pilot methodology was tested on a limited number of pests (14 pests identified during the monitoring activity, and 4 'control' pests whose well-known risk should be reflected either in a positive or negative score), then applied on all non-regulated pests identified through the media and scientific literature monitoring in the first 2 years of the project. After having collected feedback from the targeted final users (EU risk managers), the methodology underwent a few refinements: (i) implementation of the methodology to a set of already assessed reference pests from EFSA opinions, (ii) exclusions of three criteria from the scoring phase, (iii) identification of pests proposed for further action ('positive' pests), using a threshold defined after scoring the reference pests.

© 2022 European Food Safety Authority. *EFSA Journal* published by John Wiley and Sons Ltd on behalf of European Food Safety Authority.

Keywords: plant health, pest ranking, pest scoring, multicriteria decision-aiding method, pest risk analysis

Requestor: European Commission, Directorate General for Health and Food Safety

Question number: EFSA-Q-2017-00037

Correspondence: alpha@efsa.europa.eu

Declarations of interest: The declarations of interest of all scientific experts active in EFSA's work are available at <https://ess.efsa.europa.eu/doi/doiweb/doisearch>.

Acknowledgments: This document was prepared in cooperation with the French Agency for Food, Environmental and Occupational Health & Safety (ANSES) under the tasking grant GP/EFSA/ALPHA/2017/02. EFSA wishes to acknowledge (i) the EFSA Plant Health Panel and Network, DG SANTE and Member State representatives in the PAFF Committee section on Plant Health for the contribution to the methodology definition; (ii) Caterina Campese for the scientific contributions along the whole project, in particular on the testing of the PeMoScoring; (iii) Claude Bragard and Charles Manceau for the final review of this scientific output.

Suggested citation: EFSA (European Food Safety Authority), Tayeh C, Mannino MR, Mosbach-Schulz O, Stancanelli G, Tramontini S, Gachet E, Candresse T, Jaques Miret JA and Jeger MJ, 2022. Scientific Report on the proposal of a ranking methodology for plant threats in the EU. *EFSA Journal* 2022;20(1):7025, 59 pp. <https://doi.org/10.2903/j.efsa.2022.7025>

ISSN: 1831-4732

© 2022 European Food Safety Authority. *EFSA Journal* published by John Wiley and Sons Ltd on behalf of European Food Safety Authority.

This is an open access article under the terms of the [Creative Commons Attribution-NoDerivs](https://creativecommons.org/licenses/by/4.0/) License, which permits use and distribution in any medium, provided the original work is properly cited and no modifications or adaptations are made.



The EFSA Journal is a publication of the European Food Safety Authority, a European agency funded by the European Union.



Summary

European Food Safety Authority (EFSA) has been requested by the European Commission to provide scientific and technical assistance on a horizon scanning exercise with the aim of identifying relevant information on plant pests that could be of concern to the EU. EFSA has also been asked to develop a methodology to rank the non-regulated pests recently identified through the monitoring of media and scientific literature in terms of the risk they pose. The ranking system should be able to indicate those pests for which further action (e.g. pest categorisation) should be taken first.

In the context of the specific agreement number 1 of the tasking grant 'Horizon scanning by media and scientific literature monitoring for the early identification of new or emerging plant pest risks - Pest Ranking', the EFSA's partner ANSES (French Agency for Food, Environmental and Occupational Health & Safety) developed a ranking methodology for the non-regulated pests identified, in terms of the risk they pose to the EU territory.

A relative ranking methodology was chosen after discussion with the risk managers and proposed at the end of the pilot phase. It is based on three successive steps: (1) answer questions, (2) construct matrices, (3) analyse the multicriteria matrix.

In step (1), the user must retrieve data (related to the risk posed by the pests: hosts range and distribution, natural and human-assisted pathways, pest risk assessment (PRA) area, potential impact, etc.) in order to score 16 criteria retained for the test. In this step, the uncertainties related to missing data are also identified. This step is spreadsheet-based.

In step (2), the score matrix and the uncertainty matrix are automatically constructed from the answers given in step (1).

In step (3), the multi-criteria matrix of scores is submitted to the multi-criteria analysis method PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluation) through the Visual PROMETHEE. This software allows the import of the score matrix, the weighting of criteria and the comparison of different scenarios as well as the analysis of results. The methodology was tested with 18 pests: 14 pests were selected based on the monitoring activity carried out in the period February 2017–December 2018, while the remaining four pests included two positive and two negative 'control' pests.¹

Several scenarios with different weightings were run to identify 'core pests'¹, namely pests whose ranking is always high whatever the weighting scenario.

The performance of the ranking system put in place during the pilot phase was explored running the system on a larger set of pests (non-regulated pests identified through the media and scientific literature monitoring in the first 2 years of the project) and discussing the results with risk managers.

After further EFSA internal fine tuning of the ranking process, some amendments were made to the proposed methodology.

The first was the implementation of the methodology to a set of reference pests¹ from EFSA pest categorisations and the EU candidate priority pests: Those recommended by EFSA as candidates to the EU quarantine regulation and pests candidate priority pests identified by Member States were used as 'positive reference pests'¹, while those not recommended by EFSA as quarantine pests were used as 'negative pests'. The reference data set consisted of 43 pests: 33 classified as positive, and 10 classified as negative reference pests.

The second amendment consisted in the exclusions of three criteria from the scoring. C3 (total volume of host plant commodity traded into the PRA area) was excluded because presenting high uncertainties for a reliable score. C4 (difficulty of visual detection of the pest during inspection) and C6 (presence of the pest in the PRA area) were excluded because of their inconsistent results on the reference data set.

Furthermore, in the updated methodology (PeMoScoring), instead of running several scenarios with different weightings to identify 'core pests', the pests proposed for further action ('positive'¹ pests) were identified using a predefined threshold. This threshold was obtained in a preliminary phase (i.e. during the development of the PeMoScoring methodology) after scoring a set of reference pests.

In the frame of the project, EFSA also built the PeMoScore Calculator. This tool is implemented as Excel file and allows the calculation of the final score (Phi-score) from the scores attributed to the criteria. For each pest, it also compares the computed Phi-score with the retained threshold and proposes its classification as 'positive' or 'negative' pest.

¹ Definition provided in the Glossary.

From a methodological point of view, based on the feedbacks received, EFSA would consider the possibility to enlarge and update the reference data set and to develop a tool structuring the decision process and the data storing.

The PeMoScoring tool is sufficiently flexible and easy to use to allow the scoring exercise to be carried out as soon as a new pest appears in the media or in the scientific literature, thus fully fulfilling its role as an alert tool on new plant health risks for the EU.

Table of contents

Abstract.....	1
Summary.....	3
1. Introduction.....	6
1.1. Background and Terms of Reference as provided by the requestor.....	6
1.2. Interpretation of the Terms of Reference.....	6
2. Ranking methodology – Pilot phase.....	6
2.1. Step 1: answer questions by scoring criteria.....	7
2.1.1. Data retrieval.....	7
2.1.1.1. Import data.....	7
2.1.1.2. Land use.....	8
2.1.1.3. Climate.....	8
2.1.2. Scoring criteria.....	8
2.2. Step 2: construct two matrices.....	10
2.3. Step 3: analyse the multi-criteria matrix.....	10
2.4. Test, results, and discussion.....	11
2.4.1. Pests ranked in the test.....	11
2.4.2. Test results.....	11
2.4.2.1. Principle components analysis.....	12
2.4.2.2. Profiles.....	13
2.4.2.3. Identification of core pests.....	15
2.5. Conclusions and perspectives after the test of the pilot ranking methodology.....	15
2.6. Strategic options and changes decided for the continuation of the project.....	16
3. Development of the PeMoScoring methodology.....	17
3.1. Construction of the reference dataset.....	17
3.2. Statistical analysis of individual criteria.....	18
3.2.1. C1: Range of pest host plants.....	19
3.2.2. C2: Regulatory status of pathways.....	19
3.2.3. C3: Total volume of host plant commodity traded into the PRA area.....	20
3.2.4. C4: Difficulty of visual detection of the pest during inspection.....	20
3.2.5. C5: Possibility of entry into the PRA area through natural means.....	20
3.2.6. C6: Presence of the pest in the PRA area.....	21
3.2.7. Need for a vector and its occurrence in the PRA area.....	22
3.2.8. C8: Cultivated host plant surface area in the PRA area.....	22
3.2.9. C9: Cultivated host plant distribution in the PRA area.....	23
3.2.10. C10: Occurrence of other host plants that are not crops in the PRA area.....	23
3.2.11. C11: Climate suitability.....	24
3.2.12. C12: Possibility of spread by natural means.....	25
3.2.13. C13: Possibility of spread by human assistance.....	25
3.2.14. C14: Description of yield losses in the pest’s current area of distribution.....	26
3.2.15. C15: Description of quality losses or plant death in the pest’s current area of distribution.....	27
3.2.16. C16: Existence of control measures that could affect the pest’s impact.....	27
4. PeMoScoring exercise.....	28
4.1. First step: screening based on exclusion criteria.....	28
4.2. Second step: scoring pests.....	29
5. Conclusions and perspectives.....	33
References.....	33
Glossary.....	34
Abbreviations.....	34
Appendix A – The 16 criteria used to score pests in the pilot ranking methodology.....	35
Appendix B – Features of the PROMETHEE method.....	43
Appendix C – Score matrix of the 18 pests selected for the test of the pilot methodology.....	46
Appendix D – Uncertainty matrix of the 18 pests selected for the test of the pilot methodology.....	47
Appendix E – Preference functions and thresholds for the test of the pilot methodology.....	48
Appendix F – Score matrix of the reference pests used in the PeMoScoring methodology.....	49
Appendix G – Updated 13 criteria in the PeMoScoring methodology.....	51
Appendix H – Updated preference functions and thresholds for the PeMoScoring methodology.....	53
Appendix I – Manual for calculation with the PeMoScore Calculator.....	55

1. Introduction

1.1. Background and Terms of Reference as provided by the requestor

EFSA has been requested by the EC to provide scientific and technical assistance on a horizon scanning exercise in view to crisis preparedness on plant health for the EU territory. The aim is to identify relevant information on plant pests that could be of concern to the EU and may therefore require consideration by risk assessors and risk managers.

Media and scientific literature are screened using the IT Platform of MEDISYS (Medical Information System <https://medisys.newsbrief.eu/medisys/homeedition/en/home.html>). This platform screens news and articles published on the plant pests listed in the EU legislation or in the EPPO lists. In order to improve EU crisis preparedness in addressing new plant health risks, work is also carried out on pests not listed in the texts mentioned above. The results of the automated media and literature monitoring are screened for relevance and duplications before being published monthly in commented newsletters. Methodology and outputs of activities carried out to answer to this request are presented in the EFSA report on Horizon Scanning for Plant Health (EFSA, 2021).

In parallel, EFSA has been asked to develop a methodology to rank the non-regulated pests identified through the monitoring activity in terms of the risk they pose to the EU territory.

1.2. Interpretation of the Terms of Reference

This report was produced in the context of the partnership established between EFSA and ANSES (French Agency for Food, Environmental and Occupational Health & Safety) in the area of Plant Health.

The tasks were entrusted by EFSA to ANSES through the Framework Partnership Agreement (FPA) 'GP/EFSA/ALPHA/2017/02 – Lot 1 GA 1: Horizon scanning by media and literature monitoring for the early identification of new or emerging plant pest risks - Pest Ranking'.

In the context of the specific agreement number 1 of this tasking grant, two tasks, namely the production of a review of pest ranking systems already in use, and the development of a ranking system for the identified new non-regulated pests in terms of the risk they represent for the EU territory have been carried out.

The review of pest ranking systems was the subject of a previous report (EFSA, 2020). On the basis of its findings, a methodology for ranking plant threats in the EU has been developed in 2018 then updated in the period 2019–2020. The ranking methodology developed by Anses during the pilot phase as well as the updated methodology (PeMoScoring) developed by EFSA currently in use are presented in this report.

2. Ranking methodology – Pilot phase

The general aim of the European Commission request is to increase crisis preparedness concerning new or emerging pests in the EU. It should help risk managers decide (i) whether further risk assessment, such as pest categorisation, is needed, (ii) whether EU surveillance and import control must be enforced for newly identified specific pests. The ranking system will thus order pests by risks posed to EU and provide a tool to support risk managers in the decision of actions to take. EU risk managers have been consulted during the development and testing phase of this new methodology and a series of decisions were taken with them.

The conclusions drawn from the review of existing ranking systems (EFSA, 2020) and consequent reflexions during the developmental phase of this new system identified a set of requirements to be satisfied. The ranking system should be:

- proactive.
- generic enough to deal with a variety of pests.
- rapid, as the analyses carried out via the ranking system are not intended to replace a categorisation or a full risk assessment.
- simple: some pests' traits will be summarised, as addressing each one individually would make the system complex and suggest a level of detail that cannot be justified in this exercise.

To keep in line with the exercise, this system favours rapidity and robustness over sophistication and complexity. When interpreting the results, it is recommended to first examine the overall results,

then to apply sensitivity analyses to detect the most crucial aspects and address uncertainties to ensure transparency as well as a better understanding of the results.

The proposed ranking methodology is based on three successive steps:

- Step 1: Answer questions by scoring criteria.
- Step 2: Construct matrices.
- Step 3: Analyse the multicriteria matrix.

Each of these steps will be developed in the following sections.

2.1. Step 1: Answer questions by scoring criteria

In this step, the user must (a) retrieve data related to the pest(s), to the PRA area and general data, (b) answer questions and (c) identify uncertainty related to missing data. All these actions are spreadsheet-based.

2.1.1. Data retrieval

The data to be retrieved falls into one of three categories: general data, data about the pest to be ranked and data about host plants in the PRA area. Data titles and sources are indicated in Table 1. When needed, data are described precisely, and their quality discussed in the following paragraphs.

Table 1: Information about data

	Main sources
General data	
EU Legislation (prohibited pathways)	EC Plant Health and Biosecurity
Climate of countries where the pest has been reported and in the territory of the EU Member States (MSs)	Köppen–Geiger (Kottek et al., 2006)
Pest data	
Distribution	EPPO GD
Host range	CABI Crop Protection Compendium (CPC)
Availability of detection methods	Scientific literature
Impacts	Grey literature, including media (via MEDISYS)
Management	
Host plants (crops and forest stands)	
Surface area and distribution in the EU	Eurostat , EFISCEN Database
Imports into the EU	Eurostat

2.1.1.1. Import data

For imports into the EU, the Combined Nomenclature (CN) classification was selected because it is the most comprehensive commodity classification used throughout the EU. It has a logical structure based on the state of the product (fresh, processed, etc.). Furthermore, it corresponds to the harmonised system (HS) (managed by the World Customs Organisation (WCO)) plus a further breakdown at eight digit level satisfying specific EU needs.²

Chapters and subheadings were selected (Table 2) from the full CN classification (97 chapters in 2016). The selection was based on the type of products that could host plant pests.

For each CN8 code, a scientific name was attached to define the imported plant (at species level when possible) and a host commodity to define the state of the product and its final use.

As mentioned above, the used Eurostat data set version is from 2016, because it was the most complete and recent set of data when this task was undertaken.

² Eurostat website at <https://ec.europa.eu/eurostat/web/international-trade-in-goods/methodology/classifications> (last access 11 August 2021).

Table 2: Chapters selected from Eurostat to quantify imported plant commodities

Chapters in Eurostat	Titles
CHAPTER 6	LIVE TREES AND OTHER PLANTS; BULBS, ROOTS AND THE LIKE; CUT FLOWERS AND ORNAMENTAL FOLIAGE
CHAPTER 7	EDIBLE VEGETABLES AND CERTAIN ROOTS AND TUBERS
CHAPTER 8	EDIBLE FRUIT AND NUTS; PEEL OF CITRUS FRUIT OR MELONS
CHAPTER 9	COFFEE, TEA, MATÉ AND SPICES
CHAPTER 10	CEREALS
CHAPTER 12	OIL SEEDS AND OLEAGINOUS FRUITS; MISCELLANEOUS GRAINS, SEEDS AND FRUIT; INDUSTRIAL OR MEDICINAL PLANTS; STRAW AND FODDER
CHAPTER 14	VEGETABLE PLAITING MATERIALS; VEGETABLE PRODUCTS NOT ELSEWHERE SPECIFIED OR INCLUDED
CHAPTER 18	COCOA AND COCOA PREPARATIONS
CHAPTER 24	TOBACCO AND MANUFACTURED TOBACCO SUBSTITUTES
CHAPTER 44	WOOD AND ARTICLES OF WOOD. WOOD CHARCOAL
CHAPTER 52	COTTON
CHAPTER 53	OTHER VEGETABLE TEXTILE FIBRES; PAPER YARN AND WOVEN FABRICS OF PAPER YARN

2.1.1.2. Land use

In the pilot methodology, data for cultivated crops were collected from the Eurostat database 2016 (<https://ec.europa.eu/eurostat/fr/data/database>). Eighty-six crops were identified, and scientific names assigned at species level when possible. When no data were communicated by Member States, they were considered as null. In the final methodology, other sources (e.g. FAOSTAT) were considered to collect data for minor crops not included in the Eurostat database. Those additional data were also stored to be available afterwards for the scoring of other pests with the same host plants.

In the pilot methodology, data on forests were retrieved from the EFISCEN database (<https://www.efi.int/knowledge/models/efiscen/inventory>). This is a forest inventory database for European countries based on inputs from national inventory experts, the only source where data at species level are available for most European countries.

However, data on forests could be improved because they present two weak points:

- Data are not available for Cyprus, Greece, Malta and Spain, which represent sizeable part of EU forest areas.
- Data input dates back to 2006, so data are not up to date.

In the light of these findings, these forest data need consolidation from other resources or from national forest inventories (e.g. the European Atlas of Forest Tree Species from the JRC).

2.1.1.3. Climate

The Köppen–Geiger main climate classification (Class A = Tropical, Class B = Arid, Class C = Temperate, Class D = Cold continental and Class E = Polar) (Kottek et al., 2006) was used. For each country, the surface area occupied by each class is available, and thus, the percentage of area covered by each class.

2.1.2. Scoring criteria

The ranking system relies on 16 criteria (Table 3) related to the steps of the pest risk assessment scheme: entry, establishment, spread and impact (Figure 1). These criteria are treated independently, yet some are correlated. For example, the need for and occurrence of a vector (C7) is related to the transfer of the pest from the imported commodity to host plants at the end of the entry section, to its establishment and to its further natural spread. Another example concerns the range of potential host plants (C1): This aspect affects the number and the type of entry pathways of the pest (C3), the PRA area at risk of establishment (from C8 to C10), of the possibility of spread by human assistance (C13) and potential impacts (from C14 to C16). Such questions are considered as general traits affecting almost all PRA steps.

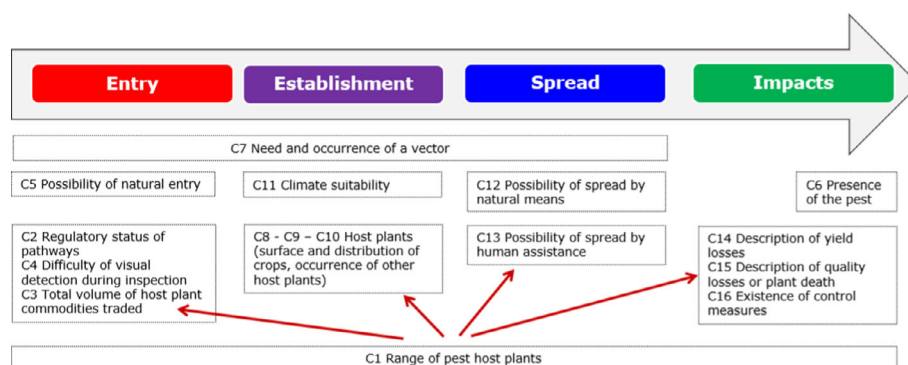


Figure 1: Distribution of criteria along the PRA scheme

The finally retained criteria (Table 3) were identified through a review of ranking systems in place in some EU Member States and third countries. Before reaching the pilot version of the ranking system, different draft versions were tested and adjusted: A new scoring method was defined for two criteria (C1: range of pest host plants, and C9: host plant distribution in the PRA area), one criterion was reformulated (difficulty of visual detection during inspection), one criterion (entry through natural means) was divided into two new criteria (C5: possibility of entry through natural means and C6: presence of the pest in the PRA area) and one criterion was added (C10: occurrence of host plants that are not crops in the PRA area).

The scoring method implemented is described in Appendix A.

Table 3: Criteria retained for the ranking test

Criterion	Description
C1	Range of pest host plants
C2	Regulatory status of pathways
C3	Total volume of host plant commodities traded into the PRA area
C4	Difficulty of visual detection of the pest during inspection
C5	Possibility of entry into the PRA area through natural means
C6	Presence of the pest in the PRA area
C7	Need for a vector and its occurrence in the PRA area
C8	Cultivated host plant surface area in the PRA area
C9	Cultivated host plant distribution in the PRA area
C10	Occurrence of host plants that are not crops in the PRA area
C11	Climate suitability
C12	Possibility of spread by natural means
C13	Possibility of spread by human assistance
C14	Description of yield losses in the pest's current area of distribution
C15	Description of quality losses or plant death in the pest's current area of distribution
C16	Existence of control measures that could affect the pest's impact.

C1, C6 and C7 address pests' general traits. C2–C5 are related to pest entry, C8–C11 to pest establishment, C12 and C13 to pest spread, C14–C16 to pest impact.

A rapid screening of data availability regarding the pests to be ranked showed that data could be missing for some pests, such as those lacking any pest risk analysis or CPC datasheet. This alerted to the need for a 'missing data' management strategy and to the need to point out uncertainties when evaluating any pest.

Whenever data are missing when answering a question (or scoring criterion), the user takes two actions:

- Fill-in the missing data value in order to reduce the number of missing values in the score matrix following the worst-case scenario, the midpoint scenario or no score for no information. In this last option, the score is replaced by a question mark.

- Highlight uncertainty in order to allow the construction of an informative uncertainty matrix. For each criterion, the user must allocate:
 - A score of 0 = no uncertainty, an answer is identified in the literature.
 - A score of 1 = uncertainty, the missing value is replaced according to the predefined scenario for each criterion.

2.2. Step 2: construct two matrices

In this step, two matrices are constructed.

First, all the answers given for a pest are automatically reported in a unique score matrix. The score matrix is organised as follows, where $S_{x,y}$ is the score of pest x for criterion y (Table 4).

Table 4: Score matrix

	Criterion 1	Criterion 2	Criterion m...
Pest 1	$S_{1,1}$	$S_{1,2}$	$S_{1,m}$
Pest 2	$S_{2,1}$	$S_{2,2}$	$S_{2,m}$
Pest n	$S_{n,1}$	$S_{n,2}$	$S_{n,m}$

An uncertainty matrix is also constructed for all the pests during this step. The uncertainty matrix is organised as follows, where $U_{x,y}$ is the uncertainty score of pest x for criterion y and is either 0 (no uncertainty) or 1 (Table 5).

Table 5: Uncertainty matrix

	Criterion 1	Criterion 2	Criterion m...
Pest 1	$U_{1,1}$	$U_{1,2}$	$U_{1,m}$
Pest 2	$U_{2,1}$	$U_{2,2}$	$U_{2,m}$
Pest n	$U_{n,1}$	$U_{n,2}$	$U_{n,m}$

2.3. Step 3: analyse the multi-criteria matrix

Once the multi-criteria matrix has been obtained, it is submitted to a multi-criteria analysis. The multi-criteria analysis method PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluation) has been chosen. This method was developed in 1986 by Brans et al. and is cited in 1142 publications according to a request made in the Scopus database (October 2018), including 42 in agricultural and biological sciences and 185 in environmental sciences. The implementation of the PROMETHEE method in a system to rank pests threatening plants in a geographic area is the subject of a more recent publication (Tayeh et al., 2021).

This method is easily applicable because it benefits from a graphical application via the Visual PROMETHEE (VP) software, which can be used to import a matrix, to define the weight of criteria and offers many tools to study the ranking results. In addition, it allows to compare different scenarios.

The PROMETHEE method is an outranking method, so the ranking is dynamic and relative. It allows the use of both quantitative and qualitative criteria in the same exercise. This strategy allows to concentrate efforts on setting up criteria that are relevant to the exercise rather than having to develop a new scoring method.

Visual PROMETHEE includes functionalities such as the weighting, the principal component analysis (PCA) and the profiles.

The weighting is used to allocate different weights to criteria and compare different scenarios. It is also possible to turn off criteria to make a new scenario in which these criteria are not relevant. The PCA is used to define a series of orthogonal dimensions (principal components) that keep as much information as possible on the relative positions of the pest in dimensional space. PCA helps to understand the obtained ranking. The profiles are used to identify which criteria contribute to placing the pest at the top of the ranking or on the contrary those which contribute to placing the pest at the bottom of the ranking.

The features of the PROMETHEE method are described in detail in Appendix B and can be found in the Visual PROMETHEE manual (Mareschal, 2015).

2.4. Test, results and discussion

The following section describes the test carried out in the pilot phase, then presents and discusses the results.

2.4.1. Pests ranked in the test

The test was conducted on 18 pests (Table 6), which included.

- 14 emerging pests identified via the horizon scanning exercise,
- 2 'positive control pests', which are pests that are known as high-risk pests to the EU and are regulated,
- 2 'negative control pests', which are pests that are known as no- or low-risk pests to the EU.

When choosing the pests to be included in the test, care was taken to include a sufficiently large and varied set of pests (insects and mites, fungi and oomycetes, bacteria and phytoplasmas, nematodes, viruses) in order to reflect their relative proportions observed in the total number of non-regulated pests identified during the monitoring phase (i.e. the most represented pests being insects followed by fungi).

At least one pest that is described for the first time and does not have an EPPO datasheet or a CABI CPC datasheet was included.

Table 6: Pests included in the test

Pests	Type of pest	Status
<i>Aceria litchi</i>	Insect	New or emerging pest
<i>African cassava mosaic virus</i>	Virus	Negative control
<i>Agilus auroguttatus</i>	Insect	New or emerging pest
<i>Bactrocera kirki</i>	Insect	Negative control
<i>Fiorinia phantasma</i>	Insect	New or emerging pest
<i>Fusarium oxysporum</i> f. sp. <i>lactucae</i>	Fungus	New or emerging pest
<i>Lema bilineata</i>	Insect	New or emerging pest
<i>Liberomyces pistaciae</i>	Fungus	New or emerging pest
<i>Lycorma delicatula</i>	Insect	New or emerging pest
<i>Meloidogyne enterolobii</i>	Nematode	New or emerging pest
<i>Oryctes rhinoceros</i>	Insect	New or emerging pest
<i>Phyllosticta citricarpa</i>	Fungus	Positive control
<i>Phytophthora chrysanthemi</i>	Fungus	New or emerging pest
<i>Pterochloroides persicae</i>	Insect	New or emerging pest
<i>Raffaelea lauricola</i>	Fungus	New or emerging pest
<i>Resseliella maxima</i>	Insect	New or emerging pest
<i>Tomato brown rugose fruit virus</i>	Virus	New or emerging pest
<i>Xylella fastidiosa</i>	Bacterium	Positive control

2.4.2. Test results

The score and the uncertainty matrices are presented in Appendix C and Appendix D, respectively. The preference functions used are presented in Appendix E.

The results of the ranking of the 18 pests according to a basic scenario are given in Table 7 where the Phi net value of each pest is presented. In the test, all the criteria were weighted one.

In the PROMETHEE method, the Phi net is computed to consolidate the results of the pairwise comparisons as a balance between the positive preference flow (how much an 'action' – a pest in this exercise – is 'preferred' to the others) and the negative preference flow (how much other pests are 'preferred' to a given pest) of each pest (Appendix B.3). In this exercise, the Phi net was used to rank the pests from the riskiest one (highest Phi net value) to the less risky one (lowest Phi net value).

Table 7: Ranking test results

Rank	Pests	Phi net
1	<i>Xylella fastidiosa</i> ^(*)	0.3588
2	<i>Meloidogyne enterolobii</i> ^(*)	0.2060
3	<i>Lycorma delicatula</i>	0.1868
4	<i>Agrilus auroguttatus</i>	0.1646
5	<i>Tomato brown rugose fruit virus</i> ^(*)	0.1142
6	<i>Phyllosticta citricarpa</i>	0.0734
7	<i>Fusarium oxysporum</i> f.sp. <i>lactucae</i> ^(*)	0.0611
8	<i>Resseliella maxima</i>	0.0599
9	<i>Pterochloroides persicae</i> ^(*)	0.0358
10	<i>Phytophthora chrysanthemi</i> ^(*)	0.0139
11	<i>Liberomyces pistaciae</i> sp. nov. ^(*)	-0.0607
12	<i>Fiorinia phantasma</i>	-0.0751
13	<i>Oryctes rhinoceros</i>	-0.0968
14	<i>Lema bilineata</i> ^(*)	-0.0993
15	<i>Raffaelea lauricola</i>	-0.1492
16	<i>Aceria litchi</i>	-0.2195
17	<i>African cassava mosaic virus</i>	-0.2379
18	<i>Bactrocera kirki</i>	-0.3360

(*): Pest present in the EU.

One of the challenges of any ranking system is to find a balance between specificity (the proportion of true-negative pests correctly identified by the ranking system) and sensitivity (the proportion of true-positive pests correctly identified by the ranking system). Given the results, the ranking system succeeded in identifying the negative control pests – namely *African cassava mosaic virus* and *Bactrocera kirki* – and in placing them at the bottom of the ranking, so a good specificity was achieved. A high sensitivity was also attained since one of the positive control pests, *Xylella fastidiosa*, was ranked number 1, even though the other positive control test, namely *Phyllosticta citricarpa* (causal agent of citrus black spot), was ranked in sixth place. The placement of this pest is discussed in the section profiles. However, these findings must be verified by conducting the ranking on a larger batch of pests. The distances in *Phi net* should also be analysed in order to see whether the top pests are much preferred over the pests below them. If further ranking tests show that more positive control pests are quite far from the top of the ranking, sensitivity could be improved by proposing new preference function settings, for example.

2.4.2.1. Principle components analysis

The relationships between criteria and their contribution to the final ranking are illustrated by GAIA (Geometrical Analysis for Interactive Aid), the graphic resource associated with Visual PROMETHEE (Figure 2). The GAIA plane tool is a two-dimensional representation of the multicriteria analysis containing the maximum possible quantity of information in two dimensions. The quality of the representation is indicated by the percentage of information represented by the chart that corresponds to 71.6% in the ranking test.

Each criterion (or group of criteria) is represented by an axis drawn from the centre of the GAIA plane. Criteria expressing similar preferences have axes that are close to each other, such as 'general', 'impacts' and 'establishment'.

The length of the criteria axes (or groups of criteria axes) is also relevant. The longer an axis is, the more discriminant the criterion. In the current ranking, the 'spread group' axis is the longest. This means that the differences in scores between pests in spread-related criteria are more important than the differences in scores observed in other groups of criteria. The discriminant capacity of a group of criteria must be taken into account when the weighting of criteria is implemented in the ranking. For example, the 'entry' group of criteria may be very important for the decision maker, but if all the scores are in a narrow range, this group of criteria will not contribute to the ranking.

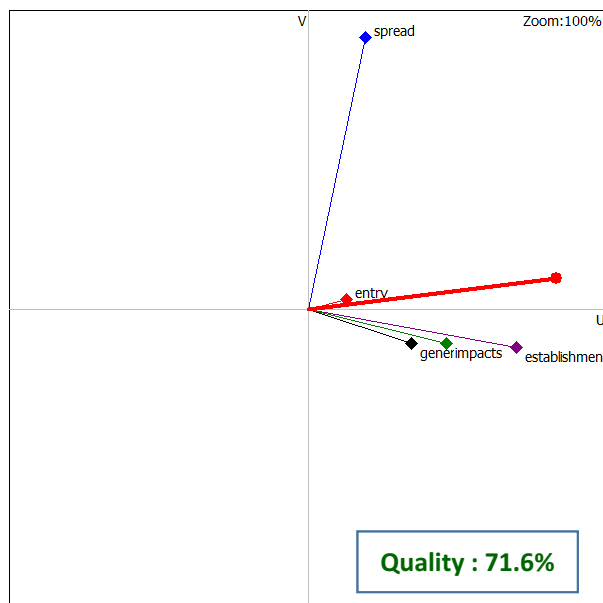


Figure 2: Principle components analysis results of the current ranking represented by the GAIA plane

The decision axis (thicker red axis in Figure 2) represents the weighing of the criteria groups. When the weight of the criteria is modified, the position of the decision axis is modified. The criteria that better explain the final ranking are those closest to the decision axis.

The length of the decision axis represents its reliability. A decision axis is short when paced at a large angle from the GAIA plane, then not well represented by the two-dimensional chart. In the current ranking, the decision axis is long, so it is considered as reliable.

The orientation of the decision axis indicates which criteria are in agreement with the PROMETHEE ranking and which are not. In the current ranking, no group of criteria is in opposition to the decision axis, which means that pests with the highest scores in each group of criteria are expected to be at the top of the ranking.

In addition to the possibility of weighting criteria, the choice of the preference functions can render criteria more or less discriminating. These two parameters are tools that could help decision makers find the most 'fit for purpose' ranking.

2.4.2.2. Profiles

Pest profiles are generated to illustrate the results (Figure 3). These are graphical representations that indicate: (i) the criteria net preference flow scores (provided by Visual PROMETHEE in the form of weight-independent bars) and (ii) the uncertainty curve (from the uncertainty matrix). The criterion net preference flow is measure of the contribution of each criterion to the overall ranking of the pest. Positive bars represent criteria that help to place the pest near the top of the ranking, while negative bars pull the pest downwards in the ranking. The uncertainty curve indicates criteria for which data are missing. In the test, we chose to address uncertainty separately through the construction of an uncertainty matrix that reflects the availability of data. We also proposed a 'missing data' management system that applies a predefined score for each criterion in the event of missing data.

For instance, the criteria contributing the most to placing *X. fastidiosa* near the top of the ranking are its host range (C1), its probability of establishment (especially C8), impacts (especially C14) and its presence in the PRA area (C6).

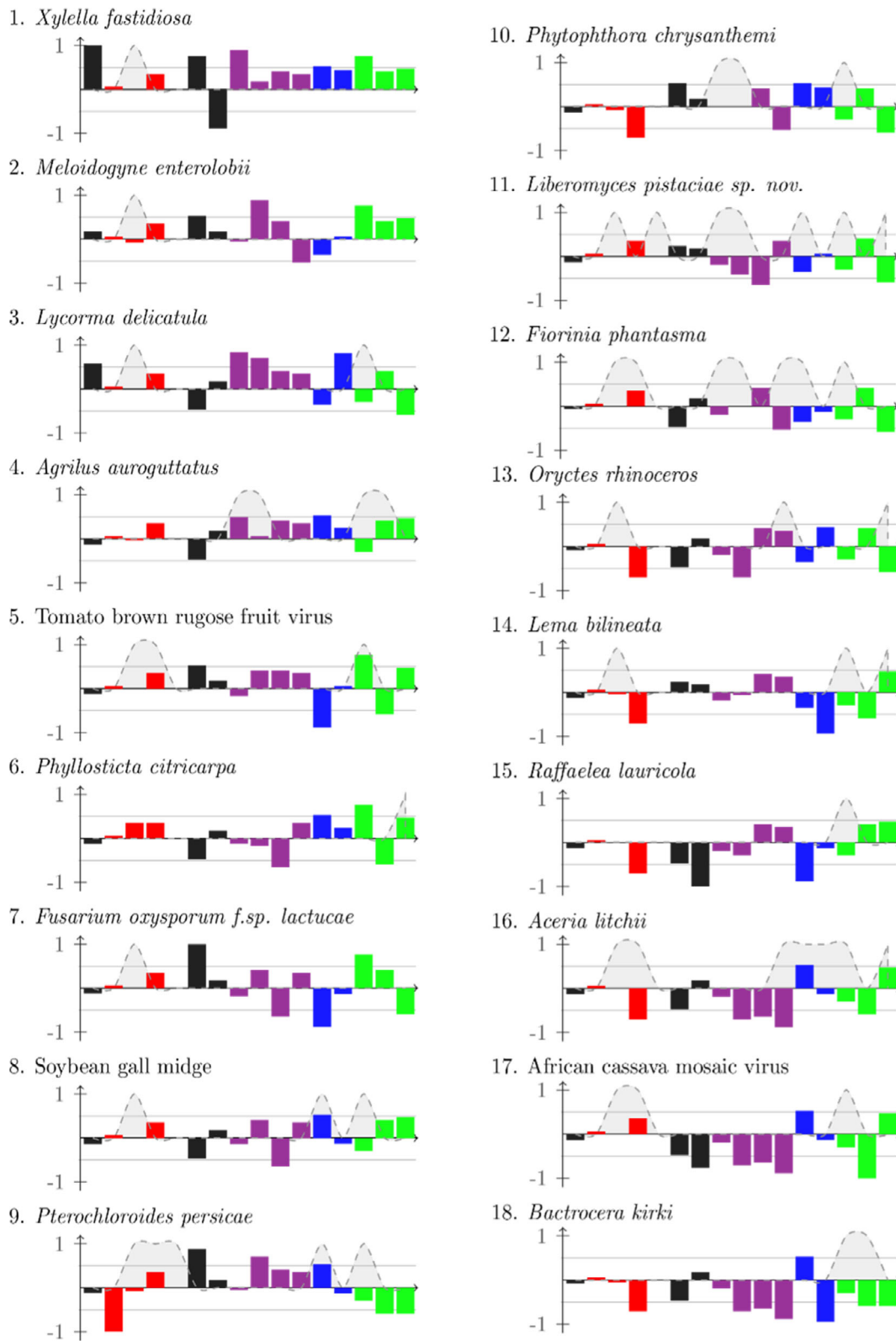


Figure 3: Pest profiles in the order of the current ranking. Bars represent criteria in order of their listing in Table 3. Criteria in black relate to general traits of the pest, in red to entry, in purple to establishment, in blue to spread and in green to impacts. The curve represents the uncertainty

A first look at these profiles and the score and uncertainty matrices (Appendices C and D) shows that data on the volume of imports (trade data for criterion 3) are often missing, especially when the host commodities are plants for planting of specific species.

The positive control pest, *X. fastidiosa*, has only one missing data item for criterion 3. This is also the case for *P. citricarpa*, the other positive control pest and *Meloidogyne enterolobii*. All the other pests' scores present more uncertainty in criteria C3, C4 and C5. This indication is important since it alerts the risk manager that although some pests are placed higher in the ranking than a positive control pest, there needs to be more bibliographical research to remove doubt and confirm their position as high-risk pests in order to increase the level of confidence in the final results. *Liberomyces pistaciae* sp. nov. and *Fiorinia phantasma* have the most uncertain profiles.

The position awarded to *P. citricarpa*, a positive control pest, may be considered surprising. However, a close look at its profile provides clues to help explain this positioning. *P. citricarpa* attacks host plants of the Rutaceae family only, so the host range is very narrow (C1). Moreover, the relative small surface area occupied by its host plants (C8), their distribution in only seven Member States (C9) and the inexistence of other host plants that are not crops (C10) drive this pest down to the sixth position. In addition, this pest is not spread by plants for planting or seeds unlike most of the pests that are placed between rank 2 and rank 8. Therefore, this makes it less risky according to the criterion C13 viewpoint, which considers commodities for consumption as less risky. Moreover, the impacts other than yield impact are only on the quality of the harvest as no tree deaths are reported due to this pest (C15), unlike for some pests considered as riskier according to the ranking.

2.4.2.3. Identification of core pests

One of the objectives of this ranking exercise was to identify those pests that are likely to be a problem for plants in the EU and therefore require further attention. However, it is difficult for the risk manager to decide which threshold to use to define pests that should be placed in this category. Would these pests be in the top five or top 10? This difficulty would have been the same if the ranking system was a 'final score ranking system', which is a system that calculates a score for a particular pest regardless of the other pests included in the ranking exercise.

Risk managers can run several scenarios with different weightings to identify 'core' pests, namely pests whose ranking is always high (among the top five or top 10 according to the size of the set of pests), whatever the weighting scenario.

Seven different scenarios were run illustrating different points of view regarding the relative importance of various criteria (Table 8). In the current exercise, the core pests corresponded to the third top-listed following pest ranking.

Table 8: Relative weights (in percentage) of the groups of criteria according to seven scenario

Groups of criteria	Scenario 1 – basic ^(a)	Scenario 2 – equal ^(b)	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
General	19	20	40	15	15	15	15
Entry	25	20	15	40	15	15	15
Establishment	25	20	15	15	40	15	15
Spread	12	20	15	15	15	40	15
Impacts	19	20	15	15	15	15	40

(a): Basic Scenario, where all the criteria are weighted 1. Thus, the weight of each group of criteria depends on the number of criteria within the group.

(b): Equal Scenario, where all the groups of criteria have the same weight independently of the number of criteria within the group.

After running the seven different scenarios, only two pests remained in the top six in all scenarios: *X. fastidiosa* and *M. enterolobii*. *Lycorma delicatula* and *Agilus auroguttatus* remained in the top six in six out of seven scenarios, and *Tomato brown rugose fruit virus* and *P. citricarpa* remained in the top six in five out of seven scenarios.

2.5. Conclusions and perspectives after the test of the pilot ranking methodology

In the previous sections, the development of a pilot ranking system for new or emerging pests as well as the results of a test have been provided. One of the challenges of this project was to develop a

system that is specific, sensitive, stable and simple. The results of the first test indicate that the final product meets this profile. Lines of improvement concerning data e.g. are outlined in the report and the flexibility offered by the settings in Visual PROMETHEE is highlighted.

In the long term, the dynamic potential of the system to meet the context of 'new or emerging pests' is reliant on data updating. This is an important action point that needs to be addressed. Indeed, data on the distribution of pests and land use should be regularly updated. These updates could become burdensome when a large data set is concerned, especially since this kind of operation cannot be automated for this model under its current spreadsheet format. The inconvenience of using spreadsheet-based models is that this format can generate a high error risk when handling large files. On the other hand, its accessibility to non-experts in the field of computer programming is a great advantage, because developing databases as well as web or graphical interfaces requires advanced skills in computer programming. For the future, an emphasis should be placed on the steps that are programmed in Excel. It could be therefore envisaged a future development of a multi-users tool where all the steps of the process are automatically connected and the decision process properly stored and retrievable. Furthermore, the creation of structured databases on emerging pests will favour collaborations among projects in the field of plant health.

2.6. Strategic options and changes decided for the continuation of the project

The methodology described above was implemented on non-regulated pests identified through the media and scientific literature monitoring in the first 2 years of the project. The results were presented at meetings of the Plant Health section of the Standing Committee on Plants, Animals, Food and Feed (PAFF) Committee in July and November 2019. The presentation of July 2019 covered the non-regulated pests identified through the media monitoring carried out between February 2017 and April 2019. The exercise was then extended to non-regulated pests identified in the scientific literature, extending the monitoring period to May 2019.

Following the discussion with European Commission and MS representatives in the PAFF Committee, and after further EFSA internal fine tuning of the ranking process, some amendments were made to the proposed methodology:

- **Exclusion of pests with existing EFSA or EPPO pest risk assessments or EFSA pest categorisations**

In the first implementation of the methodology, all the non-regulated pests found through the monitoring were the object of the ranking exercise.

Considering that the main objective of the ranking is to support risk managers in their decision for action on non-regulated pests based on the available knowledge, it was decided to exclude from the exercise the non-regulated pests for which such kind of information is already provided by existing pest risk assessments or pest categorisations performed by EFSA or EPPO. This decision led to the exclusion of 19 pests from the exercise performed following the updated methodology.

- **Exclusion of the criterion C3 'Total volume of host plant commodity traded into the PRA area'**

This criterion was initially included to score pests in relation to the existence of a trade pathway through the volume of host plant commodities imported in the EU. Only the total imported volume was used because it was considered not feasible, in a quick exercise, to take into account the origin of the imported host commodities and to distinguish whether they come from a country where the pest is already present.

In the first scoring exercise, the difficulty in interpreting the CN codes and consequently a reliable and reproducible estimation of the imported volumes from the EUROSTAT database was noted. The removal of these uncertainties, in a quick exercise, was considered impossible. Furthermore, comparing different kinds of commodities (e.g. wood vs. plants for planting), using the same unit of measurement (e.g. 100 kg), could be misleading.

Another relevant reason that led to exclude this criterion was the difficulty in a quick exercise to retrieve data on plants for planting.

- **Interpretation of the results: from the 'core pests' (pilot methodology) to the 'positive pests' (updated methodology)**

In order to support risk managers in their decision, the initial methodology explored the possibility of running different weighting scenarios to identify the pests to be considered for further action ('core pests'), among those systematically top-listed following pest ranking, irrespective of the weighting applied to the criteria (see Section 2.4.2.3).

Although interesting from a theoretical point of view, the use of different weightings assigned to the criteria complicates the process because it requires the definition and the choice of scenarios and the establishment of the ranking level above which to define the systematically top-ranked pests.

In the updated methodology, presented in next two chapters, the pests proposed for further action, named the 'positive pests', are identified using a predefined threshold. This threshold was obtained defined after scoring a set of reference pests, whose 'positive' or 'negative' status was expected from previous assessments in EFSA opinions.

3. Development of the PeMoScoring methodology

For the further implementation of the ranking system in risk management, two main effects of the pairwise comparison have been observed: (i) It does not provide an absolute ranking; (ii) it highlights differences among pests within the data set, but without an immediate indication of the most influencing criteria.

To address these questions, the methodology was applied to a reference data set composed by pests whose status (quarantine and non-quarantine) was already known. This section describes the results of the methodology on the reference data set.

3.1. Construction of the reference data set

The reference data set is composed by pests selected from two different projects:

- EFSA pest categorisations: The pests were selected among those assessed between 2017 and 2020 (find the published outputs at the dedicated virtual issue³). Those recommended by EFSA as candidates to the EU quarantine regulation were used as 'positive pests', while those not recommended by EFSA as quarantine pests were used as 'negative pests'.
- EU candidate priority pests: The candidate priority pests identified by the MSs and submitted to EFSA assessment (EFSA, 2019) are all pests expected to have the most severe potential economic, environmental or social impact as defined by the Regulation (EU) 2016/2031. For this reason, pests selected from this list were all allocated to the 'positive pests' category.

It counts, at the moment, 43 pests: 33 classified as positive, and 10 classified as negative reference pests (Table 9). The score matrix can be found in Appendix F.

Table 9: 'Positive' and 'negative' pests included in the reference data set

	Taxonomy	Source project ^(a)		Taxonomy	Source project ^(a)
Positive reference pests			Negative reference pests		
<i>Acrobasis pirivorella</i>	Insect	PC_QP	<i>African cassava mosaic virus</i>	Virus	None ^(b)
<i>Agrilus anxius</i>	Insect	PP	<i>Apple geminivirus</i>	Virus	PC no QP
<i>Agrilus planipennis</i>	Insect	PP	<i>Apple hammerhead viroid</i>	Viroid	PC no QP
<i>Anastrepha ludens</i>	Insect	PP	<i>Hirschmanniella behningi</i>	Nematode	PC no QP
<i>Anoplophora chinensis</i>	Insect	PP	<i>Margarodes floridanus</i>	Insect	PC no QP
<i>Anoplophora glabripennis</i>	Insect	PP	<i>Neomargarodes cucurbitae</i>	Insect	PC no QP
<i>Anthonomus eugeni</i>	Insect	PP	non-EU <i>potato virus A</i>	Virus	PC no QP
<i>Apiosporina morbosa</i>	Fungus	PC_QP	<i>Prunus geminivirus A</i>	Virus	PC no QP
<i>Aromia bungii</i>	Insect	PP	Small-spored <i>Alternaria</i>	Fungus	PC no QP
<i>Arrhenodes minutus</i>	Insect	PC_QP	<i>Wild vitis virus 1</i>	Virus	PC no QP

³ [https://efsa.onlinelibrary.wiley.com/doi/toc/10.1002/\(ISSN\)1831-4732.Pest-categorisations](https://efsa.onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1831-4732.Pest-categorisations)

	Taxonomy	Source project ^(a)		Taxonomy	Source project ^(a)
Positive reference pests			Negative reference pests		
<i>Bactericera cockerelli</i>	Insect	PP			
<i>Bactrocera dorsalis</i>	Insect	PP			
<i>Bactrocera kirki</i>	Insect	PC_QP			
<i>Bactrocera zonata</i>	Insect	PP			
<i>Bretziella fagacearum</i>	Fungus	PP			
<i>Bursaphelenchus xylophilus</i>	Nematode	PP			
<i>Candidatus Liberibacter africanus</i> , <i>C. L. asiaticus</i> , <i>C. L. americanus</i>	Bacteria	PP			
<i>Coniferiporia sulphurascens</i>	Fungus	PC_QP			
<i>Conotrachelus nenuphar</i>	Insect	PP			
<i>Dendrolimus sibiricus</i>	Insect	PP			
<i>Grapholita inopinata</i>	Insect	PC_QP			
<i>Phyllosticta citricarpa</i>	Fungus	PP			
<i>Popillia japonica</i>	Insect	PP			
<i>Rhagoletis pomonella</i>	Insect	PP			
<i>Satsuma dwarf virus</i>	Virus	PC_QP			
<i>Spodoptera eridania</i>	Insect	PC_QP			
<i>Spodoptera frugiperda</i>	Insect	PP			
<i>Thaumatotibia leucotreta</i>	Insect	PP			
<i>Thrips palmi</i>	Insect	PP			
<i>Tilletia indica</i>	Fungus	PP			
<i>Toxoptera citricida</i>	Insect	PC_QP			
<i>Xanthomonas citri</i>	Bacterium	PP			
<i>Xylella fastidiosa</i>	Bacterium	PP			

(a): 'PC_QP': pests recommended by EFSA pest categorisations as candidates to the EU quarantine regulation (positive reference).
 'PC no QP': pests not fulfilling all the criteria to be recommended as candidates to the EU quarantine regulation (negative reference).

'PP': pests recommended by EFSA as candidates to the category of priority pests (positive reference pests).

(b): 'none': negative reference pest from the previous methodology.

3.2. Statistical analysis of individual criteria

Due to the fact, that PRAs or categorisations are already available for the pests of the reference data set, the scoring was based on these existing documents. In this section, the correlation of each criterion with the threat classification is analysed.

It should be noted that the PeMoScoring criteria were constructed to allow the rapid evaluation the health threat posed by pests to plants in the EU using a limited set of information. The situation is different for the reference pests, where more complete evaluations were done. Nevertheless, the PeMoScoring exercise should give also in this situation a rough but consistent picture of whether the pests pose an immediate health threat (positive reference) or not (negative reference) to plants in the EU. It should be clarified that pests belonging to negative references could still represent a threat to plants in the EU: often, particularly in case of new taxa, the level of uncertainty due to the lack of information does not make them immediately suitable for further assessment. In that case, the species remains monitored via media and scientific literature screening. For these reasons, the final conclusion of the PeMoScoring exercise should be used to distinguish between pests immediately suitable for further action or not (see Section 4.2).

3.2.1. C1: Range of pest host plants

C1 describes the host range of the pest. While 90% of the negative reference pests are restricted to only one family, 58% of the positive reference pests are polyphagous and attack hosts in two or more families (Table 10 and Figure 4). Although there are exceptions, the general trend is that the higher the polyphagia of a pest, the riskier. This is due to the increased/more diverse target population, but also to a higher diversity of entry/spread pathways and impacts.

Thus, this criterion shows a significant discrimination of the negative and positive reference pests and was retained for further scoring.

Table 10: Comparison of classes of C1 between negative and positive reference pests

C1: range of pest host plants	Score	Reference pests		
		Classification		Total
		Negative	Positive	
Host plants belong to one species	0.1	1	0	1
Host plants belong to one genus	0.2	6	5	11
Host plants belong to 1 family	1	2	9	11
Host plants belong to 2–5 families	2	1	4	5
Host plants belong to 6–10 families	3	0	3	3
Host plants belong to more than 10 families	4	0	12	12
Total		10	33	43

p-value of the Chi² test of independence: 0.0152.

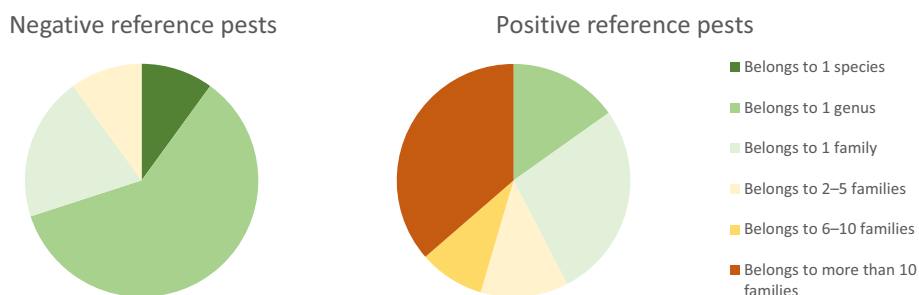


Figure 4: Distribution of classes of C1 for negative and positive reference pests

3.2.2. C2: regulatory status of pathways

C2 shows only a weak difference between negative and positive reference pests, as for 90% of the negative and 100% of the positive reference pests at least one entry pathway allowed by EU legislation in place at the time the risk assessment or categorisation used to inform the criterion was performed (Table 11 and Figure 5). In a single case, of a negative reference pest, all entry pathways were closed by legislation.

The criterion was retained for further scoring, although it has a limited power to discriminate negative from positive reference pests.

Table 11: Comparison of classes of C2 between negative and positive reference pests

C2: regulatory status of pathways	Score	Reference pests		
		Classification		Total
		Negative	Positive	
All pathways are already prohibited by current legislation	0	1	0	1
At least one pathway is allowed	1	9	33	42
Total		10	33	43

p-value of the Chi² test of independence: 0.0660.

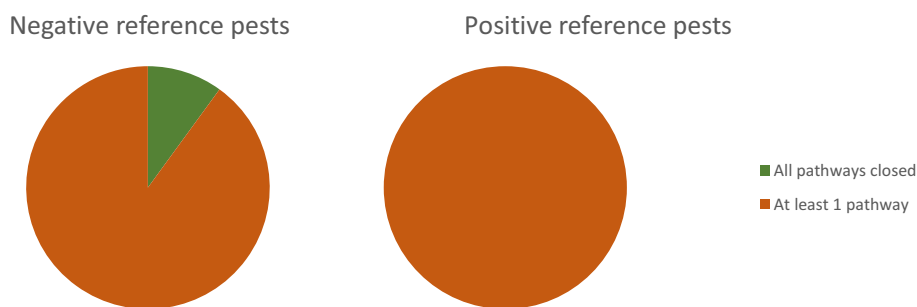


Figure 5: Distribution of classes of C2 for negative and positive reference pests

3.2.3. C3: Total volume of host plant commodity traded into the PRA area

C3 was already excluded after the first implementation (2.6).

3.2.4. C4: Difficulty of visual detection of the pest during inspection

C4 is evaluating the difficulty to detect the pest visually. From this criterion, it results that 100% of the negative reference pests are difficult to detect, while 73% of the positive reference pests have specific methods or are easy to detect (Table 12 and Figure 6).

Even when this criterion has a high discriminatory power, it behaves inconsistently within the system (i.e. being all the negative pests those with the highest score for this criterion), therefore it was excluded from further scoring.

Table 12: Comparison of classes of C4 between negative and positive reference pests

C4: Difficulty of visual detection of the pest during inspection	Score	Reference pests		
		Classification		Total
		Negative	Positive	
Specific and easy	1	0	8	8
Either specific or easy	2	0	16	16
Unspecific and difficult	3	10	9	19
Total		10	33	43

p-value of the Chi² test of independence: 0.0003.

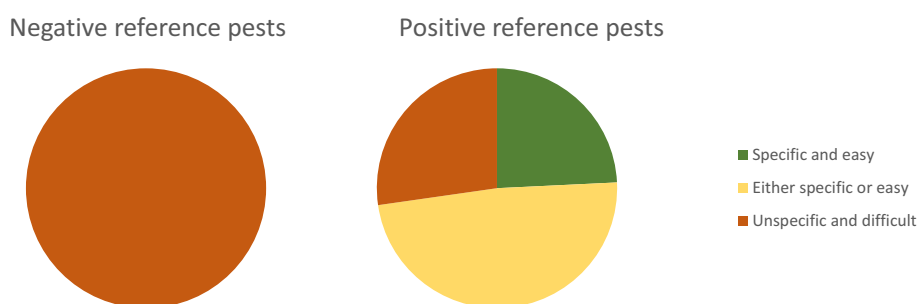


Figure 6: Distribution of classes of C4 for negative and positive reference pests

3.2.5. C5: Possibility of entry into the PRA area through natural means

C5 looks at the ability of the pest to enter the PRA area by natural means (i.e. flight, wind or water spread (not irrigation), natural migration, rhizome growth and movement across land). In both categories, 30% of the pests are able to enter the PRA area by natural means (Table 13 and Figure 7).

This criterion shows no discriminatory power on the reference data set. Nevertheless, it remains for further consideration due to the theoretical reasons considered during the construction of the list of criteria and because a weak criterion may become more significant when it correlates with other criteria.

Table 13: Comparison of classes of C5 between negative and positive reference pests

C5: Possibility of entry into the PRA area through natural means	Score	Reference pests		
		Classification		Total
		Negative	Positive	
Pest unable to enter the PRA area by natural means	0	7	23	30
Pest able to enter the PRA area by natural means	1	3	10	13
Total		10	33	43

p-value of the Chi² test of independence: 0.9854.

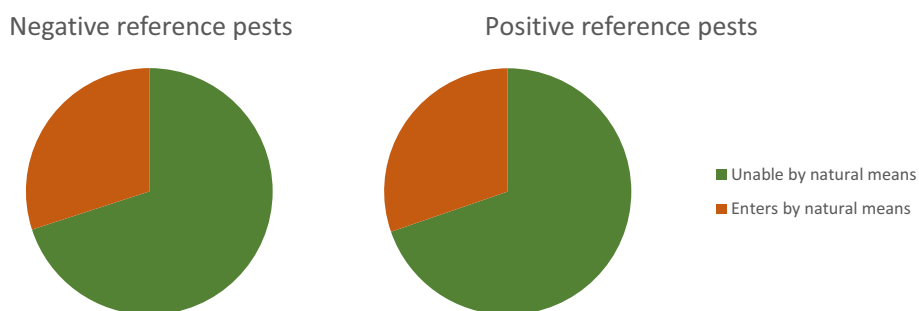


Figure 7: Distribution of classes of C5 for negative and positive reference pests

3.2.6. C6: Presence of the pest in the PRA area

C6 counts the number of member states in which the pest is already present, with the assumption that a pest already present in the risk assessment area involves a higher risk. Thirty per cent of the negative and only 24% of the positive reference pests are already present in the EU (Table 14 and Figure 8): The results indicate an inconsistent behaviour of the criterion within the system; therefore, it was excluded from further scoring.

Table 14: Comparison of classes of C6 between negative and positive reference pests

C6: presence of the pest in the PRA area	Score	Reference pests		
		Classification		Total
		Negative	Positive	
Number of countries where the pest is present in the PRA area				
No presence in EU	0	7	25	32
Present in 1 country	No. of countries	0	1	1
Present in 2 countries		2	3	5
Present in 3 countries		0	3	3
Present in 4 countries		0	0	0
Present in 5 or more countries		1	1	2
Total		10	33	43

p-value of the Chi² test of independence: 0.5861.

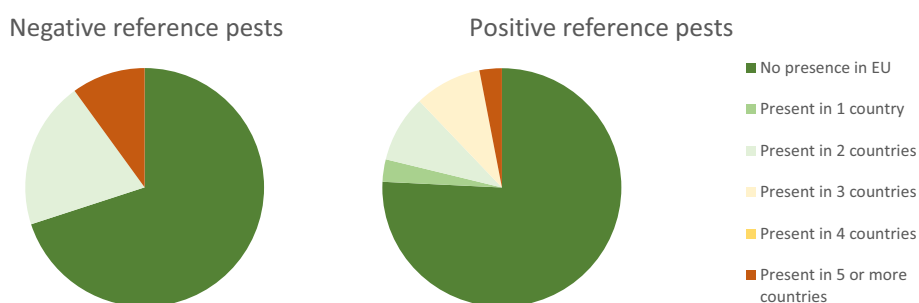


Figure 8: Distribution of classes of C6 for negative and positive reference pests

3.2.7. Need for a vector and its occurrence in the PRA area

C7 evaluates, whether a vector is needed and, if so, whether this vector is already present in the EU. In case no vector is needed all countries are counted as suitable in the PRA area. 66% of the negative reference pests need a vector, which is present in only five or less Member States, while for 97% of the positive reference pest, no vector is needed, or the vector already is present in more than five member states (Table 15 and Figure 9).

This indicates a strong correlation between criterion C7 and the classification of the health threat. This criterion was retained for further scoring.

Table 15: Comparison of classes of C7 between negative and positive reference pests

C7: Need for a vector and its occurrence in the PRA area	Score	Reference pests		
		Classification		Total
		Negative	Positive	
Number of 28 ⁴ EU countries where the vector is present				
Vector in 5 or less countries	No. of countries	6	1	7
Vector in more than 5 countries		3	32	35
For pests that do not need a vector	28			
Total		9	33	42

p-value of the Chi² test of independence: < 0.0001.

For one negative reference pest, the vector status is unknown.

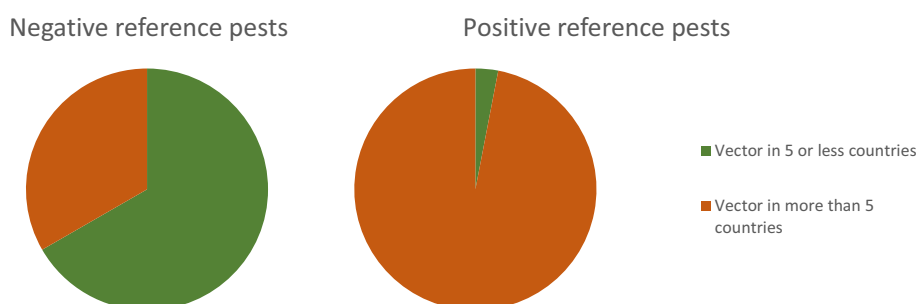


Figure 9: Distribution of classes of C7 for negative and positive reference pests

3.2.8. C8: Cultivated host plant surface area in the PRA area

The total cultivation area of possible hosts is evaluated for C8. The criterion allows a clear differentiation between negative and positive reference pests. While 70% of the negative reference pests are cultivated on 106 ha or less, 75% of the positive are cultivated on more than 106 ha (Table 16 and Figure 10).

This criterion was retained for further scoring.

Table 16: Comparison of classes of C8 between negative and positive reference pests

C8: Cultivated host plant surface area in the PRA area	Score	Reference pests		
		Classification		Total
		Negative	Positive	
Sum of the cultivated surface area of host plant species				
1 Mha or less	In ha	7	8	15
1 ≤ 10 Mha		2	12	14
More than 10 Mha		1	13	14
Total		10	33	43

p-value of the Chi² test of independence: 0.0263.

⁴ At the moment the methodology was put in place, UK was an EU MS.

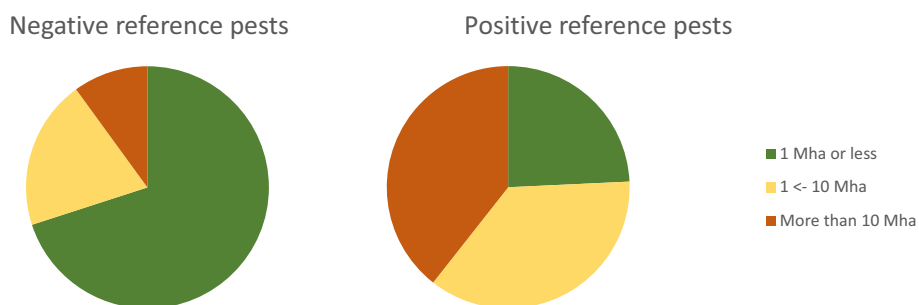


Figure 10: Distribution of classes of C8 for negative and positive reference pests

3.2.9. C9: Cultivated host plant distribution in the PRA area

Looking at the distribution of the host plants in the EU gives an inconclusive result. Positive reference pests show higher relative appearance in the class ‘6 to 20 countries’, but less in the other classes (Table 17 and Figure 11).

The dependence between number of Member States with possible host plants and the classification of health threats to plants is questionable and very likely connected to the type of host range specific of each pest (i.e. oligophagous vs. polyphagous). Because the host area (C8) was clearly informative, this related criterion was nevertheless retained for scoring.

Table 17: Comparison of classes of C9 between negative and positive reference pests

C9: Cultivated host plant distribution in the PRA area	Score	Reference pests		Total
		Classification		
		Negative	Positive	
Number of countries where the host plant is cultivated in the PRA area				
No hosts in EU		0	0	0
Host in 5 or less countries	No. of countries	1	2	3
Host in 6–20 countries		1	9	10
Host in more than 20 countries		8	22	30
Total		10	33	43

p-value of the Chi² test of independence: 0.5090.

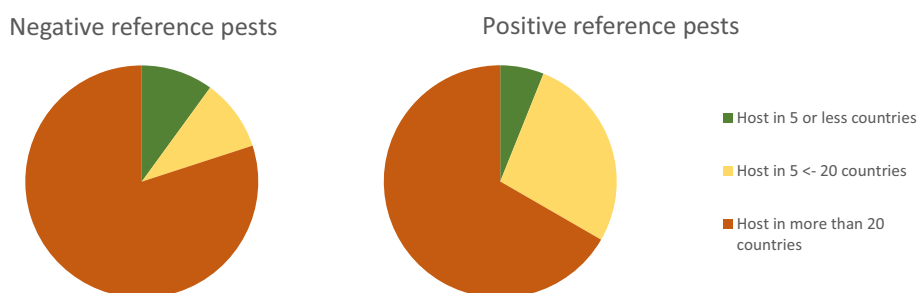


Figure 11: Distribution of classes of C9 for negative and positive reference pests

3.2.10. C10: Occurrence of other host plants that are not crops in the PRA area

C10 shows only a weak difference between negative and positive reference pests, as for 90% of the negative and 100% of the positive reference pest, there exists major host plants that are not cultivated as crops in the PRA area (Table 18 and Figure 12). Like polyphagia, non-crop hosts may increase the threat to plant health in general.

The criterion was retained for further scoring, although as a stand-alone criterion, it has a limited discrimination power.

Table 18: Comparison of classes of C10 between negative and positive reference pests

C10: Occurrence of other host plants that are not crops in the PRA area	Score	Reference pests		
		Classification		Total
		Negative	Positive	
No reported presence of major host plants that are not crops in the EU	0	1	0	1
At least one major non-crop host plant is present in at least one MS	1	9	33	42
Total		10	33	43

p-value of the Chi² test of independence: 0.0660.

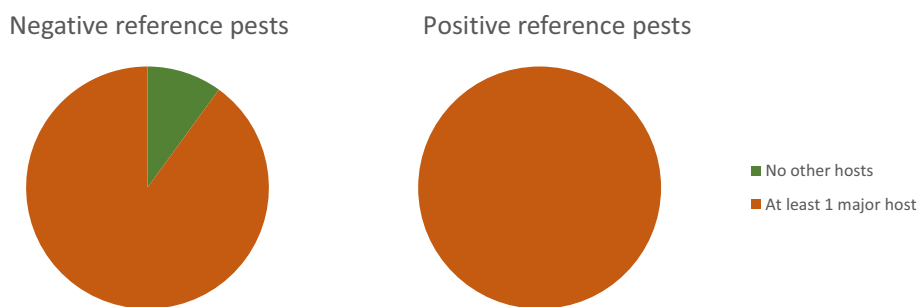


Figure 12: Distribution of classes of C10 for negative and positive reference pests

3.2.11. C11: Climate suitability

A similar weak difference between negative and positive reference pests can be seen for the climatic suitability, as for 90% of the negative and 97% of the positive reference pests at least one optimal climate occurred in the PRA area (Table 19 and Figure 13). The criterion was retained for further scoring.

Table 19: Comparison of classes of C11 between negative and positive reference pests

C11: Climate suitability	Score	Reference pests		
		Classification		Total
		Negative	Positive	
Neither climatic nor production conditions are suited to pest reproduction	0	1	0	1
The PRA area does not provide an optimal climate for establishment, but the production conditions of host plants do (e.g. in greenhouses)	1	0	1	1
The PRA area provides at least one optimal climate for establishment	2	9	32	41
Total		10	33	43

p-value of the Chi² test of independence: 0.1619.

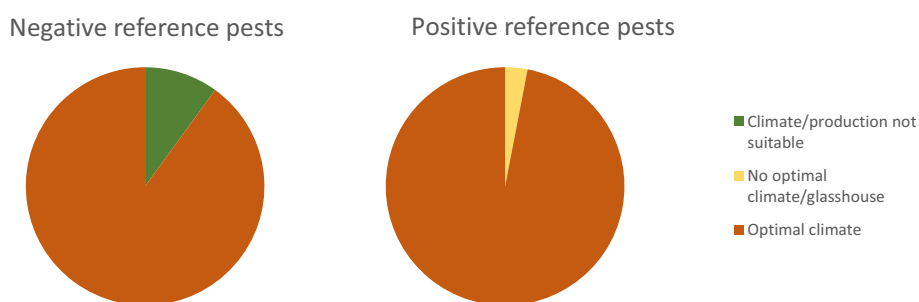


Figure 13: Distribution of classes of C11 for negative and positive reference pests

3.2.12. C12: Possibility of spread by natural means

C12 evaluates the spread capabilities of the pest. The difference between negative and positive reference pests is not strong, but 30% of the negative and 58% of the positive reference pests are able to spread long distances by natural means (Table 20 and Figure 14).

The criterion was retained for further scoring.

Table 20: Comparison of classes of C12 between negative and positive reference pests

C12: Possibility of spread by natural means	Score	Reference pests		
		Classification		Total
		Negative	Positive	
No natural means for spread or vector is the only means of natural spread and vector is absent in the PRA area	0	1	1	2
The pest can spread on a local scale via rhizome growth or terrestrial moves by itself or by a vector present in the PRA area	1	6	13	19
The pest can spread over long distance via wind, flight or water (running water) by itself or by a vector present in the PRA area	2	3	19	22
Total		10	33	43

p-value of the Chi² test of independence: 0.2619.

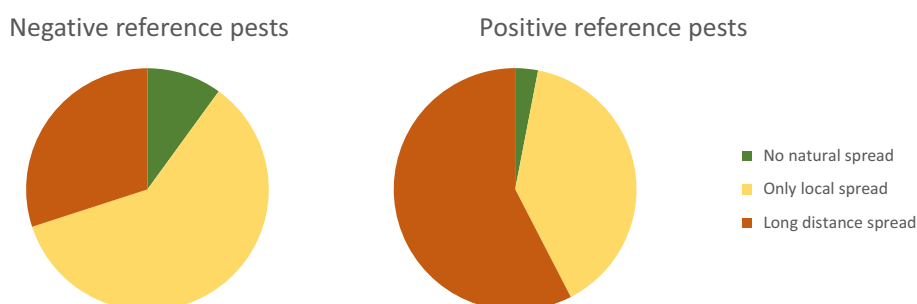


Figure 14: Distribution of classes of C12 for negative and positive reference pests

3.2.13. C13: Possibility of spread by human assistance

For the human-assisted spread, the 12th criterion sums up different modes of spread. While 60% of the negative reference pests are connected to more than one mode, this is valid for 88% of the positive reference pests.

Table 21 and Figure 15 show a significant difference between negative and positive reference pests. Therefore, the criterion was retained for further scoring.

Table 21: Comparison of classes of C13 between negative and positive reference pests

C13: Possibility of spread by human assistance	Score	Reference pests		
		Classification		Total
		Negative	Positive	
1 = The pest is spread locally through agricultural practices (mechanical transmission by human activities)	1	1	1	2
2 = The pest is unintentionally dispersed along major transportation routes (hitchhiker behaviour)	2	0	0	0
3 = The pest is spread via commodities intended for consumption, for transformation or as ephemeral ornaments	3	0	2	2
3 + 2	5	0	1	1
3 + 2 + 1	6	0	1	1

C13: Possibility of spread by human assistance	Score	Reference pests		
		Classification		Total
		Negative	Positive	
7 = The pest is spread via plants designated for planting in a sustainable way (ornamental plants, nursery seedlings, vegetable plants) or via plant organs intended to produce other plants (seeds, bulbs, tubers, budwood, rootstock)	7	3	1	4
7 + 1	8	4	1	5
7 + 2	9	1	7	8
7 + 2 + 1 or 7 + 3	10	1	14	15
7 + 3 + 1	11	0	1	1
7 + 3 + 2	12	0	4	4
Total		10	33	43

p-value of the Chi² test of independence: 0.0111.

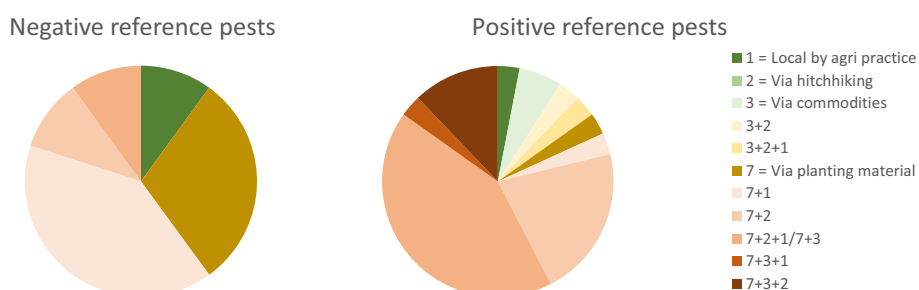


Figure 15: Distribution of classes of C13 for negative and positive reference pests

3.2.14. C14: Description of yield losses in the pest's current area of distribution

The ability to cause yield loss shows clear differences between negative and positive reference pests. Massive yield loss can be caused by only 20% of the negative, but 67% of the positive reference pests (Table 22 and Figure 16).

This criterion was retained for further scoring.

Table 22: Comparison of classes of C14 between negative and positive reference pests

C14: Description of yield losses in the pest's current area of distribution	Score	Reference pests		
		Classification		Total
		Negative	Positive	
No yield loss	0	6	1	7
Limited yield loss	1	2	10	12
Massive yield loss	2	2	22	24
Total		10	33	43

p-value of the Chi² test of independence: < 0.0001.

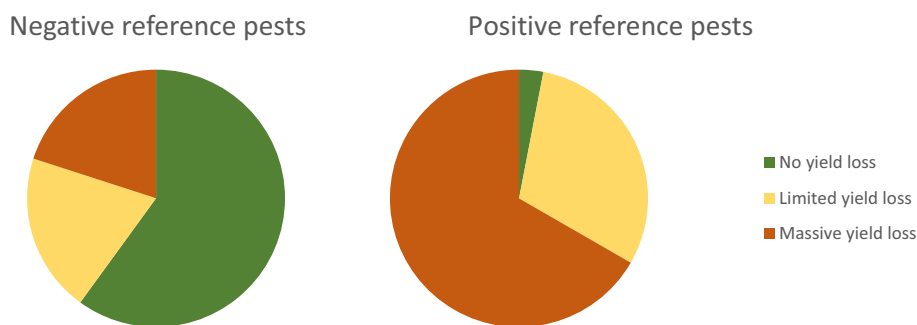


Figure 16: Distribution of classes of C14 for negative and positive reference pests

3.2.15. C15: Description of quality losses or plant death in the pest’s current area of distribution

The type of yield loss is clearly different between negative and positive reference pests. While 100% of the negative reference pests show no or only quality loss, for 39% of the positive reference pests, plant death is reported (Table 23 and Figure 17).

Accordingly, this criterion was retained for further scoring.

Table 23: Comparison of classes of C15 between negative and positive reference pests

C15: Description of quality losses or plant death in the pest’s current area of distribution	Score	Reference pests		Total
		Classification		
		Negative	Positive	
No reported crop quality loss or plant death	0	7	1	8
Reported quality losses	1	3	19	22
Reported plant death	2	0	13	13
Total		10	33	43

p-value of the Chi² test of independence: < 0.0001.

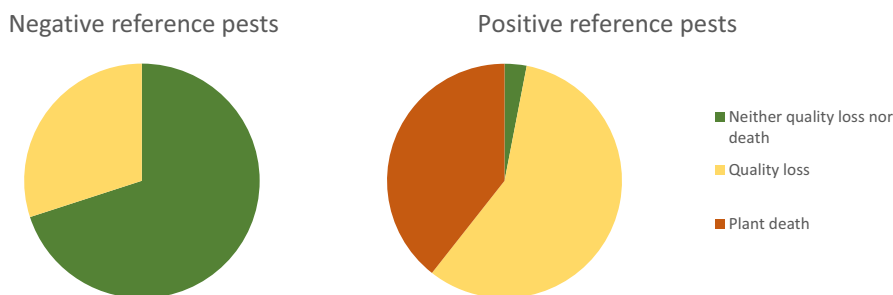


Figure 17: Distribution of classes of C15 for negative and positive reference pests

3.2.16. C16: Existence of control measures that could affect the pest’s impact

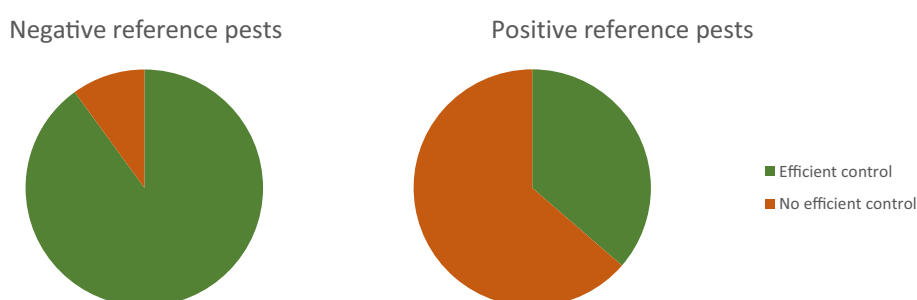
The last criterion evaluates existing measures against the pest. While for 90% of the negative reference pests efficient measures exist, no such measures are available for 64% of the positive reference pests (Table 24 and Figure 18).

The criterion shows a clear difference between negative and positive reference pests and was retained for further scoring.

Table 24: Comparison of classes of C16 between negative and positive reference pests

C16: Existence of control measures that could affect the pest's impact	Score	Reference pests		
		Classification		Total
		Negative	Positive	
Efficient control measures exist, the pest has been eradicated or the population reduced to a level below the economic threshold	1	9	12	21
No efficient control measures are described for the pest or the pest has never been eradicated or populations never reduced to a level below the economic threshold	2	1	21	22
Total		10	33	43

p-value of the Chi² test of independence: 0.030.

**Figure 18:** Distribution of classes of C16 for negative and positive reference pests

4. PeMoScoring exercise

This section presents the new methodology called 'PeMoScoring' (scoring pests from monitoring activity). The following paragraphs describe its implementation on pests non-regulated in the EU which have been identified by the monitoring activities of carried out in the period February 2017–December 2020.

4.1. First step: screening based on exclusion criteria

The exercise was carried out into two steps.

In the first step, a preliminary screening of the pests identified during the horizon scanning exercise was performed based on exclusion criteria. This allowed to focus the scoring efforts only on pests for which such an exercise is deemed necessary for risk managers' decision.

During the horizon scanning activities between February 2017 and December 2019, EFSA found 302 non-regulated pests, 81 reported in media newsletters and 221 in scientific newsletters (Table 25). As indicated in Section 2.6, pests already object of an EFSA or EPPO assessment were excluded from the exercise. The preliminary screening also excluded from the scoring pests (i) already established in the EU, (ii) for which there was not enough data available for scoring, (iii) which are non-pathogenic, (iv) which were non-regulated when reported in the newsletters but which were subsequently regulated or (v) which were reported in the newsletters for subjects other than findings, outbreaks or spread.

Table 25: Results of the first screening of pests following the updated methodology

Categories of non-regulated pests identified during media and scientific literature monitoring	Pests from media monitoring (February 2017–December 2019)	Pests from scientific literature monitoring (November 2018–December 2019)
Non-regulated pests in the EU found and included in the newsletters	81	221
Pests established in some EU regions	8	28
Pests without enough information for scoring	6	116
Pests with insufficient evidence on impact	1	9

Categories of non-regulated pests identified during media and scientific literature monitoring	Pests from media monitoring (February 2017–December 2019)	Pests from scientific literature monitoring (November 2018–December 2019)
Pest identity not defined	12	2
Later regulated pests	5	5
Pests covered by EFSA pest categorisations and other assessments	0	8
Pests covered by EPPO risk assessments	6	5
Pests from items on topics other than findings, outbreaks or spread	0	11
Candidate pests to scoring	39	24

As a result of this first screening, the number of pests to be scored was reduced from 302 to 63, 39 of which were identified from media monitoring and 24 from scientific literature monitoring.

4.2. Second step: scoring pests

As a result of the analysis described above, a total of 13 criteria were retained after their individual evaluation on the reference data set. These are listed in Table 26 and described in Appendix G.

Table 26: 13 criteria retained for the pest scoring.

Criterion	Description
C1	Range of pest host plants
C2	Regulatory status of pathways
C5	Possibility of entry into the PRA area through natural means
C7	Need for a vector and its occurrence in the PRA area
C8	Cultivated host plant surface area in the PRA area
C9	Cultivated host plant distribution in the PRA area
C10	Occurrence of host plants that are not crops in the PRA area
C11	Climate suitability
C12	Possibility of spread by natural means
C13	Possibility of spread by human assistance
C14	Description of yield losses in the pest's current area of distribution
C15	Description of quality losses or plant death in the pest's current area of distribution
C16	Existence of control measures that could affect the pest's impact

The PROMETHEE methodology (Appendix B) was used to rank the reference pests with these 13 remaining criteria and to calculate the overall Phi-score for each pest, which is the basis for the final ranking. Table 27 shows these overall scores for the reference pests including their classification as health threats for plants in the EU.

Table 27: Reference pests with Phi-scoring of PROMETHEE by their 'known' threat classification (the red-coloured names represent false positives and false negatives, as clarified in the text below)

Pest name	Suitability for further action	PROMETHEE Phi-score
33 positive reference pests		
<i>Anoplophora chinensis</i>	Positive	0.3682
<i>Xylella fastidiosa</i>	Positive	0.2764
<i>Bursaphelenchus xylophilus</i>	Positive	0.2624
<i>Anoplophora glabripennis</i>	Positive	0.248
<i>Thaumatotibia leucotreta</i>	Positive	0.2313

Pest name	Suitability for further action	PROMETHEE Phi-score
<i>Spodoptera frugiperda</i>	Positive	0.2113
<i>Dendrolimus sibiricus</i>	Positive	0.1777
<i>Bactericera cockerelli</i>	Positive	0.1433
<i>Coniferiporia sulphurascens</i>	Positive	0.1427
<i>Agrilus planipennis</i>	Positive	0.1303
<i>Thrips palmi</i>	Positive	0.1228
<i>Tilletia indica</i>	Positive	0.1002
<i>Spodoptera eridania</i>	Positive	0.0892
<i>Popillia japonica</i>	Positive	0.0762
<i>Arrhenodes minutus</i>	Positive	0.0747
<i>Agrilus anxius</i>	Positive	0.0738
<i>Aromia bungii</i>	Positive	0.0716
<i>Bactrocera dorsalis</i>	Positive	0.0716
<i>Bretziella fagacearum</i>	Positive	0.0509
<i>Bactrocera zonata</i>	Positive	0.0429
<i>Rhagoletis pomonella</i>	Positive	0.0342
<i>Grapholita inopinata</i>	Positive	0.0107
<i>Phyllosticta citricarpa</i>	Positive	0.0107
<i>Candidatus Liberibacter africanus</i>	Positive	0.005
<i>Conotrachelus nenuphar</i>	Positive	-0.0029
<i>Satsuma dwarf virus</i>	Positive	-0.0244
<i>Apiosporina morbosa</i>	Positive	-0.0412
<i>Xanthomonas citri</i>	Positive	-0.0595
<i>Toxoptera citricida</i>	Positive	-0.0649
<i>Anthonomus eugenii</i>	Positive	-0.0682
<i>Bactrocera kirki</i>	Positive	-0.0839
<i>Acrobasis pirivorella</i>	Positive	-0.092
<i>Anastrepha ludens</i>	Positive	-0.1308
10 negative reference pests		
<i>Non-EU potato virus A</i>	Negative	0.1124
<i>Small-spored Alternaria</i>	Negative	0.0637
<i>Hirschmanniella behningi</i>	Negative	-0.1046
<i>Apple hammerhead viroid</i>	Negative	-0.254
<i>Prunus geminivirus A</i>	Negative	-0.3403
<i>Neomargarodes cucurbitae</i>	Negative	-0.341
<i>African cassava mosaic virus</i>	Negative	-0.3804
<i>Apple geminivirus</i>	Negative	-0.3903
<i>Margarodes floridanus</i>	Negative	-0.4065
<i>Wild vitis virus 1</i>	Negative	-0.4174

The overall score ranges from '-1' for the lowest suitability for further action to '1' for the highest suitability for further action (e.g. pest categorisation). The scores of the reference dataset were used to estimate the distribution within the 'negative' and 'positive' populations of reference pests, which are shown in Figure 19 and Table 28.

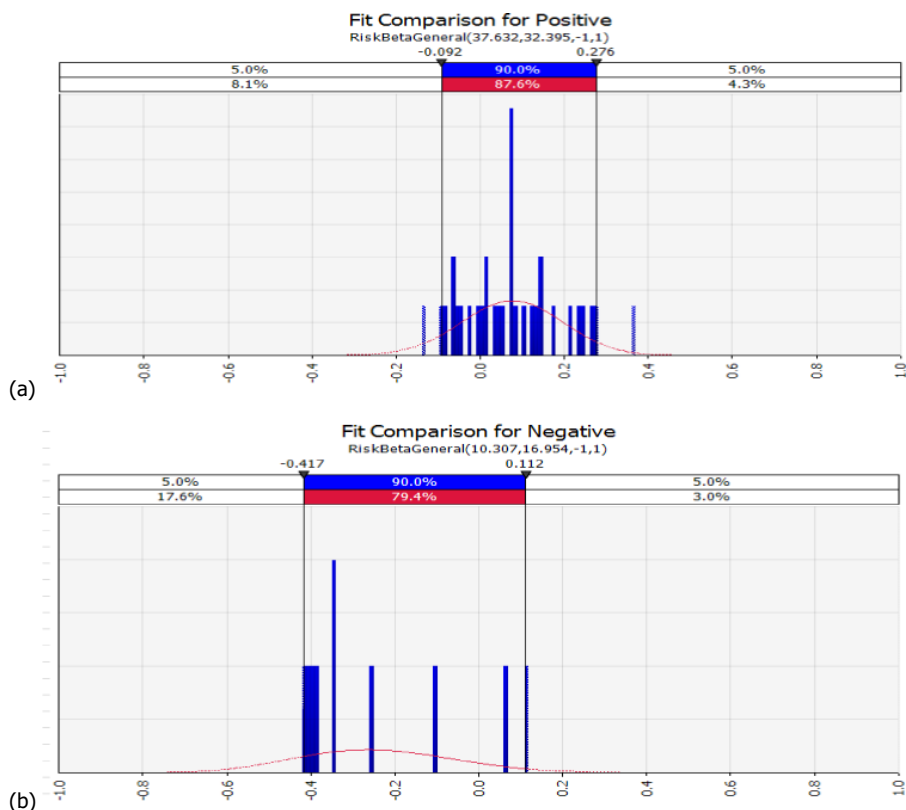


Figure 19: Fitted General Beta distributions to the PROMETHEE overall Phi-score values of the 33 positive (a) and 10 negative (b) reference pests

Table 28: Estimated distributions of the overall scores of negative and positive reference pests

Pests	Distribution
Positive reference pests	General Beta (37.632, 32.395, -1, 1)
Negative reference pests	General Beta (10.307, 16.954, -1, 1)

The two distributions in Figure 20 present a partial overlap. Nevertheless, they can be used to optimise a decision rule to classify a non-regulated pest as negative or positive using its overall Phi-score. Using the crossing point of the density functions of the two distributions allows the definition of a threshold (Phi-score = 0.083), which divides the scores into two parts: for scores below the threshold, the likelihood (density function) of the negative reference pests is higher. It is therefore more likely for pests with these score values to be similar to a negative reference pest than to a positive one. For scores above the threshold, the likelihood (density function) of the positive reference pests is higher. Now, it is more likely for a pest with these values to be similar to a positive reference pest.

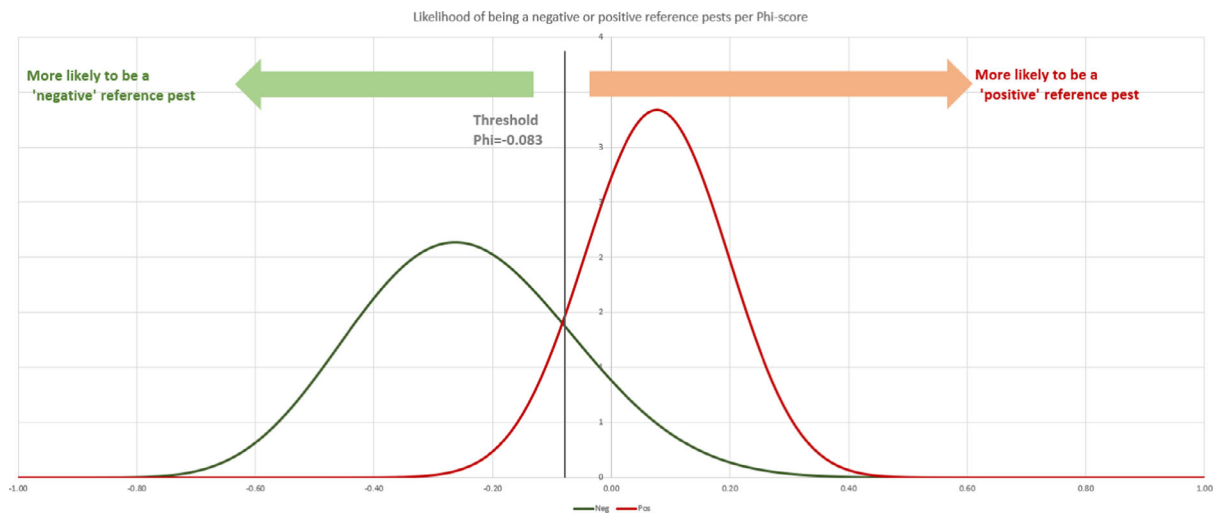


Figure 20: Distribution of the overall Phi-scores for negative (green) and positive pest (red) as density functions estimated from the reference data set. The decision rule uses the density values to assess, which classification is more likely for the different general score values (on the horizontal axis)

To estimate the classification errors:

- False-positive classification: The classification of a pest not suitable for further action as positive pest.
- False-negative classification: The classification of a pest suitable for further action as negative pest.

It is more convenient to use the distribution functions (Figure 21). The total classification error is the sum of the descending distribution function for the negative reference pests plus the ascending distribution function of the positive reference pests. The decision rule, derived from the densities, is minimising the total error. In case of the estimated distributions, the error for false-positive classification is 19.1%, while the error for false-negative classification is 9.3%.

In the reference data set, this is represented by five pests (red coloured in Table 27):

- two negative reference pests, which have a score above the threshold ($\Phi = 0.083$) and would be classified as positive. These are: 'non-EU *potato virus A*' and 'small-spored *Alternaria*'.
- three positive reference pests, which have score values below the threshold ($\Phi = 0.083$) and would be classified as negative. These are *Anastrepha ludens*, *Acrobasis pirivorella* and *Bactrocera kirki*.



Figure 21: Distribution functions of the overall Phi-scores for negative (descending, green) and positive pest (ascending, red) estimated from the reference data set. The grey curve is the sum of both distribution functions indicating the total misclassification error. The decision rule (vertical line) minimises the total error. The crossings with the individual curves are the false-positive and false-negative classification rate

The distribution functions can be used to identify the characteristics of any other decision rule based on the PROMETHEE Phi-scores. For risk management, it could be favourable to decrease the false-negative classification rate by selecting a lower threshold (precautionary principle), at the cost of increasing the total classification error.

As the influence of the circumstances of specific pests decreases when the set of reference pests increases, it is expected that precision in the estimation of the misclassification rates will increase.

For this project, the decision rule with minimised total error is applied:

- PROMETHEE Phi-score below: -0.083 .
Pest is not (yet) proposed for further action, i.e. assessment of the potential threat posed to plants in the EU.
- PROMETHEE Phi-score (Phi) above: -0.083 .
Pest is proposed for further action, i.e. assessment of the potential threat posed to plants in the EU.

The calculation of the PROMETHEE Phi score for new non-regulated pests under evaluation is described in detail in Appendix H.

The PeMoScore Calculator (Appendix I), implemented as Excel file, allows the calculation of the Phi-scores from the scores attributed to the criteria. For each pest, it also compares the computed Phi-score with the retained threshold and proposes its classification as 'positive' or 'negative' pest.

In the updated methodology, uncertainties in data available for scoring are managed in two ways:

- i) Exclusion from the pairwise comparisons of the criterion for which evidences are not available in literature. This can be obtained by replacing the score with a question mark like in the PROMETHEE method.
- ii) Calculation of the Phi score with possible alternative scores for the criterion presenting uncertainty and discussion of the impact of them on the final assessment as 'positive' or 'negative' pest.

5. Conclusions and perspectives

The PeMoScoring is a sufficiently flexible and easy tool to pre-screen for suitability for further actions (i.e. assessment or management) new and emerging pests as soon as they appear in the media or in the scientific literature, thus fulfilling its role as an alert tool on new plant health risks for the EU.

Future perspectives would consider the possibility to enlarge and update the reference data set and the development of a tool structuring the decision process and the data storing.

References

- Baker RHA, Anderson H, Bishop S, MacLeod A, Parkinson N and Tuffen MG, 2014. The UK plant health risk register: a tool for prioritizing actions. *EPPO Bulletin*, 44, 187–194.
- Brans JP, Vincke PH and Mareschal B, 1986. How to select and how to rank projects: the PROMETHEE method. *European Journal of Operational Research*, 24, 228–238.
- D'hondt B, Vanderhoeven S, Roelandt S, Mayer F, Versteirt V, Adriaens T, Ducheyne E, San Martin G, Grégoire J-C, Stiers I, Quoilin S, Cigar J, Heughebaert A and Branquart E, 2015. Harmonia+ and Pandora+: risk screening tools for potentially invasive plants, animals and their pathogens. *Biological Invasions*, 17, 1869–1883.
- EFSA (European Food Safety Authority), Baker R, Gilioli G, Behring C, Candiani D, Gogin A, Kaluski T, Kinkar M, Mosbach-Schulz O, Neri FM, Siligato R, Stancanelli G and Tramontini S, 2019. Scientific report on the methodology applied by EFSA to provide a quantitative assessment of pest-related criteria required to rank candidate priority pests as defined by Regulation (EU) 2016/2031. *EFSA Journal* 2019;17(6):5731, 61 pp. <https://doi.org/10.2903/j.efsa.2019.5731>
- EFSA (European Food Safety Authority), Mannino MR, Larenaudie M, Linge JP, Candresse T, Jaques Miret JA, Jeger MJ, Gachet E, Maiorano A, Muñoz Guajardo I and Stancanelli G, 2021. Horizon Scanning for Plant Health: report on 2017-2020 activities. *EFSA Supporting Publication* 2021;EN-2010, 113 pp. <https://doi.org/10.2903/sp.efsa.2021.EN-2010>
- EFSA (European Food Safety Authority), Tayeh C and Mannino MR, 2020. A review of ranking models for plant threats in EU Member States and Third Countries: concepts and applications. *EFSA Supporting Publication* 2020;EN-1615, 26 pp. <https://doi.org/10.2903/sp.efsa.2020.EN-1615>
- van der Gaag DJ, van Leeuwen G, Loomans A, Pottting R and Verhoeven J, 2017. Prioritizing risks for plant health in the Netherlands: a method to rank pests according to their probability of introduction. *EPPO Bulletin*, 47, 69–78.

- Heikkilä J, Tuomola J, Pouta E and Hannunen S, 2016. FinnPRIO: a model for ranking invasive plant pests based on risk. *Biological Invasions*, 18, 1827–1842.
- Kottek M, Grieser J, Beck C, Rudolf B and Rubel F, 2006. World Map of the Köppen-Geiger climate classification updated. *Meteorologische Zeitschrift*, 15, 259–263.
- Mareschal B, 2015. Visual PROMETHEE User Manual (including tutorials). <https://doi.org/10.13140/RG.2.1.4004.3042>
- Moignot B and Reynaud P, 2013. Developing a methodology for the prioritisation of pests in plant health. *Euro Reference*, 9, 5–9.
- Tayeh CH, Guinehut D, Le Van A, Deguercy X, Tassus X, Gachet E and Manceau C, 2021. BiOR²: when pest risk assessment meets computer-based multicriteria analysis for plant pest ranking and management. *Biological Invasions*, 23, 919–934.
- Wendell M, 2016. The ERIN system to identify, describe and rank new plant health threats in Norway. Oral presentation at the Joint EFSA-EPPO Workshop: Modelling in Plant Health – how can models support risk assessment of plant pests and decision-making? 12–14 December 2016, Parma.

Glossary

Control pests	definition applying to the Pilot phase (chapter 2). Pests whose scoring, either positive or negative, was well known before conducting the exercise: the two tested 'positive control pests' are known as high-risk pests to the EU and are therefore regulated, while the two tested 'negative control pests' are known as no- or low-risk pests.
Core pests	definition applying to the Pilot phase (chapter 2). Pests which always top-ranked, independently from the applied weighting scenario.
Reference pests	definition applying to the Development of the PeMoScoring methodology (chapter 3). The reference pests belong to a set of 43 pests (Appendix F) selected among EFSA pest categorisations and the EU candidate priority pests, with the scope of composing the reference data set for the definition of the threshold. This threshold is applied, in a next step, to classify as 'positive' or 'negative' a new species assessed with the PeMoScoring methodology.
Positive pests	definition applying to the PeMoScoring exercise (chapter 4). A pest is considered positive when it positions itself above the predefined threshold and therefore is interpreted as a species suitable for further action (e.g. EFSA pest categorisation).
Negative pests	definition applying to the PeMoScoring exercise (chapter 4). A pest is considered negative when it positions itself below the predefined threshold and therefore is interpreted as a species not suitable for further action due to the limited available evidence or potential plant health threat. In any case, the species name will remain monitored via the regular horizon scanning activity.

Abbreviations

ANSES	French Agency for Food, Environmental and Occupational Health & Safety
CABI	Centre for Agriculture and Bioscience International
CPC	Crop Protection Compendium (CABI)
EPPO	European and Mediterranean Plant Protection Organization
MEDISYS	Medical Information System
MS	Member State
PRA	Pest Risk Analysis
PROMETHEE	Preference Ranking Organization Method for Enrichment Evaluation
VP	Visual PROMETHEE

Appendix A – The 16 criteria used to score pests in the pilot ranking methodology

In this Appendix, each criterion is presented through several points:

- 'Inclusion in other EU ranking systems': This section is used to indicate whether other EU pest-ranking systems use the criterion, even if it is not implemented following the same approach. The ranking systems considered are from:
 - Belgium: Belgian Harmonia+ and Pandora+ (D'hondt et al., 2015) referred to as H+/P+,
 - Finland: Finnish FinnPRIO (Heikkilä et al., 2016) referred to as FinnPRIO,
 - France: Moignot and Reynaud (2013) and Biological Organisms data Retrieval and Ranking system (Tayeh et al., 2021); these systems are referred to as M&R and BiOR² in the manuscript,
 - Norway: ERIN system (Wendell, 2016) referred to as ERIN, even though it is not an EU country,
 - The Netherlands: NVWA scheme (van der Gaag, 2017) referred to as NVWAs,
 - The United Kingdom: the UK Plant Health Risk Register (Baker et al., 2014) referred to as PHRR.
- 'Description': this section is used to describe the criterion,
- 'Need for an automatic approach': the possibility of an automated approach to be applied in the future is suggested: yes or no,
- 'Scoring': this section is used to present the scoring method and the scenario of how missing data are handled is indicated if relevant,
- 'Data': this section is used to indicate the data needed (specifying sources whenever possible),
- 'Example': various examples are given. Pests may be regulated or new emerging pests; in the case of regulated pests, they were chosen because they facilitate the illustration of the scoring system.

C1. Range of pest host plants

<u>Inclusion in other EU ranking systems</u>	PHRR, BiOR ² , M&R	
<u>Need of automatic approach</u>	Yes	
<u>Description</u>	This criterion considers the list of host plants independently from the PRA zone and the importance of the host plant. A pest that attacks different genera and families is considered riskier than one with a smaller target population. The hypothesis is that pathogens that can attack many different host plants are more prone to infect new plant species in the same genus and/or family, thus allowing for more potential entry pathways via the importation of host plants.	
<u>Scoring</u>	C	Indicator
	n	Number of families to which the host plants belong when there is more than one genus
	0.2	Host plants belong to a single genus
	0.1	Host plant belongs to a single species
	Score = C(indicator)	
<u>Data</u>	List of host plants, taxonomy of host plants	
<u>Example</u>	<i>Meloidogyne chitwoodi</i> has host species in 12 distinct genera (<i>Avena</i> , <i>Beta</i> , <i>Dacus</i> , <i>Hordeum</i> , <i>Medicago</i> , <i>Phaseolus</i> , <i>Pisum</i> , <i>Scorzonera</i> , <i>Solanum</i> , <i>Taraxacum</i> , <i>Triticum</i> , <i>Zea</i>) themselves corresponding to six distinct families (<i>Poaceae</i> , <i>Amaranthaceae</i> , <i>Apiaceae</i> , <i>Fabaceae</i> , <i>Asteraceae</i> , <i>Solanaceae</i>)	
	= 6	

C2. Regulatory status of pathways

<u>Inclusion in other EU ranking systems</u>	None						
<u>Need of automatic approach</u>	No						
<u>Description</u>	This criterion considers the host plant pathways that are prohibited from entry into the PRA region under current legislation.						
<u>Scoring</u>	<p>Score = C(indicator) C is given as follow</p> <table border="1"> <thead> <tr> <th>C</th> <th>Indicator</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>At least one pathway is allowed</td> </tr> <tr> <td>0</td> <td>All pathways are already prohibited by current legislation</td> </tr> </tbody> </table>	C	Indicator	1	At least one pathway is allowed	0	All pathways are already prohibited by current legislation
C	Indicator						
1	At least one pathway is allowed						
0	All pathways are already prohibited by current legislation						
<u>Data</u>	List of host plants, host commodities, current legislation						
<u>Example</u>	<p><i>Citrus vein enation virus</i>. Introduction of plants of <i>Citrus L.</i>, <i>Fortunella Swingle</i>, <i>Poncirus Raf.</i> and their hybrids, other than fruit and seeds, are prohibited in all member states from third countries according to Council Directive 200/29/CE, ANNEX III.</p> <p style="text-align: right;">= 0</p>						

C3. Total volume of host plant commodity traded into the PRA area

<u>Inclusion in other EU ranking systems</u>	BiOR ² , M&R, FinnPRIO, NVWA
<u>Need of automatic approach</u>	Yes
<u>Description</u>	<p>This criterion is related to the existence of a trade pathway and aims only to indicate whether the host plant commodity is traded and the volume of trading. Only total volume is considered because it is neither feasible at this stage to take into account the origin of the imported host commodities nor to distinguish whether they come from a country where the pest is already present.</p> <p>Data on plants for planting will be difficult to retrieve.</p>
<u>Scoring</u>	<p>Score = V_{TOTAL} V_{TOTAL} is the total import volume of host commodities If 'No info', apply the no score for no information (Score = ?)</p>
<u>Data</u>	List of host plants, host commodities, trade
<u>Example</u>	<p><i>Phyllosticta citricarpa</i>. <i>Citrus sinensis</i> fruits (navel) were imported into the EU in 2017.</p> <p style="text-align: right;">= 153,951 tons</p>

C4. Difficulty of visual detection of the pest during inspection

<u>Inclusion in other EU ranking systems</u>	PHRR, BiOR ² , FinnPRIO
<u>Need of automatic approach</u>	No
<u>Description</u>	<p>This criterion considers factors that facilitate visual detection:</p> <ul style="list-style-type: none"> • distinctiveness or specificity of symptoms α (the symptoms might look like those of other organisms or sources of damage such as mechanical damage or injury due to cold conditions), • ease of detection of the pest β according to the life stage that is likely to be present (some stages are more readily detected than others: adult insects e.g. may be easier to see than their eggs or viruses) and the location of the pest on/in the commodity (surface feeders may be more readily detected than internal feeders).

<u>Scoring</u>	<p>Score = $P(\alpha, \beta)$</p> <p>$P(\alpha, \beta)$ are likelihood factors for the pest passing inspection as explained below.</p> <p>$\alpha = 1$ if symptoms are specific ($\alpha = 0$ if not or if the symptoms do not develop on HC)</p> <p>$\beta = 1$ if visual detection of the pest is easy ($\beta = 0$ if not)</p> <p><i>If there is more than one host commodity, the highest P score is considered</i></p> <table border="1"> <tr> <td>P</td> <td>3</td> <td>2</td> <td>2</td> <td>1</td> </tr> <tr> <td>α</td> <td>0</td> <td>1</td> <td>0</td> <td>1</td> </tr> <tr> <td>β</td> <td>0</td> <td>0</td> <td>1</td> <td>1</td> </tr> </table> <p><i>If 'No info', apply the worst-case scenario (Score = 3)</i></p>	P	3	2	2	1	α	0	1	0	1	β	0	0	1	1
P	3	2	2	1												
α	0	1	0	1												
β	0	0	1	1												
<u>Data</u>	List of host plants, host commodities, description of symptoms															
<u>Example</u>	<p><i>Xanthomonas citri</i> could be present on citrus fruits with specific symptoms but is borne internally.</p> <p style="text-align: right;">P(1, 0) = 2</p>															

C5. Possibility of entry into the PRA area through natural means

<u>Inclusion in other EU ranking systems</u>	PHRR, BiOR ² , M&R, H+/P+, FinnPRIO, NVWA, ERIN						
<u>Need of automatic approach</u>	No						
<u>Description</u>	This criterion identifies the distribution of the pest around the PRA area in an attempt to evaluate the probability of entry by natural means. Natural means to be taken into consideration are flight, wind or water spread (including irrigation), natural migration, rhizome growth and movement across land.						
<u>Scoring</u>	<p>Score = C(indicator)</p> <p>C is given as follows:</p> <table border="1"> <thead> <tr> <th>C</th> <th>Indicator</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Pest able to enter the PRA area by natural means</td> </tr> <tr> <td>2</td> <td>Pest unable to enter the PRA area by natural means</td> </tr> </tbody> </table> <p><i>If 'No info', apply the no score for no information (Score = ?)</i></p>	C	Indicator	1	Pest able to enter the PRA area by natural means	2	Pest unable to enter the PRA area by natural means
C	Indicator						
1	Pest able to enter the PRA area by natural means						
2	Pest unable to enter the PRA area by natural means						
<u>Data</u>	Pest distribution and biology						
<u>Example</u>	<p><i>Agrilus auroguttatus</i>. The pest is only present in Mexico and the USA (Arizona, and California) and could not reach the EU by flight.</p> <p style="text-align: right;">= 0</p>						

C6. Presence of the pest in the PRA area

<u>Inclusion in other EU ranking systems</u>	None
<u>Need of automatic approach</u>	Yes
<u>Description</u>	This criterion identifies the distribution of the pest within the PRA area. A pest is considered riskier if it is already present in the PRA area.
<u>Scoring</u>	<p>Score = $N_{\text{Countries}}$</p> <p>$N_{\text{Countries}}$ is the number of countries where the pest is present in the PRA area</p> <p><i>If 'No info', apply the no score for no information (Score = ?)</i></p>
<u>Data</u>	Distribution of the pest
<u>Example</u>	<p><i>Lycorma delicatula</i>. The pest is only present in USA, China, India, Japan, Republic of Korea, Lao, Taiwan and Vietnam.</p> <p style="text-align: right;">= 0</p>

C7. Need for a vector and its occurrence in the PRA area

<u>Inclusion in other EU ranking systems</u>	PHRR, BiOR ² , FinnPRIO, NVWA
<u>Need of automatic approach</u>	Yes
<u>Description</u>	Factors considered are the pest's need for a vector to transfer from pathways, and availability of a vector in the PRA area.
<u>Scoring</u>	<p>Score = 28 - x</p> <p>For pests that need a vector: x is the number of countries where the vector is not known to occur</p> <p>For pests that do not need a vector, x = 0 and the score is by default 28</p> <p><i>S = 28 if no information is available about the need for a vector (worst-case scenario)</i></p> <p><i>S = 14 if the pest needs a vector but no information is available about the presence of the vector in MSs (medium-risk scenario).</i></p>
<u>Data</u>	Biology of the pest, distribution of vectors
<u>Example</u>	<p><i>Phytophthora chrysanthemi</i>. No need for a vector for transfer.</p> <p style="text-align: right;">= 28</p> <p><i>Candidatus Liberibacter africanus</i>. Need for a vector, <i>Trioza erythrae</i>, present in Portugal and Spain.</p> <p style="text-align: right;">= 28 - 26 = 2</p>

C8. Cultivated host plant surface area in the PRA area

<u>Inclusion in other EU ranking systems</u>	PHRR, BiOR ² , M&R, H ⁺ /P ⁺ , FinnPRIO, NVWA, ERIN
<u>Need of automatic approach</u>	Yes
<u>Description</u>	This criterion identifies the extent of the area where host plants are cultivated (crops) in the PRA area.
<u>Scoring</u>	<p>Score = $\sum S_{HP}$</p> <p>$\sum S_{HP}$ is the cultivated surface area of host plant species</p>
<u>Data</u>	List of host plants, land use
<u>Example</u>	<p><i>Nilaparvata lugens</i>. Rice is the only host plant cultivated in the EU.</p> <p style="text-align: right;">= 44,800 ha</p>

C9. Cultivated host plant distribution in the PRA area

<u>Inclusion in other EU ranking systems</u>	PHRR, BiOR ² , M&R, H ⁺ /P ⁺ , FinnPRIO, NVWA, ERIN
<u>Need of automatic approach</u>	Yes
<u>Description</u>	This criterion identifies the distribution of host plants at EU level.
<u>Scoring</u>	<p>Score = N_{countries}</p> <p>N_{countries} is the number of countries where the host plant is cultivated in the PRA area</p>
<u>Data</u>	List of host plants, land use
<u>Example</u>	<p><i>Nilaparvata lugens</i>. Rice is cultivated in the EU: it was grown in Bulgaria, Greece, Spain, France, Italy, Hungary, Portugal and Romania in 2016.</p> <p style="text-align: right;">= 8</p>

C10. Occurrence of host plants that are not crops in the PRA area

<u>Inclusion in other EU ranking systems</u>	PHRR, BiOR ² , M&R, H ⁺ /P ⁺ , FinnPRIO, NVWA, ERIN						
<u>Need of automatic approach</u>	Yes						
<u>Description</u>	This criterion identifies the extent of the presence of major host plants that are not cultivated as crops in the PRA area. This allows the inclusion of species that are not cultivated but are present in EU MSs and able to contribute to the establishment of the pest without the need for quantification. It will greatly rely on experts' knowledge.						
<u>Scoring</u>	<p>Score = C(Indicator)</p> <p>C is given as follows:</p> <table border="1"> <thead> <tr> <th>C</th> <th>Indicator</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>At least one major non-crop host plant is present in at least one MS</td> </tr> <tr> <td>0</td> <td>No reported presence of major non-crop host plants in the EU</td> </tr> </tbody> </table>	C	Indicator	1	At least one major non-crop host plant is present in at least one MS	0	No reported presence of major non-crop host plants in the EU
C	Indicator						
1	At least one major non-crop host plant is present in at least one MS						
0	No reported presence of major non-crop host plants in the EU						
<u>Data</u>	List of host plants, land use						
<u>Example</u>	<i>Lycorma delicatula</i> . <i>Ailanthus altissima</i> , a major host plant of <i>Lycorma delicatula</i> , is naturalised in UK, Belgium, France, Germany and Austria. = 1						

C11. Climate suitability

<u>Inclusion in other EU ranking systems</u>	PHRR, BiOR ² , M&R, H ⁺ /P ⁺ , FinnPRIO, NVWA												
<u>Need of automatic approach</u>	Yes												
<u>Description</u>	This criterion evaluates the suitability of climatic conditions in the PRA area for the pest's establishment. The Köppen–Geiger climate classification is used. Production conditions, such as growing host plants in greenhouses, are also taken into consideration. The assumption is that host plants that are cultivated in greenhouses did not find a suitable environment outdoors and thus the pest's establishment, in the same conditions as its host plants, is dependent on agricultural practices that are subject to change.												
	<table border="1"> <thead> <tr> <th>Classes</th> <th>Types of climates</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>Tropical</td> </tr> <tr> <td>B</td> <td>Arid</td> </tr> <tr> <td>C</td> <td>Temperate</td> </tr> <tr> <td>D</td> <td>Cold continental</td> </tr> <tr> <td>E</td> <td>Polar</td> </tr> </tbody> </table>	Classes	Types of climates	A	Tropical	B	Arid	C	Temperate	D	Cold continental	E	Polar
Classes	Types of climates												
A	Tropical												
B	Arid												
C	Temperate												
D	Cold continental												
E	Polar												
<u>Scoring</u>	<p>Score = C(Indicator)</p> <p>C is given as follows:</p> <table border="1"> <thead> <tr> <th>C</th> <th>Indicator</th> </tr> </thead> <tbody> <tr> <td>2</td> <td>The PRA area provides at least one suitable climate for establishment</td> </tr> <tr> <td>1</td> <td>The PRA area does not provide an optimal climate for establishment, but the production conditions of host plants do (in greenhouses for example)</td> </tr> <tr> <td>0</td> <td>Neither climatic nor production conditions are suitable for establishment</td> </tr> </tbody> </table>	C	Indicator	2	The PRA area provides at least one suitable climate for establishment	1	The PRA area does not provide an optimal climate for establishment, but the production conditions of host plants do (in greenhouses for example)	0	Neither climatic nor production conditions are suitable for establishment				
C	Indicator												
2	The PRA area provides at least one suitable climate for establishment												
1	The PRA area does not provide an optimal climate for establishment, but the production conditions of host plants do (in greenhouses for example)												
0	Neither climatic nor production conditions are suitable for establishment												
<u>Data</u>	Climate, production conditions, pest biology												

<u>Example</u>	<i>Trogoderma granarium</i> . The beetle is found in hot, dry conditions, predictably in areas with a mean temperature over 20°C and an RH below 50% for at least 4 months per year. It could find these conditions in the EU's Mediterranean countries (climates B and C). = 2
----------------	--

C12. Possibility of spread by natural means

<u>Inclusion in other EU ranking systems</u>	PHRR, BiOR ² , M&R, H ⁺ /P ⁺ , FinnPRIO, NVWA, ERIN								
<u>Need of automatic approach</u>	No								
<u>Description</u>	This criterion evaluates the pest's ability to spread within the PRA area depending on its means of natural spread – flight, wind or water spread, natural migration, rhizome growth, movement across land. The need for transportation by vectors such as insects, birds or other animals is also considered (when the vector is present in the same geographical area as the pest's distribution area).								
<u>Scoring</u>	<p>Score = C(indicator) C is given as follows:</p> <table border="1"> <thead> <tr> <th>C</th> <th>Indicator</th> </tr> </thead> <tbody> <tr> <td>2</td> <td>The pest can spread over long distance via wind, flight or water (running water) by itself or through the activity of a vector present in the PRA area</td> </tr> <tr> <td>1</td> <td>The pest can spread on a local scale via rhizome growth or terrestrial moves by itself or through the activity of a vector present in the PRA area</td> </tr> <tr> <td>0</td> <td>No natural means for spread or vector is the only means of natural spread and vector is absent in the PRA area</td> </tr> </tbody> </table> <p>If 'No info', apply the midpoint scenario (Score = 1)</p>	C	Indicator	2	The pest can spread over long distance via wind, flight or water (running water) by itself or through the activity of a vector present in the PRA area	1	The pest can spread on a local scale via rhizome growth or terrestrial moves by itself or through the activity of a vector present in the PRA area	0	No natural means for spread or vector is the only means of natural spread and vector is absent in the PRA area
C	Indicator								
2	The pest can spread over long distance via wind, flight or water (running water) by itself or through the activity of a vector present in the PRA area								
1	The pest can spread on a local scale via rhizome growth or terrestrial moves by itself or through the activity of a vector present in the PRA area								
0	No natural means for spread or vector is the only means of natural spread and vector is absent in the PRA area								
<u>Data</u>	Pest biology								
<u>Example</u>	<i>Phytophthora chrysanthemi</i> . Natural spread via water, presumably rarely via air. = 2								

C13. Possibility of spread by human assistance

<u>Inclusion in other EU ranking systems</u>	BiOR ² , M&R, H ⁺ /P ⁺
<u>Need of automatic approach</u>	No
<u>Description</u>	<p>This criterion considers the pest's means of spread with human assistance beyond its biological capacity within the PRA area. Mechanical transmission via human activities (by grafting or cutting and by contaminated hands, clothes or tools used to cut or thin out plants or prepare the soil) usually occurs over short distances within the production site. The lowest score is given for this means.</p> <p>Spreading through the movement of goods, packing materials, luggage, mail or conveyances, and a pest's ability to be unintentionally dispersed along major transportation routes (hitchhiker behaviour) are also considered. Different scores are given to the means depending on their final use and distribution.</p>

<u>Scoring</u>	<p>Score = $\sum C$ C is given as follows:</p> <table border="1"> <thead> <tr> <th>C</th> <th>Means of artificial spread</th> </tr> </thead> <tbody> <tr> <td>7</td> <td>The pest is spread via plants for planting in a sustainable way (ornamental plants, nursery seedlings, vegetable plants) or via plant organs intended to produce other plants (seeds, bulbs, tubers, budwood, rootstock)</td> </tr> <tr> <td>3</td> <td>The pest is spread via commodities intended for consumption, for transformation or as ephemeral ornaments</td> </tr> <tr> <td>2</td> <td>The pest is unintentionally dispersed along major transportation routes (hitchhiker behaviour)</td> </tr> <tr> <td>1</td> <td>The pest is spread locally through agricultural practices (mechanical transmission by human activities)</td> </tr> </tbody> </table>	C	Means of artificial spread	7	The pest is spread via plants for planting in a sustainable way (ornamental plants, nursery seedlings, vegetable plants) or via plant organs intended to produce other plants (seeds, bulbs, tubers, budwood, rootstock)	3	The pest is spread via commodities intended for consumption, for transformation or as ephemeral ornaments	2	The pest is unintentionally dispersed along major transportation routes (hitchhiker behaviour)	1	The pest is spread locally through agricultural practices (mechanical transmission by human activities)
C	Means of artificial spread										
7	The pest is spread via plants for planting in a sustainable way (ornamental plants, nursery seedlings, vegetable plants) or via plant organs intended to produce other plants (seeds, bulbs, tubers, budwood, rootstock)										
3	The pest is spread via commodities intended for consumption, for transformation or as ephemeral ornaments										
2	The pest is unintentionally dispersed along major transportation routes (hitchhiker behaviour)										
1	The pest is spread locally through agricultural practices (mechanical transmission by human activities)										
<u>Data</u>	List of host plants, host commodities, pest biology										
<u>Example</u>	<p><i>Hosta virus X</i>. Artificial spread by commodities ('plants for planting') and mechanical transmission through human activities (grafting tools).</p> <p style="text-align: right;">7 + 1 = 8</p>										

C14. Description of yield loss in the pest's current area of distribution

<u>Inclusion in other EU ranking systems</u>	PHRR, BiOR ² , M&R, ERIN																
<u>Need of automatic approach</u>	No																
<u>Description</u>	<p>This criterion considers the damage caused by each pest in the absence of management measures on the main host plant in its current area of distribution. Effects on crop yield are usually expressed as a relative decrease (%) per crop per ha. Thresholds are defined for crop yield. For crops grown in protected conditions/greenhouses (tomatoes, cut flowers, potted plants) and forestry, annual yield fluctuations are usually very small and a yield loss greater than 10% can be considered as a massive impact. For crops with large yearly fluctuations, e.g. fruit and arable products, nursery stock and outdoor vegetables, a loss of more than 30% would be needed before it could be considered a massive impact.</p>																
<u>Scoring</u>	<p>Score = C(Indicator) C is given as follows:</p> <table border="1"> <thead> <tr> <th>C</th> <th>Indicator</th> <th>Crops grown in protected conditions/greenhouses (tomatoes, cut flowers, potted plants) and forestry</th> <th>Nursery stock, outdoor vegetables and fruit and arable products</th> </tr> </thead> <tbody> <tr> <td>2</td> <td>Massive yield loss</td> <td>> 10%</td> <td>> 30%</td> </tr> <tr> <td>1</td> <td>Limited yield loss</td> <td>[0–10] %</td> <td>]0–30] %</td> </tr> <tr> <td>0</td> <td>No yield loss</td> <td>0</td> <td>0</td> </tr> </tbody> </table> <p><i>If 'No info', apply the midpoint scenario (Score = 1)</i></p>	C	Indicator	Crops grown in protected conditions/greenhouses (tomatoes, cut flowers, potted plants) and forestry	Nursery stock, outdoor vegetables and fruit and arable products	2	Massive yield loss	> 10%	> 30%	1	Limited yield loss	[0–10] %]0–30] %	0	No yield loss	0	0
C	Indicator	Crops grown in protected conditions/greenhouses (tomatoes, cut flowers, potted plants) and forestry	Nursery stock, outdoor vegetables and fruit and arable products														
2	Massive yield loss	> 10%	> 30%														
1	Limited yield loss	[0–10] %]0–30] %														
0	No yield loss	0	0														
<u>Data</u>	List of host plants, data on damage																
<u>Example</u>	<p><i>Fusarium oxysporum</i> f. sp. <i>lactucae</i>. Yield losses reported are up to 50% on lettuce in protected plastic tunnels.</p> <p style="text-align: right;">= 2</p>																

C15. Description of quality loss or plant death in the pest's current area of distribution

<u>Inclusion in other EU ranking systems</u>	PHRR, BiOR ² , M&R, H ⁺ /P ⁺ , FinnPRIO, NVWA, ERIN								
<u>Need of automatic approach</u>	No								
<u>Description</u>	This criterion considers the damage caused by each pest in the absence of management measures on the main host plant in its current area of distribution. Harmfulness includes direct losses of host plants in terms of plant death or a drop-in crop quality.								
<u>Scoring</u>	<p>Score = C(Indicator)</p> <p>C is given as follows:</p> <table border="1"> <thead> <tr> <th>C</th> <th>Indicator</th> </tr> </thead> <tbody> <tr> <td>2</td> <td>Reported plant death</td> </tr> <tr> <td>1</td> <td>Reported quality losses</td> </tr> <tr> <td>0</td> <td>No reported crop quality loss or plant death</td> </tr> </tbody> </table> <p>If 'No info', apply the no score for no information (Score=?)</p>	C	Indicator	2	Reported plant death	1	Reported quality losses	0	No reported crop quality loss or plant death
C	Indicator								
2	Reported plant death								
1	Reported quality losses								
0	No reported crop quality loss or plant death								
<u>Data</u>	List of host plants, data on damage								
<u>Example</u>	<i>Neonectria neomacrospora</i> . Tree mortality has often been observed on <i>Abies</i> spp. in landscape plantings, Christmas tree production fields and in forest stands.								
	= 2								

C16. Existence of control measures that could affect the pest's impact

<u>Inclusion in other EU ranking systems</u>	PHRR, BiOR ²						
<u>Need of automatic approach</u>	No						
<u>Description</u>	This criterion reports the existence, in the current area of distribution of the pest, of efficient control measures or cases where the pest has been eradicated or its population maintained below the economic threshold.						
<u>Scoring</u>	<p>Score = C (Indicator)</p> <p>C is given as follows:</p> <table border="1"> <thead> <tr> <th>C</th> <th>Indicator</th> </tr> </thead> <tbody> <tr> <td>2</td> <td>No efficient control measures are described for the pest, or the pest has never been eradicated, or populations never reduced to a level below the economic threshold</td> </tr> <tr> <td>1</td> <td>Efficient control measures exist, the pest has been eradicated or the population reduced to a level below the economic threshold</td> </tr> </tbody> </table> <p>If 'No info' for a crop, apply the worst-case scenario (Score = 2)</p>	C	Indicator	2	No efficient control measures are described for the pest, or the pest has never been eradicated, or populations never reduced to a level below the economic threshold	1	Efficient control measures exist, the pest has been eradicated or the population reduced to a level below the economic threshold
C	Indicator						
2	No efficient control measures are described for the pest, or the pest has never been eradicated, or populations never reduced to a level below the economic threshold						
1	Efficient control measures exist, the pest has been eradicated or the population reduced to a level below the economic threshold						
<u>Data</u>	Control measures						
<u>Example</u>	<i>Phytophthora chrysanthemi</i> . Use of certified healthy propagation and planting material, strict hygiene in the production company; disinfection of contaminated irrigation and excess water, no reuse of contaminated substrate/soil, application of fungicides in consultation with the local Plant Health Service (development of resistance must be strictly avoided).						
	= 1						

Appendix B – Features of the PROMETHEE method

The content of this appendix has been extracted and elaborated from the Visual PROMETHEE manual (Mareschal, 2015).

B.1. Pairwise comparison

The two main components of the PROMETHEE method are:

- The action: The term action is used to designate an item to evaluate. Visual PROMETHEE compares different actions that are evaluated on the basis of several criteria.
- The criterion: A criterion is an attribute associated with each action that makes it possible to compare the actions and to determine the best ones. It can be quantitative (a number is associated with each action, such as the price of an item) or qualitative (in this case, a qualitative scale must be defined with several ordered levels, such as very bad, bad, average, good, very good).

PROMETHEE is based on the principle of pairwise comparison of the actions.

A first step in PROMETHEE modelling is thus to compare each action with all the others. This is done by computing a multicriteria preference index in the following way:

$$\pi(a, b) = \sum_{j=1}^k w_j \times P_j(a, b),$$

where

- $w_j > 0$ is the normalised weight allocated to criterion f_j (the more important f_j is, the larger w_j will be),
- $P_j(a, b)$ is the value of the preference function for criterion f_j when action a is compared to action b .

With normalised weights, $\pi(a, b)$ is a number between 0 and 1. It expresses how much 'a' is preferred to 'b' taking into account all the criteria and their weights. For instance:

- if $\pi(a, b) = 0$: All the $P_j(a, b)$ values are equal to 0 which means that 'a' is never even slightly preferred to 'b' on any criterion,
- if $\pi(a, b) = 1$: All the $P_j(a, b)$ values are equal to 1 which means that 'a' is strongly preferred to 'b' on all the criteria.

So that:

- $\pi(a, b) \approx 0$ means that there is a weak preference for 'a' over 'b'.
- $\pi(a, b) \approx 1$ means that there is a strong preference for 'a' over 'b'.

B.2. Preference functions

PROMETHEE is based on the pairwise comparison of actions. This means that the deviation between the evaluation of two actions on a criterion has first to be modelled. For small deviations, there will probably be either a weak preference or no preference at all for the best action as the decision maker will consider this deviation as small or negligible. For larger deviations, larger preference levels are expected. With PROMETHEE, preference levels are measured on a scale going from 0 to 1: 0 means no preference at all while 1 means a full preference. The deviation must be translated into a preference degree between 0 and 1, which is the purpose of the preference function. PROMETHEE requires a preference function to be associated with each criterion in order to model the way the decision maker perceives the criterion's measurement scale. There are six different types of preference function available in Visual PROMETHEE (Figure B.1).

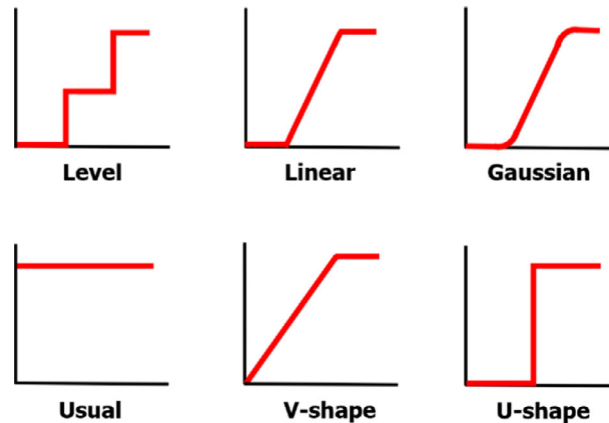


Figure B.1: Preference functions available in Visual PROMETHEE

Depending on the type of preference function that has been selected, up to two thresholds have to be assessed. These are:

- Q: the indifference threshold. This is the largest deviation that is considered as negligible by the decision maker. To determine the value of Q, one should start with a very small deviation (for instance a few euros) and progressively increase it until it is not considered to be negligible anymore. This means that Q is just below this first significant value.
- P: the preference threshold. This is the smallest deviation that is considered as sufficient to generate a full preference. To determine the value of P, one should start with a very large deviation (for instance several thousand euros) and progressively reduce it until some hesitation arises. This means that P is slightly above this last value.
- S: the Gaussian threshold. The Gaussian threshold corresponds to the inflection point of the Gaussian curve (like the standard deviation in statistics). It is thus a deviation for which the preference degree is equal to 0.39, so it is in between a Q and a P value. It is also more difficult to assess. A rule of thumb could be to determine a Q and a P value and to set S equal to their average ($S = (Q + P)/2$).

B.3. Preference flows

Preference flows are computed to consolidate the results of the pairwise comparisons of the actions, and to rank all the actions from best to worst.

Three different preference flows are computed:

- Φ^+ (φ^+): the positive (or outgoing) flow
- Φ^- (φ^-): the negative (or incoming) flow
- Φ (φ): the net flow

The positive preference flow $\varphi^+(a)$ measures how much action 'a' is preferred to the other $n - 1$ actions. It is a global measurement of the strengths of action 'a'. The larger $\varphi^+(a)$, the better the action.

$$\varphi^+(a) = \frac{1}{n - 1} \sum_{b \neq a} \pi(a, b).$$

The negative preference flow $\varphi^-(a)$ measures how much the other $n-1$ actions are preferred to action 'a'. It is a global measurement of the weaknesses of action 'a'. The smaller $\varphi^-(a)$, the better the action.

$$\varphi^-(a) = \frac{1}{n - 1} \sum_{b \neq a} \pi(b, a).$$

The net preference flow $\varphi(a)$ is the balance between the positive and negative preference flows:

$$\varphi(a) = \varphi^+(a) - \varphi^-(a).$$

It thus takes into account and aggregates both the strengths and weaknesses of an action into a single score. $\varphi(a)$ can be positive or negative. The larger $\varphi(a)$ is, the better the action is.

Rank reversal, which is the change in the relative positions of two pests, can occur when another action is added or deleted from the set of pests. This phenomenon is inherent to pairwise-comparison-based multicriteria decision aid methods such as PROMETHEE. This is because the scores used to rank the actions are based on pairwise comparisons of all the pests. Different sets of pests thus provide different scores and ranks can be reversed. However, in the case of the PROMETHEE method, rank reversal is very limited. Indeed, the PROMETHEE rankings are consistent with the dominance relation: If a pest is dominated by another one, it will never be preferred to that one in the PROMETHEE rankings. Moreover, rank reversal can only happen when the flow values of the pests are relatively close to each other, which means that rank reversal mostly occurs between pests that are already very close to each other in the PROMETHEE rankings. An accurate choice of the adequate preference functions limits the rank reversal's occurrence.

Appendix C – Score matrix of the 18 pests selected for the test of the pilot methodology

Pests	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
<i>Aceria litchii</i>	0.1	1	?	2	0	0	28	0	0	0	0	2	7	1	1	2
<i>African cassava mosaic virus</i>	0.1	1	?	3	0	0	22	0	0	0	0	2	7	1	0	2
<i>Agrilus auroguttatus</i>	0.2	1	515,418	3	0	0	28	9,354,406	17	1	2	2	9	1	2	2
<i>Bactrocera kirki</i>	10	1	335,307	2	0	0	28	0	0	0	0	2	2	1	1	1
<i>Fiorinia phantasma</i>	24	1	?	3	0	0	28	0	?	1	1	1	7	1	2	1
<i>Fusarium oxysporum f.sp. lactucae</i>	2	1	?	3	0	7	28	90,680	25	0	2	0	9	2	2	1
<i>Lema bilineata</i>	1	1	411,634	2	0	1	28	80,460	12	1	2	1	2	1	1	2
<i>Liberomyces pistaciae</i> sp. nov.	0.1	1	?	3	0	1	28	3,600	1	0	2	1	8	1	2	1
<i>Lycorma delicatula</i>	40	1	?	3	0	0	28	16,811,235.5	27	1	2	1	12	1	2	1
<i>Meloidogyne enterolobii</i>	31	1	40,857	3	0	2	28	2,056,610	28	1	1	1	8	2	2	2
<i>Oryctes rhinoceros</i>	8	1	?	2	0	0	28	0	0	1	2	1	10	1	2	1
<i>Phyllosticta citricarpa</i>	1	1	5,465,656.9	3	0	0	28	991,160	7	0	2	2	9	2	1	2
<i>Phytophthora chrysanthemi</i>	0.1	1	6,443	2	0	2	28	?	?	1	1	2	10	1	2	1
<i>Pterochloroides persicae</i>	3	0	0	3	0	6	28	2,068,370	27	1	2	2	7	1	1	1
<i>Raffaelea lauricola</i>	1	1	?	2	0	0	0	12,240	4	1	2	0	7	1	2	2
<i>Resseliella maxima</i>	0.1	1	?	3	0	0	28	832,150	25	0	2	2	7	1	2	2
<i>Tomato brown rugose fruit virus</i>	2	1	?	3	0	2	28	303,500	25	1	2	0	8	2	1	2
<i>Xylella fastidiosa</i>	82	1	?	3	0	3	9	20,858,457.7	23	1	2	2	10	2	2	2

Appendix D – Uncertainty matrix of the 18 pests selected for the test of the pilot methodology

Pests	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
<i>Aceria litchii</i>	0	0	1	1	0	0	0	0	0	0	1	1	1	1	0	1
<i>African cassava mosaic virus</i>	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0
<i>Agrilus auroguttatus</i>	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0
<i>Bactrocera kirki</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
<i>Fiorinia phantasma</i>	0	0	1	1	0	0	0	1	1	0	1	1	0	1	0	0
<i>Fusarium oxysporum f.sp. lactucae</i>	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lema bilineata</i>	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1
<i>Liberomyces pistaciae</i> sp. nov.	0	0	1	0	1	0	0	1	1	0	0	1	0	1	0	1
<i>Lycorma delicatula</i>	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Meloidogyne enterolobii</i>	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Oryctes rhinoceros</i>	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1
<i>Phyllosticta citricarpa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>Phytophthora chrysanthemi</i>	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0
<i>Pterochloroides persicae</i>	0	0	1	1	1	0	0	0	0	0	0	1	0	1	0	0
<i>Raffaelea lauricola</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Resseliella maxima</i>	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0
<i>Tomato brown rugose fruit virus</i>	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0
<i>Xylella fastidiosa</i>	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix E – Preference functions and thresholds for the test of the pilot methodology

Criteria	Preference function	Threshold	Q	P
C1	V-shape	Absolute	–	42.20
C2	Usual	Absolute	–	–
C3	V-shape	Absolute	–	3,949,029.63
C4	Usual	Absolute	–	–
C5	Usual	Absolute	–	–
C6	V-shape	Absolute	–	1.00
C7	V-shape	Absolute	–	1.00
C8	V-shape	Absolute	–	12,582,662.63
C9	V-shape	Absolute	–	1.00
C10	Usual	Absolute	–	–
C11	Usual	Absolute	–	–
C12	Usual	Absolute	–	–
C13	Linear	Absolute	0	5.02
C14	Usual	Absolute	–	–
C15	Usual	Absolute	–	–
C16	Usual	Absolute	–	–

Q: Indifference threshold; P: Preference threshold.

Appendix F – Score matrix of the reference pests used in the PeMoScoring methodology

Pest	C1	C2	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	Project source	Class
<i>Acrobasis pirivorella</i>	0.2	1	1	0	0	28	117,261	26	1	2	1	9	2	1	1	PC QP	Positive
<i>African cassava mosaic virus</i>	0.1	1	3	0	0	23	0	0	0	0	2	7	1	0	2	PC no QP	Negative
<i>Agrilus anxius</i>	0.2	1	2	0	0	28	3,562,893.7	5	1	2	2	10	2	2	2	PP	Positive
<i>Agrilus planipennis</i>	0.2	1	1	1	0	28	283,915.652	4	1	2	2	9	2	2	2	PP	Positive
<i>Anastrepha ludens</i>	3	1	2	0	0	28	698,620	15	1	2	1	10	1	1	1	PP	Positive
<i>Anoplophora chinensis</i>	4	1	1	1	3	28	27,267,204.828	28	1	2	2	10	2	2	2	PP	Positive
<i>Anoplophora glabripennis</i>	4	1	1	1	5	28	4,711,652.486	10	1	2	2	10	2	2	2	PP	Positive
<i>Anthonomus eugenii</i>	1	1	2	0	1	28	2,013,150	28	1	2	1	9	2	1	1	PP	Positive
<i>Apiosporina morbosus</i>	0.2	1	3	0	0	28	1,246,340	26	1	2	1	7	2	2	1	PC QP	Positive
<i>Apple geminivirus</i>	0.2	1	3	0	0	0	523,700	27	1	2	1	1	0	0	1	PC no QP	Negative
<i>Apple hammerhead viroid</i>	0.2	1	3	0	0	0	523,700	27	1	2	1	7	1	1	1	PC no QP	Negative
<i>Aromia bungii</i>	0.2	1	2	1	2	28	1,312,830	24	1	2	1	10	1	2	2	PP	Positive
<i>Arrhenodes minutus</i>	2	1	2	0	0	28	11,166,184.75	17	1	2	1	12	2	1	2	PC QP	Positive
<i>Bactericera cockerelli</i>	4	1	2	0	0	28	2,093,610	28	1	2	2	9	1	2	2	PP	Positive
<i>Bactrocera dorsalis</i>	4	1	2	0	0	28	6,558,050	28	1	2	1	6	2	1	2	PP	Positive
<i>Bactrocera kirki</i>	3	1	2	0	0	28	1,012,045	26	1	1	2	3	2	1	1	PC QP	Positive
<i>Bactrocera zonata</i>	4	1	2	0	0	28	2,968,650	28	1	2	1	5	2	1	2	PP	Positive
<i>Bretziella fagacearum</i>	1	1	3	0	0	24	10,393,114.47	17	1	2	2	9	1	2	2	PP	Positive
<i>Bursaphelenchus xylophilus</i>	2	1	2	1	2	23	61,171,013.14	22	1	2	2	9	2	2	2	PP	Positive
<i>Candidatus Liberibacter africanus</i>	1	1	3	0	0	2	518,662	8	1	2	2	10	2	2	2	PP	Positive
<i>Coniferiporia sulphurascens</i>	2	1	3	0	0	28	54,093,372.346	14	1	2	1	10	2	2	2	PC QP	Positive
<i>Conotrachelus nenuphar</i>	3	1	1	0	0	28	5,279,640	28	1	2	1	10	2	1	1	PP	Positive
<i>Dendrolimus sibiricus</i>	1	1	2	1	0	28	60,329,588.374	21	1	2	1	11	1	2	2	PP	Positive
<i>Grapholita inopinata</i>	1	1	1	0	0	28	640,965	28	1	2	2	10	2	1	1	PC QP	Positive
<i>Hirschmanniella behningi</i>	1	1	3	1	2	28	90,445,800	28	1	2	0	7	0	0	1	PC no QP	Negative
<i>Margarodes floridanus</i>	0.2	1	3	0	0	0	991,160	7	1	2	1	8	0	0	1	PC no QP	Negative

Pest	C1	C2	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	Project source	Class
<i>Neomargarodes cucurbitae</i>	0.2	1	3	0	0	0	75,940	24	1	2	1	8	0	0	1	PC no QP	Negative
<i>non-EU potato virus A</i>	2	1	3	1	5	28	1,825,810	28	1	2	2	10	2	1	1	PC no QP	Negative
<i>Phyllosticta citricarpa</i>	1	1	3	0	0	28	518,662	8	1	2	2	9	2	1	2	PC QP	Positive
<i>Popillia japonica</i>	4	1	2	0	3	28	23,453,885	28	1	2	1	1	2	1	2	PP	Positive
<i>Prunus geminivirus A</i>	0.2	1	3	0	0	0	377,580	24	1	2	1	8	0	0	1	PC no QP	Negative
<i>Rhagoletis pomonella</i>	2	1	2	0	0	28	1,953,813	28	1	2	2	10	2	1	1	PP	Positive
<i>Satsuma dwarf virus</i>	1	1	3	0	0	28	1,099,920	27	1	2	0	10	2	1	2	PC QP	Positive
<i>small-spored Alternaria</i>	1	1	3	1	2	?	640,965	28	1	2	2	9	2	1	1	PC no QP	Negative
<i>Spodoptera eridania</i>	4	1	1	0	0	28	20,094,880	28	1	2	2	12	1	1	1	PC QP	Positive
<i>Spodoptera frugiperda</i>	4	1	2	1	0	28	123,884,012.014	28	1	2	2	3	1	1	2	PP	Positive
<i>Thaumatotibia leucotreta</i>	4	1	1	0	0	28	33,728,235.746	28	1	2	2	10	2	1	2	PP	Positive
<i>Thrips palmi</i>	4	1	2	0	0	28	118,985,410	28	1	2	2	12	1	1	1	PP	Positive
<i>Tilletia indica</i>	1	1	3	1	0	28	27,024,908	28	1	2	2	10	1	1	1	PP	Positive
<i>Toxoptera citricida</i>	4	1	2	1	2	28	518,540	7	1	2	2	12	0	0	1	PC QP	Positive
<i>Wild vitis virus 1</i>	0.2	0	3	0	0	0	3,141,300	21	1	2	1	8	0	0	1	PC no QP	Negative
<i>Xanthomonas citri</i>	1	1	3	1	0	28	518,662	8	1	2	1	8	1	1	2	PP	Positive
<i>Xylella fastidiosa</i>	4	1	3	0	3	28	20,858,457.746	23	1	2	2	10	2	2	2	PC QP	Positive

Appendix G – Updated 13 criteria in the PeMoScoring methodology

Criterion	Description and scores	Group
1. Range of pest host plants	0.1: 1 species, 0.2: more than 1 species belonging to 1 genus, 1: more than 1 genus belonging to 1 family, 2: more than 1 genus belonging to 2-5 families, 3: more than 1 genus belonging to 6-10 families, 4: more than 1 genus belonging to more than 10 families.	General
2. Regulatory status of pathways	0: all pathways prohibited by current legislation, 1: at least one pathway is allowed by current legislation.	Entry
3. Possibility of entry into the PRA area by natural means	0: pest not having the ability to enter in the EU by natural means, 1: pest having the ability to enter in the EU by natural means.	Entry
4. Need for a vector and its occurrence in the PRA area	28: not need of a vector, 28-x (where x = number of MS where the vector is not present).	General
5. Cultivated host plant surface area in the PRA area	Hectares of cultivated host plant in the PRA area (EUROSTAT and EFISCEN database for forestry).	Establishment
6. Cultivated host plant distribution in the PRA area	Number of Member States where host plants are present (EUROSTAT and EFISCEN database for forestry).	Establishment
7. Occurrence of host plants that are not crops in the PRA area	0: no reported presence of major non-crop host plants in the EU, 1: at least one major non-crop host plant is present in at least one Member State.	Establishment
8. Climate suitability	0: Neither climate nor productions conditions are suitable to pest establishment, 1: the EU does not provide one climate for establishment, but production conditions of host plants do (e.g. greenhouses), 2: the EU provides at least one climate suitable for establishment.	General
9. Possibility of spread by natural means	0: no natural means of spread or vector is the only mean of natural spread and vector is absent in the EU, 1: pest can spread on local scale via flight at very short distance, rhizome growth or terrestrial movements by itself (jumping, walking), 2: pest can spread over long distance via wind or flight or water (including irrigation) by itself or by a vector present in the EU.	Spread
10. Possibility of spread by human assistance	Total score calculated adding scores corresponding to the possibilities listed below. 1: local spread through agricultural practices (mechanical transmission by human activities), 2: spread on commodities intended for consumption or for transformation or ephemeral ornament (including wood), 3: unintentional spread along major transportation routes (hitchhiker behaviour), 7: spread through plants for planting (including seeds, bulbs, tubers, budwood, rootstock).	Spread
11. Description of yield losses in the pest's current area of distribution	0: no yield loss described in the pest's current area of distribution, 1: Low yield losses (]0–10] % for crops grown in protected conditions and forestry,]0–30] % for other crops), 2: Massive yield losses (> 10% for crops grown in protected conditions/greenhouses and forestry, > 30% for other crops).	Impact

Criterion	Description and scores	Group
12. Description of quality losses or plant death in the pest's current area of distribution	0: no reported quality losses or plant death in the pest's current area of distribution, 1: reported quality losses in the pest's current area of distribution, 2: reported plant death in the pest's current area of distribution.	Impact
13. Existence of control measures that could affect the pest's impact	1: efficient control measures exist, or pest eradicated, or population reduced to a level below the economic threshold, 2: no efficient control measures are described, or pest's populations have been never eradicated or reduced to a level below the economic threshold.	Impact

Appendix H – Updated preference functions and thresholds for the PeMoScoring methodology

The PeMoScoring is constructed using the PROMETHEE methodology. As starting point the PROMETHEE methodology was used on the reference data set to define the scoring functions for the selected 13 criteria.

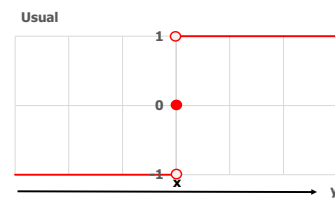
One of the main features of the PROMETHEE methodology is to perform a pairwise comparison within the set of different pest characteristics to identify the main differences in relation to the health threat for plants in the EU. This procedure was done for the reference data to develop the correct parameter and final Phi-scoring.

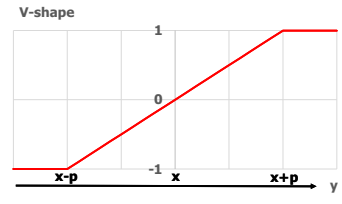
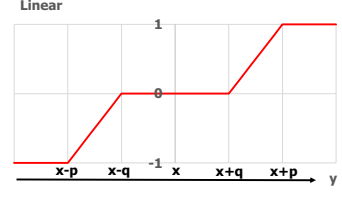
The PeMoScoring is using the same method to compare a new pest with all reference pests.

Abbr.	Range	Description
r	r = 1–43/R = 43	Index to identify a reference pest (Total of 43 reference pests)
c	c = 1,2,5,7–16/C = 13	Index to identify a criterion (Total of 16 criteria, but only 13 are used)
$x_{r,c}$	r = 1–43 c = 1, 2, 5, 7–16	Score value of reference pest r for criterion c (Score matrix, App. G)
y_c	c = 1, 2, 5, 7–16	Score value of the new pest for criterion c (Input values)
$\varphi_c(y, x)$	c = 1, 2, 5, 7–16	Scoring function for criterion c (y more risky than x)
w_c	c = 1, 2, 5, 7–16	Weight of criterion c (Set to 1/13, equal weights)

Criterion	Index	Scoring functions	q_c	p_c
1. Range of pest host plants	c = 1	$\varphi_1(y,x)$ V-shape	#	4
2. Regulatory status of pathways	c = 2	$\varphi_2(y,x)$ Usual	#	#
3. Possibility of entry into the PRA area by natural means	c = 5	$\varphi_5(y,x)$ Usual	#	#
4. Need for a vector and its occurrence in the PRA area	c = 7	$\varphi_7(y,x)$ V-shape	#	5
5. Cultivated host plant surface area in the PRA area	c = 8	$\varphi_8(y,x)$ Linear	10^6	10^7
6. Cultivated host plant distribution in the PRA area	c = 9	$\varphi_9(y,x)$ Linear	5	20
7. Occurrence of host plants that are not crops in the PRA area	c = 10	$\varphi_{10}(y,x)$ Usual	#	#
8. Climate suitability	c = 11	$\varphi_{11}(y,x)$ Usual	#	#
9. Possibility of spread by natural means	c = 12	$\varphi_{12}(y,x)$ Usual	#	#
10. Possibility of spread by human assistance	c = 13	$\varphi_{13}(y,x)$ V-Shape	#	10
11. Description of yield losses in the pest's current area of distribution	c = 14	$\varphi_{14}(y,x)$ Usual	#	#
12. Description of quality losses or plant death in the pest's current area of distribution	c = 15	$\varphi_{15}(y,x)$ Usual	#	#
13. Existence of control measures that could affect the pest's impact	c = 16	$\varphi_{16}(y,x)$ Usual	#	#

With following functions:

Scoring function	
Usual	$\varphi_c(y, x) = \text{indicator}(y > x)$ $- \text{indicator}(x > y)$
	

Scoring function		
V-shape	$\varphi_c(y, x) = \text{minimum}(1, \text{maximum}(0, (y - x)/p_c)) - \text{minimum}(1, \text{maximum}(0, (x - y)/p_c))$	
Linear	$\varphi_c(y, x) = \text{minimum}(1, \text{maximum}(0, (y - x - q_c)/(p_c - q_c))) - \text{minimum}(1, \text{maximum}(0, (x - y - q_c)/(p_c - q_c)))$	
General	$\varphi(y, x) = \varphi^+(y, x) - \varphi^-(y, x) = \varphi^+(y, x) - \varphi^+(x, y)$	

The final PeMoScore is the average of all comparisons between the scored criteria of the new pest y_c with scores of all reference pests $x_{r,c}$ using the appropriate scoring function $\varphi_c(y_c, x_{r,c})$:

$$\Phi = \frac{1}{C} \sum_{C=1}^C \left[\frac{1}{R} \cdot \sum_{r=1}^R \varphi_c(y_c, x_{r,c}) \right]$$

Appendix I – Manual for calculation with the PeMoScore Calculator

For the calculation of PeMoScores for new pests, the PeMoScore Calculator is made. It is implemented as Excel file, allows the input of the judgements on the relevant criteria for a single new pest, compares the judgements with the reference pests and finally calculates the PeMoScore and proposed classification of the health threat to plants in the EU.

Figure I.1 shows the Excel sheet with its cells for data input (green cells), its background data from the reference data set (grey cells) and its outputs (yellow cells):

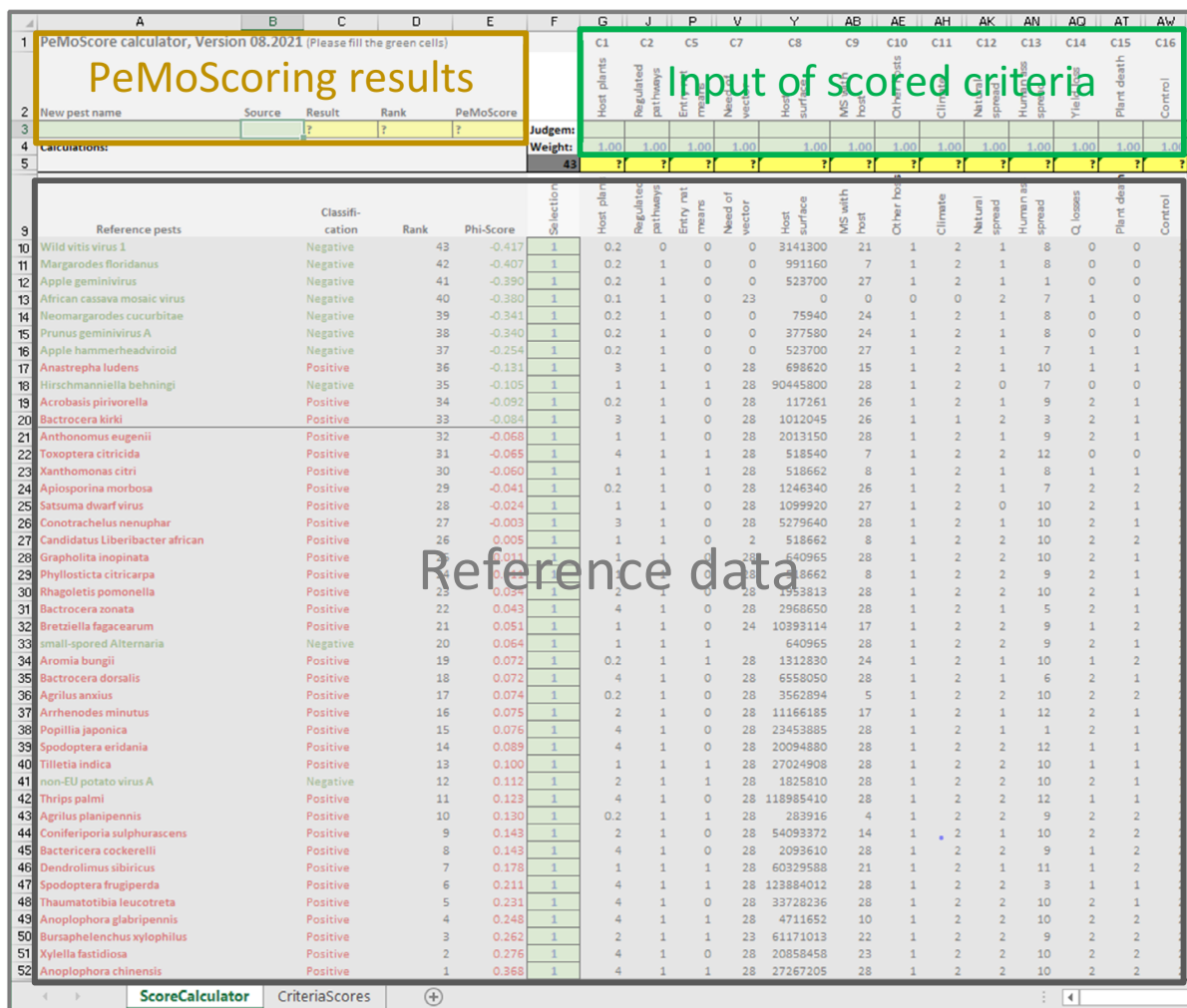


Figure I.1: Main sheet of the PeMoScore Calculator with its different sections for data input (green), reference data (grey), and scoring results (yellow)

The necessary inputs could be done in the green cells in the third line of the PeMoScore Calculator (Figure I.2):

- Cell 'A3' takes the PEST NAME of the pest under evaluation
- Cell 'A4' allows further specification of the assessment, e.g. project, evaluator or date
- Cell 'G3' takes the EVALUATION of the first criterion on host plants
- Until cell 'AW3', which takes the EVALUATION of the 16th criterion on control measures

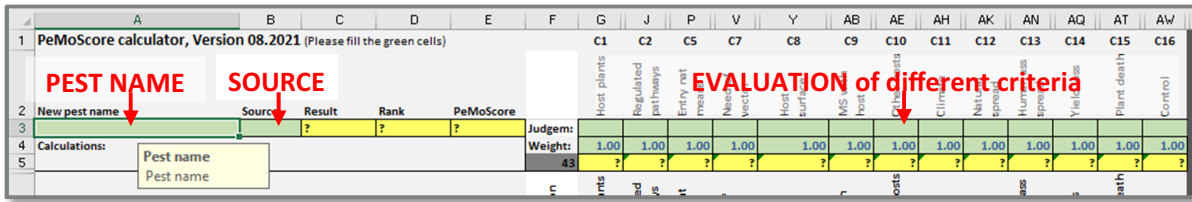


Figure I.2: Main input section of the PeMoScore Calculator in the third line with: PEST NAME, SOURCE, and EVALUATION of different criteria

Each cell for the scoring of the criteria has a pop-up with short explanations and, if appropriate, a selection list of possible answers (Figure I.3). The complete coding scheme is documented in Appendix G.

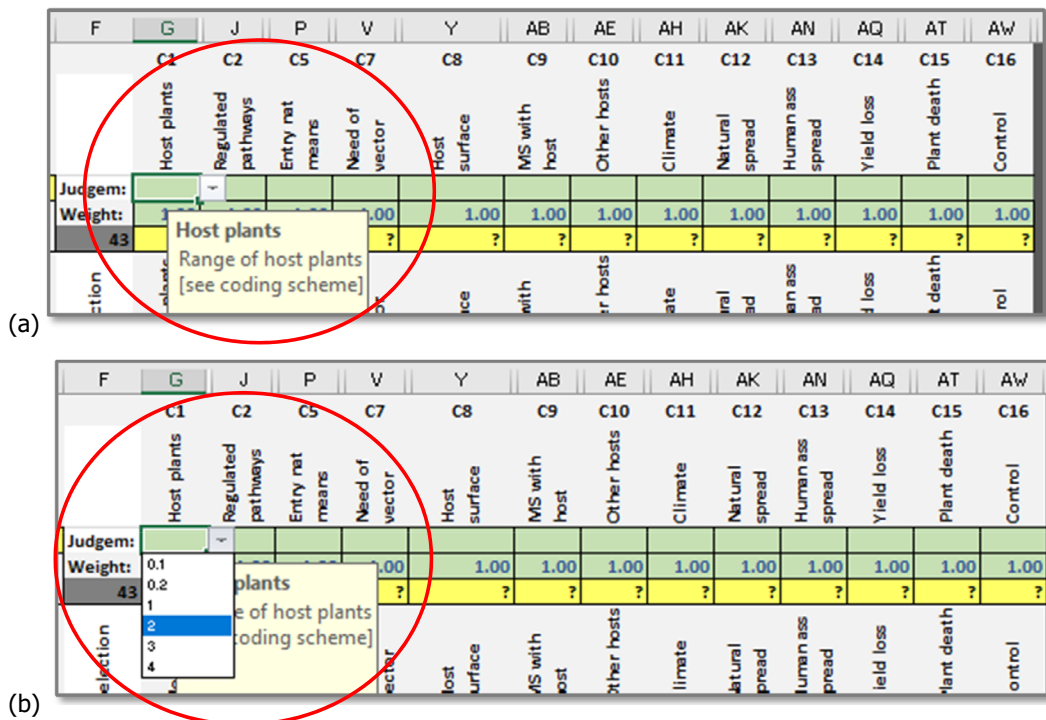


Figure I.3: Short description (a) and selection box (b) for the cells to enter the evaluation of different criteria, here the first criterion on host plants in cell "G1"

After entering a scoring for one criterion, the calculator performs the comparison of this criterion with all reference pests. The result is shown in the yellow result field below the input (Figure I.4):

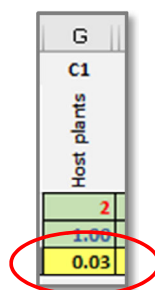


Figure I.4: Calculation of the criterion specific comparison of the new pest with the reference pests

This value is the average deviation of the evaluated criterion of the new from the reference pests. The value '+1' means maximum increased health threat in comparison to all reference pests, while the

value '1' indicates maximum decreased health threat in comparison to all reference pests. The value represents a combination of the criterion-specific scoring function and the distribution of this criterion in the set of reference pests.

For all given criteria, the PeMoScore is calculated as average score, as rank within the set of reference pest (from rank = 1 'highest health threat' to rank = 43 'lowest health threat'), and compared to the threshold classified as 'positive' (above the threshold of -0.083) or 'negative' (below or equal the threshold of -0.083) to be proposed as pest with health threats to plants in the EU (Figures I.5 and I.6). Please note that the interpretation of ranking and classification is only valid, when all criteria are completely evaluated.

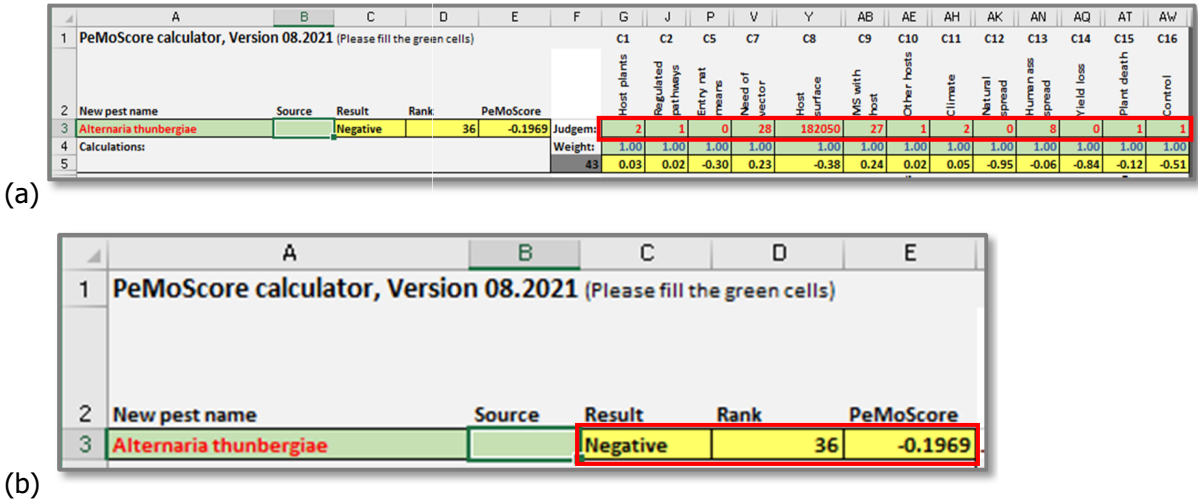


Figure I.5: Criterion specific comparisons of the pest under evaluation with the reference pests (a), and the average over all criteria, the PeMoScore (b). The ranking identifies the position of the pest under evaluation within the dataset of reference pests: from rank=1 'highest health threat' to rank=43 'lowest health threat'. Finally, the pest is classified as 'positive' (above the threshold of -0.083) or 'negative' (below or equal the threshold of -0.083) to be proposed as pest with health threats to plants in the EU

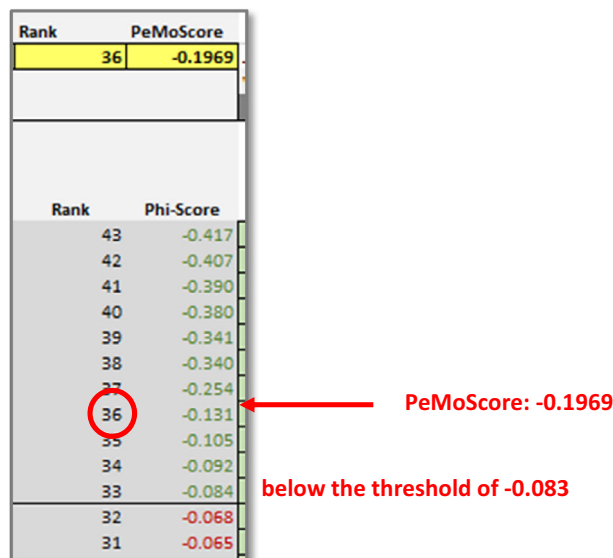


Figure I.6: Comparing the PeMoScore with the Phi-Scores of the reference dataset resulting in a rank of 36 and a negative classification for a probable health threat

The sensitivity of the PeMoScore can be easily tested by changing the evaluation of uncertain criteria. The results will be immediately adapted to the changed inputs.

Extensions

The PeMoScore Calculator includes some additional features. To activate some features, it is necessary to unprotect the sheet (no password required) and to unhide some rows and columns. For a pure calculation of the PeMoScore, it is not recommended to unprotect the sheet.

As the final score is calculated as weighted average of the specific evaluations, the weight per criterion can be adapted to different settings (Figure I.7). As weights all positive numbers and zero are allowed. A weight of zero will exclude the specific criterion. This is done for the fourth and sixth criteria, both are hidden (column 'M' and column 'S') in the normal view. A positive weight will identify the relative importance of the criteria for the final PeMoScore. The default setting is equal weighting of all relevant criteria. The ranking within the reference data set and comparison with the threshold is only valid for this default setting.

	F	G	J	P	V	Y	AB	AE	AH	AK	AN	AQ	AT	Aw
		C1	C2	C5	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
		Host plants	Regulated pathways	Entry rat means	Need of vector	Host surface	MS with host	Other hosts	Climate	Natural spread	Human ass spread	Yield loss	Plant death	Control
Judgem:		2	1	0	28	182050	27	1	2	0	8	0	1	1
Weight:		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
43					0.23	-0.38	0.24	0.02	0.05	-0.95	-0.06	-0.84	-0.12	-0.51

Figure I.7: Weights to express the relative importance of each criterium. The default setting is equal weighting

Similar to the criteria, the reference pests can be included ('1') or excluded ('0') from the comparison and calculation of the PeMoScore (Figure I.8). This can be done in the selection fields in column 'F' in the section with the reference pests. The default setting is the inclusion of all reference pests. The ranking within the reference data set and comparison with the threshold is only valid for this default setting.

	Reference pests	Classification	Rank	Phi-Score	Selection	Host plants	Regulated pathways	Entry rat means	Need of vector	Host surface	MS with host	Other hosts	Climate	Natural spread	Human ass spread	Yield loss	Plant death	Control	
10	Wild vitis virus 1	Negative	43	-0.417	1	0.2	0	0	0	3141300	21	1	2	1	8	0	0	1	
11	Margarodes floridanus	Negative	42	-0.407	1	0.2	1	0	0	991160	7	1	2	1	8	0	0	1	
43	Agrilus planipennis	Positive	10	0.130	1	0.2	1	1	28	283916	4	1	2	2	9	2	2	2	
44	Coniferiporia sulphurascens	Positive	9	0.143	1	2	1	0	28	54093372	14	1	2	1	10	2	2	2	
45	Bactericera cockerelli	Positive	8	0.143	1	0.2	1	0	28	2093610	28	1	2	2	9	1	2	2	
46	Dendrolimus sibiricus	Positive	7	0.178	1	0.2	1	1	28	60329588	21	1	2	1	11	1	2	2	
47	Spodoptera frugiperda	Positive	6	0.211	1	0.2	1	1	28	123884012	28	1	2	2	3	1	1	2	
48	Thaumatotibia leucotreta	Positive	5	0.231	1	0.2	1	0	28	33728236	28	1	2	2	10	2	1	2	

Figure I.8: Selection of the individual reference pest for comparison with the pest under evaluation

In the hidden lines 6–8 (Figure I.9), the parameters of the criterion-specific scoring functions are defined: the preference 'P' and indifference 'Q'. The type of scoring function is named, but not influenced by the entry.

	A	B	C	D	E	F	G	J	P	V	Y	AB	AE	AH	AK	AN	AQ	AT	AW	
1	PeMoScore calculator, Version 08.2021 (Please fill the green cells)							C1	C2	C5	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
2	New pest name	Source	Result	Rank	PeMoScore	Judgem:	Host plants	Regulated pathways	Entry net means	Need of vector	Host surface	MS with host	Other hosts	Climate	Natural spread	Human ass spread	Yield loss	Plant death	Control	
3	<i>Alternaria thunbergiae</i>		Negative	36	-0.1969	43	2	1	0	28	182050	27	1	2	0	8	0	1	1	
4	Calculations:						Weight:	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	Scoring function						43	0.03	0.02	-0.30	0.23	-0.38	0.24	0.02	0.05	-0.95	-0.06	-0.84	-0.12	-0.51
6	-Q: Indifference						V-shape	Usual	Usual	V-shape	Linear	Linear	Usual	Usual	Usual	V-shape	Usual	Usual	Usual	
7	-P: Preference						4.00				1000000	5.00					10.00			

Figure I.9: Parameter of the criterion specific scoring functions in the hidden lines 6 to 8

The calculation of the scoring functions per criterion and reference pest is done in two hidden lines following each criterion (Figure I.10). The calculation is divided in φ^+ (scores for the less risky reference pests) and φ^- (scores for the riskiest reference pests). The criterion-specific score is the difference of these parts: $\varphi^+ - \varphi^-$. To change the scoring functions, the corresponding cells have to be reprogrammed. The correct formulas can be found in Appendix H.

	A	B	C	D	E	F	G	H	I	
1	PeMoScore calculator, Version 08.2021 (Please fill the green cells)							C1		
2	New pest name	Source	Result	Rank	PeMoScore	Judgem:	Host plants			
3	<i>Alternaria thunbergiae</i>		Negative	36	-0.1969	43	2			
4	Calculations:						Weight:	1.00	Phi+	Phi-
5	Preference function						V-shape	0.03	0.19	0.16
6	-Q: Indifference									
7	-P: Preference						4.00			
9	Reference pests	Classification	Rank	Phi-Score	Selection	Host plants				
10	Wild vitis virus 1	Negative	43	-0.417	1	0.2	0.45	0.00		
11	Margarodes floridanus	Negative	42	-0.407	1	0.2	0.45	0.00		
12	Apple geminivirus	Negative	41	-0.390	1	0.2	0.45	0.00		
13	African cassava mosaic virus	Negative	40	-0.380	1	0.1	0.48	0.00		
14	Neomargarodes cucurbitae	Negative	39	-0.341	1	0.2	0.45	0.00		
15	Prunus geminivirus A	Negative	38	-0.340	1	0.2	0.45	0.00		
16	Apple hammerheadviroid	Negative	37	-0.254	1	0.2	0.45	0.00		

Figure I.10: Calculation of the scoring functions per criterion and reference pest in the two hidden columns following each criterion, here the first criterion (column "H" and "I") and the first seven reference pests (rows 10 to 16)