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Risk assessment of *Resseliella citrifrugis* for the EU

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Abstract

Following a request from the European Commission, the EFSA Panel on Plant Health performed a risk assessment of the citrus fruit midge *Resseliella citrifrugis* (Diptera: Cecidomyiidae), an oligophagous species, which feeds on fruits of *Citrus* spp., and is reported from China. The pest was temporarily regulated in October 2022 (Regulation (EU) 2022/1941, under Art. 30 (2016/2031)). The entry risk assessment focused on the citrus fruit pathway. Three scenarios were considered: A0 (current practice, i.e. regulated pest for the EU), A1 (deregulation) and A2 (A0 with additional stand-alone post-harvest cold treatment). Based on the outputs of the entry model, under scenario A0, slightly less than 40 potential founder populations per year are expected (median; 90%-uncertainty interval between about one per 30 years and about 3,000 per year). Under scenario A1, the risk of entry increases by about three times and reaches about 120 potential founder populations per year (median; 90%-uncertainty interval between about one per 10 years and about 9,000 per year). Compared to scenario A0, the risk of entry is orders of magnitude lower for scenario A2 (median = about one potential founder population per 120 years; 90%-uncertainty interval between one per about 600 million years and about two per year). The main uncertainties in the entry assessment are the probability of transfer, the RRO effectiveness (for scenario A2) and the disaggregation of consignments (transport of citrus fruit in boxes or lots to different locations). For all scenarios, the number of established populations is only slightly lower than the number of potential founder populations. Establishment is thus not expected to be a major constraint for this pest to then spread and cause impacts, despite the uncertainty about the pest thermal requirements. The median lag period between establishment and spread is estimated to be about 18 months (90%-uncertainty interval between about 7 and 54 months). After the lag period, the median rate of spread by flying and due to transport of harvested citrus fruit from orchards to packinghouses is estimated at about 100 km/year (90%-range between about 40 and 500 km/year). The main uncertainties in the spread assessment include the level of susceptibility of cultivars of different citrus species in the EU, the spread rate in China and the climate suitability of the initial spread focus in the EU. The median impact of *R. citrifrugis* in the EU citrus-growing area (proportion of infested citrus fruit out of harvested citrus fruit) is estimated at about 10% (90%-uncertainty interval between about 2% and 25%). Uncertainties affecting the impact assessment include the susceptibility of different citrus cultivars and the effect of the citrus fruit-harvesting season in the EU (mainly winter, the less suitable season for the pest).

Keywords: pathway model, pest prevalence, phytosanitary measures, risk assessment, uncertainty

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Summary

Following a request from the European Commission, the EFSA Plant Health Panel performed a risk assessment of the citrus fruit midge, *Resseliella citrifrugis* Jiang (Diptera: Cecidomyiidae) for the EU. This oligophagous species, which feeds on fruits of *Citrus* spp., is reported from China. The pest was temporarily regulated in October 2022 (Regulation (EU) 2022/1941, under Art. 30 (2016/2031)).

The only entry pathway quantified in this assessment is the EU import of citrus fruit from China. While *R. citrifrugis* has been intercepted mainly on pomelo (*Citrus maxima*), the Panel cannot exclude other *Citrus* spp. as entry pathway. Three scenarios were considered for the entry assessment: scenario A0 (current practice, i.e. regulated pest), scenario A1 (deregulation) and scenario A2 (regulated pest status with additional stand-alone post-harvest cold treatment). The control option studied in scenario A2 was chosen among several possible measures.

The entry pathway is modelled by estimating the number of potential founder populations per year in the EU citrus-growing area. The model takes into account prevalence at the origin, trade flow of citrus fruit, sorting, disaggregation of consignments (transport of citrus fruit in boxes or lots to different locations), transfer and (for scenario A2 also), the effectiveness of post-harvest cold treatment.

Based on the outputs of the entry model, under scenario A0, slightly less than 40 potential founder populations per year are expected (median; 90%-uncertainty interval between about one per 30 years and about 3,000 per year).

The risk of entry increases under scenario A1 by about three times to about 120 potential founder populations per year (median; 90%-uncertainty interval between about one per 10 years and about 9,000 per year).

Compared to both scenarios A0 and A1, the risk of entry is orders of magnitude lower for scenario A2 (median = about one potential founder population per 120 years; 90%-uncertainty interval between one per about 600 million years and about two per year).

The uncertainty is larger for scenario A2 (the 90%-uncertainty range spans nine orders of magnitude) compared to scenarios A0 and A1 (the 90%-uncertainty range spans five orders of magnitude). In all scenarios, the uncertainty in the model outcome is due to combining the uncertainties of the model parameters. The main uncertainties in the entry assessment are the probability of transfer, the RRO effectiveness (for scenario A2) and the disaggregation of consignments (a parameter reflecting the distribution of one ton of infested citrus fruit to different locations in the risk assessment area).

When including the probability of establishment in the model, under scenario A0 (current practice, i.e. regulated status), model simulations lead to a median of about 15 established populations per year (90%-uncertainty range between about one every 110 years and about 1,500 per year).

Under scenario A1 (deregulation), the risk of establishment increases by about three times to a median of about 46 established populations per year (90%-uncertainty range between about one every 30 years and about 4,400 per year).

Under scenario A2 (regulated status with additional RRO), a median of about one established population every 90 years (90%-uncertainty range between about one every two billion years and about seven per year) is expected.

For all scenarios, the number of established populations is only slightly lower than the number of potential founder populations. This implies that establishment is not expected to be a major constraint for this pest to then spread and cause impacts.

As is the case in the entry model, the risk of establishment is reduced under scenario A2 compared to scenario A0, but not eliminated, as cold treatment might not be fully effective.

The main uncertainties in the establishment assessment are the probability of transfer, the disaggregation of consignments and, for scenario A2, the effectiveness of the RROs.

The median lag period between establishment and spread, defined as the time needed for a founder population to build up to a density enabling the colonisation of a neighbouring orchard, is estimated for *R. citrifrugis* to be about 18 months (90%-uncertainty interval between about 7 and 54 months).

After the lag period, the median spread rate by natural means (flying) and due to transport of harvested citrus fruit from orchards to packinghouses (part of common agricultural practices) is estimated at about 100 km/year (90%-uncertainty interval between about 40 and 500 km/year).

The main uncertainties affecting the assessment of the lag period include climatic conditions disrupting or delaying establishment in new areas and unknown differences in susceptibility of citrus

cultivars grown in the EU. The main uncertainties affecting the assessment of the spread rate include the lack of available data about the spread rate in China and the climate suitability of the initial spread focus in the EU.

The median impact of *R. citrifrugis* in the EU citrus-growing area (proportion of infested citrus fruit out of the harvested citrus fruit) is estimated at about 10% yield loss (90%-uncertainty interval between about 2% and 25%).

Uncertainties affecting the impact assessment include the susceptibility of different *Citrus* cultivars and the effect of the citrus fruit-harvesting season in the EU (mainly winter, the less suitable season for the pest).

Despite the uncertainties, this PRA confirms the potential for entry, establishment, spread and impact of *R. citrifrugis* in the EU.

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1. Introduction

1.1. Background and terms of reference as provided by the requestor

1.1.1. Background

The new Plant Health Regulation (EU) 2016/2031, on the protective measures against pests of plants, is applying from 14 December 2019. Conditions are laid down in this legislation in order for pests to qualify for listing as Union quarantine pests, protected zone quarantine pests or Union regulated non-quarantine pests. The lists of the EU regulated pests together with the associated import or internal movement requirements of commodities are included in Commission Implementing Regulation (EU) 2019/2072. Additionally, as stipulated in the Commission Implementing Regulation 2018/2019, certain commodities are provisionally prohibited to enter in the EU (high risk plants, HRP). EFSA is performing the risk assessment of the dossiers submitted by exporting to the EU countries of the HRP commodities, as stipulated in Commission Implementing Regulation 2018/2018. Furthermore, EFSA has evaluated a number of requests from exporting to the EU countries for derogations from specific EU import requirements.

In line with the principles of the new plant health law, the European Commission with the Member States are discussing monthly the reports of the interceptions and the outbreaks of pests notified by the Member States. Notifications of an imminent danger from pests that may fulfil the conditions for inclusion in the list of the Union quarantine pest are included. Furthermore, EFSA has been performing horizon scanning of media and literature.

As a follow-up of the above mentioned activities (reporting of interceptions and outbreaks, HRP, derogation requests and horizon scanning), a number of pests of concern have been identified. EFSA is requested to provide scientific opinions for these pests, in view of their potential inclusion in the lists of Commission Implementing Regulation (EU) 2019/2072 and the inclusion of specific import requirements for relevant host commodities, when deemed necessary.

1.1.2. Terms of reference

EFSA is requested, pursuant to Article 29(1) of Regulation (EC) No 178/2002, to provide scientific opinions in the field of plant health.

EFSA is requested to deliver 50 pest categorisations for the pests listed in Annex 1A, 1B and 1D. Additionally, EFSA is requested to perform pest categorisations for the pests so far not regulated in the EU, identified as pests potentially associated with a commodity in the commodity risk assessments of the HRP dossiers (Annex 1C). Such pest categorisations are needed in the case where there are not available risk assessments for the EU.

When the pests of Annex 1A are qualifying as potential Union quarantine pests, EFSA should proceed to phase 2 risk assessment. The opinions should address entry pathways, spread, establishment, impact and include a risk reduction options analysis.

ANNEX 1 List of pests.

A)

1) *Amyelois transitella*
2) *Citripestis sagittiferella*
3) *Colletotrichum fructicola*
4) *Elasmopalpus lignosellus*
5) *Phlyctinus callosus*
6) *Resseliella citrifrugis*
7) *Retithrips syriacus*
8) *Xylella taiwanensis*

1.2. Interpretation of the terms of reference

1.2.1. Pest categorisation

The EFSA Panel on Plant Health (hereafter Panel) published a pest categorisation on the citrus fruit midge, *R. citrifrugis* (EFSA PLH Panel, 2021a), which concluded that the pest met the criteria for consideration as Union quarantine pest. The reader is referred to that document for information on the identity, biology, detection and identification, pest distribution, entry, establishment, spread and impacts of the pest. Information provided in the pest categorisation is not repeated here, unless required for the purposes of this risk assessment.

1.2.2. Interpretation of the terms of reference

The Panel interpreted the Terms of Reference as a request to perform a risk assessment on *R. citrifrugis*. All the steps (entry, establishment, spread and impact) of the PRA are to be developed. The pest was temporarily regulated in October 2022 (Regulation (EU) 2022/1941, under Art. 30 (2016/2031)) on the basis of the pest categorisation (EFSA PLH Panel, 2021a).

2. Data and methodologies

2.1. Data

A literature search on *R. citrifrugis* was conducted at the beginning of the risk assessment (May 2022) in the ISI Web of Science bibliographic database, using the scientific and common (citrus fruit midge) names of the pest as search terms, to retrieve relevant information and data appeared since the publication of the EFSA pest categorisation on this pathogen (EFSA PLH Panel, 2021a). Relevant papers were reviewed and further references and information from the Chinese literature were obtained from experts, as well as from citations within the references and grey literature.

Information on the pest distribution was retrieved from the EPPO Global Database (EPPO, 2023) and relevant literature (Rossi et al., 2023).

Data on interceptions and outbreaks of the pest within the risk assessment area were searched in the Europhyt and Traces databases.

For this opinion, the following additional data were searched:

- Data on the prevalence of *R. citrifrugis* in China.
- Data on the EU import of citrus fruit from China.
- Data on the transfer rate of the pest.
- Data on the effectiveness of risk reduction options (RROs) targeting this pest.

2.2. Methodologies

The Panel performed this risk assessment following the Panel's guidance on quantitative pest risk assessment (EFSA PLH Panel, 2018).

Entry via trade in imported citrus fruit was assessed using pathway modelling in @Risk (https://www.palisade.com/risk/default.asp).

Expert elicitation was used to estimate model input numbers for each substep of the pathway model.

2.2.1. Specification of the scenarios

The following scenarios were considered:

Entry:

- Scenario A0 (regulated pest; the pest was regulated in October 2022 (Regulation of 13 Oct 2022 (EU) 2022/1941)).
- Scenario A1 (unregulated pest)
- Scenario A2 (regulated pest with additional RRO)

The additional RRO is a stand-alone post-harvest cold treatment (see Section 2.2.3).
Establishment:

- Scenario A0 (regulated pest)
- Scenario A1 (unregulated pest)
- Scenario A2 (regulated pest with additional RRO)

Spread:

- The elicitations (of the lag period and spread rate) apply to the EU citrus-growing area, assuming that human-assisted spread between citrus orchards is excluded by perfect sanitary measures or prohibited exchange of tools/workers, but taking into account the possible movement of harvested citrus fruit from orchards to packinghouses, as this is part of common agricultural practices.

Impact:

- The elicitation of the yield loss applies to the EU citrus-growing area, once the pest has spread to its entire extent.

2.2.2. Conceptual model and definitions

2.2.2.1. Definition of the pathways

The only pathway of entry considered in the model was citrus fruit. While *R. citrifrugis* has been intercepted mainly on pomelo (*Citrus maxima*), the Panel cannot exclude other *Citrus* spp. as an entry pathway (EFSA PLH Panel, 2021a). Indeed, this insect has been reported on different *Citrus* spp., including sweet orange (*C. sinensis*), mandarin (*C. reticulata*) and trifoliate orange (*Poncirus trifoliata*) in addition to *C. maxima* (= *C. grandis*) (Xia et al., 2021). No reliable data were found on differences in prevalence on different *Citrus* spp. and cultivars (laboratory and field studies of host preferences are not consistent; Xia et al., 2021); thus, all *Citrus* spp. and cultivars were considered together in one single pathway.

Other potential entry pathways for *R. citrifrugis* are *Citrus* spp. plants for planting with fruit and soil/growing media. As these pathways are closed (EFSA PLH Panel, 2021a), they were not quantified.

2.2.2.2. Conceptual model

The entry pathway was modelled by estimating the number (per year) of potential founder populations (i.e. pest-host encounters in the EU territory) of *R. citrifrugis* in the EU due to import of citrus fruit from China. The calculation took into account the parameters listed in Table 1 (prevalence at the origin, trade flow, sorting, disaggregation of consignments and transfer). The principle of this model is to compute the quantity of infested fruits that is able to enter into the EU and to produce founder populations that may then establish, spread and have impacts.

2.2.2.3. Formal model

The following pathway model was implemented,

$$N_{inf} = N_{trade} \times p_{prevalence} \times (1 - p_{sorting}) \times (1 - RRO_{effectiveness}) \times d \times p_{transfer},$$

where the meaning and the units of the output and inputs are defined in Table 1.

Note that one of the input parameters is a disaggregation of consignments factor (d) used to disaggregate the infested material entering into the EU to different locations in the risk assessment area, as in previous Panel PRAs (EFSA PLH Panel, 2017, 2022, 2023). For example, for $d = 1$, one ton of citrus fruit is delivered to one location, whereas if $d = 2$, one ton of citrus fruit is delivered to two locations (in consignments of 500 kg each). Because of this factor, one ton of infested citrus fruit can lead to several potential founder populations.

The product $N_{trade} \times d$ represents the number of pathway units imported where pathway units in the terminology of the panel's guidance on quantitative risk assessment (EFSA PLH Panel, 2018) represent the units in which the product is imported and distributed across the EU. The assumption is that one pathway unit can give rise to one potential founder population, but not more. $p_{transfer}$ represents the probability that an infested pathway unit results in a potential founder population.

An assumption was made of homogeneity in the infestation of the pathway units. Material from different orchards will tend to be mixed in packinghouses with citrus fruit from regions with higher and lower pest prevalence. Moreover, in the field, infested citrus fruit will tend to be discarded, thus leading to more homogeneous fruit batches in packing houses, particularly those for export.

In scenario A2, an additional input factor ($RRO_{effectiveness}$) is used to account for the effectiveness of the RRO (stand-alone post-harvest cold treatment). In scenario A0, this factor is set to zero.

Table 1: Definitions of the output variable (N_{inf}) and input parameters used in the entry model (pathway citrus fruit)

Name	Description	Units
N_{inf}	Number of potential founder populations of *R. citrifrugis*	Number of potential founder populations per year
N_{trade}	Total quantity of citrus fruit (infested or not) imported by the EU from China	Tons (1,000 kg) per year
$p_{prevalence}$	Prevalence of *R. citrifrugis* at the origin where citrus fruit is harvested for export to the EU (expressed as the proportion of infested citrus fruit to all citrus fruit harvested in the areas considered)	Proportion of fruit
$p_{sorting}$	Proportion of infested citrus fruit removed following pre-export inspection (identification and removal of infested fruits before entry in the EU)	Proportion of fruit
$RRO_{effectiveness}$	Reduction in the proportion of infested citrus fruit with post-harvest cold treatment	Proportion of fruit
d	Disaggregation of consignments factor, reflecting the distribution of one ton of infested citrus fruit to several locations in the risk assessment area	Number of batches of citrus fruit/ton
$p_{transfer}$	Probability that the pest in one disaggregated batch of citrus fruit (a pathway unit) is transferred to suitable hosts, thus leading to a potential founder population	Probability of transfer

The entry model includes five input parameters in scenario A0 (six in scenario A2).

The output variable of the establishment model (N_{est}) is defined in Table 2 and obtained through the following equation using an additional parameter, p_{estab}:

$$N_{est} = N_{inf} \times p_{estab}.$$

Table 2: Definition of the output variable (N_{est}) and of the probability of establishment

Name	Definition	Units
N_{est}	Number of *R. citrifrugis* populations established in the EU	Number of established populations per year
p_{estab}	Probability that one potential founder population (from a successful entry) will establish.	Probability

Five quantiles were provided for each parameter based on data and expert judgement, following EFSA guidance on expert knowledge elicitation and uncertainty (EFSA, 2014, 2019). In short, experts elicit five quantiles for each parameter (1%, 25%, 50%, 75% and 99%) and a theoretical probability distribution is then fitted to these quantiles for each parameter, using least squares in @Risk. The fitted distributions reflect the level of plausibility of possible values of the different parameters.

The pathway model was run using Monte Carlo simulation, by repeatedly (10,000 times) drawing random realisations out of the elicited distributions for the input parameters and calculating the resulting 10,000 values of the output variable representing the number of potential founder (N_{inf}) (entry model; see Section 3.2.2) and established founder (N_{est}) (establishment model; see Section 4.2.6) populations per year in the EU as a result of import of infested units.

The model was run separately for scenarios A0, A1 and A2 (see Section 2.2.3). The model was implemented in @Risk (see Supplementary Information – Annex A).

2.2.2.4. Ecological factors and conditions in the chosen scenarios

The risk assessment was performed under current ecological factors and conditions for the citrus-growing areas of the EU (risk assessment area) and countries of origin.

2.2.2.5. Temporal and spatial scales

The risk assessment area was the EU territory.

The temporal horizon considered for the risk assessment was 10 years (2024–2034). This temporal horizon delimits the scope of the parameter elicitations done by the Panel. Entry was considered as a separate process for each year. No time-cumulative processes were accounted for in the entry model, but this was included in the spread model.

2.2.3. Potential risk reduction options

According to Xia et al. (2021), effective pest management programs for citrus in China taking into account *R. citrifrugis* have not been established yet. However, USDA (2020) recognised that effective programs for the control of *R. citrifrugis* in China existed. These opposite views between Xia et al. (2021) and USDA (2020) may be attributed to:

i) differences in the definition of what 'effective programs' are
ii) the limitations (e.g. small sample size) of the experiments on the efficacy of different RROs against *R. citrifrugis* available from China, which make the results of these experiments inconclusive (see some examples below).
iii) the lack of species-specific lures for this midge, which hampers:

- the effective detection/monitoring of adults of *R. citrifrugis*, as well as
- the use of other effective measures available against other citrus dipteran pests (i.e. tephritid fruit flies) like mass trapping or lure and kill (Cruz-Miralles et al., 2022; He et al., 2023).

The measures currently available to control *R. citrifrugis* can be split between preharvest and post-harvest measures, which could be combined in a systems approach.

2.2.3.1. Preharvest measures

According to USDA (2020) and Xia et al. (2021), there are the following options:

- Grove sanitation and soil insecticide treatments

Because *R. citrifrugis* pupates in the soil, removing infested fruits from the ground and treating the soil with insecticides should be effective in managing *R. citrifrugis*. These measures could be particularly effective against the overwintering generation (Xia et al., 2021).

- Fruit bagging

Fruit bagging is effective against fruit pests such as fruit flies (Xia et al., 2021). However, the timing of bagging (early) seems critical to successfully manage *R. citrifrugis*. USDA (2020) considered bagging in combination with the requirements for low pest prevalence in production areas to be effective at preventing fruit fly infestations in citrus fruit imported into the US from China.

- Foliar insecticide sprays

According to Xia et al. (2021), foliar insecticide sprays are the most common management option against *R. citrifrugis*. Multiple applications per year, usually a mix of organophosphate and pyrethroid insecticides targeting all citrus pests, are used in citrus groves across China. Field assessments of the efficacy of insecticides for the management of *R. citrifrugis* showed efficacies higher than 90%. However, the small size of the plots used and limitations in the experimental design and statistical analysis, make these assays difficult to interpret. Yu (2009, cited in Xia et al., 2021) conducted a laboratory study to compare the efficacy of different insecticides against adults of *R. citrifrugis*. All insecticides were effective, but the experiment included three replicates of 10 adults in a vial per treatment only.

- Biological control

According to Xia et al. (2021), a literature search did not reveal any research on natural enemies or biological control of *R. citrifrugis*, although a few extension publications mentioned that parasitoids, ants and spiders are among the natural enemies of the pest. Pupae of *R. citrifrugis* are most probably fed upon by soil-dwelling generalist predators (i.e. beetles, earwigs, spiders, ants), which are common in citrus orchards. Their activity and abundance can be enhanced by proper management of the ground cover (Cruz-Miralles et al., 2022). Moreover, soil treatments with entomopathogenic fungi and nematodes, which have been successfully used against soil-dwelling stages of other pests, including fruit flies (Yousef et al., 2018) could be effective also against *R. citrifrugis*.

2.2.3.2. Post-harvest measures

- Culling at the packinghouse

This is a standard industry practice which removes all obviously blemished, diseased and insect-infested and infected fruits from the pathway (USDA, 2020).

- Cold treatment

Chen (2010, cited in Xia et al., 2021) studied the efficacy of a cold treatment. According to their results, fourth-instar larvae were the most cold-tolerant stage. A temperature of 2°C for 12 days was lethal for all fourth instars. However, this study has important limitations as the number of larvae used in the experiment was extremely small, only 100, in just two pomelo fruits which were compared with the control.

Mexico considers *R. citrifrugis* as a quarantine pest and requires citrus fruit imported from China to be subjected to a temperature lower than (a) 1.11°C for 14 days, (b) 1.67°C for 16 days or (c) 2.22°C for 18 days (Anonymous, 2014). These requirements are not specific to *R. citrifrugis* but are in place to avoid the introduction of a number of citrus pests.

A stand-alone post-harvest cold treatment was chosen to be studied as potential additional RRO for this PRA, given the requirements currently in place for citrus fruit imported from China to Mexico, the feasibility of the measure and the available knowledge on the thermal biology of *R. citrifrugis* and other better studied, more thermophilic citrus pests. The opinion does not aim to obtain cold treatment conditions to be implemented in the import trade. Thermal treatments in place for more thermophilic citrus pests could be implemented provisionally, to be specifically studied for *R. citrifrugis* in detail.

- Irradiation

An alternative treatment to mitigate risk in citrus for fruit flies is irradiation at 150 Gy, which is approved for all Tephritidae by the USDA (Follett, 2009). Indeed, a minimum absorbed dose of 100 Gy was established in ISPM28 against *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae) (FAO, 2017). However, there is no information on the efficacy of this treatment against *R. citrifrugis*.

2.2.3.3. Systems approach

USDA identified *R. citrifrugis* as one of 15 quarantine pests associated with fresh citrus fruits from China and established a systems approach for mitigating risk (USDA, 2020). This systems approach includes general requirements, such as a treatment against fruit flies or a phytosanitary certificate, the establishment of areas of low pest prevalence, or inspection including fruit cutting and cold treatment.

Note that the effectiveness of post-harvest cold treatment as RRO is studied quantitatively in this PRA as a stand-alone measure, not as part of a systems approach. However, post-harvest cold treatment could obviously be part of a systems approach too.

3. Entry

This section presents background information, including the evidence dossier used for the elicitation of the model parameters. The scenarios used for the entry assessment are then recapitulated and the results presented. The main uncertainties are described, and an assessment of the overall uncertainty and of the dependencies among parameters is included. In the EKEs for *R. citrifrugis*, the PRA on the citrus fruit borer, *Citripestis sagittiferella* (Moore) (Lepidoptera: Pyralidae) (EFSA PLH Panel, 2023) was used in a comparative approach by the panel of experts.

3.1. Background information

3.1.1. Pest prevalence at the origin ($p_{prevalence}$)

The available literature suggests that *R. citrifrugis* is present in the major citrus-growing areas in China (Xia et al., 2021). The pest was reported to be present in several provinces in China, i.e. Fujian, Gansu, Guangdong, Guangxi, Guizhou, Hubei, Hunan, Jiangxi and Sichuan (USDA, 2017; Xia et al., 2021; EFSA PLH Panel, 2021a). *R. citrifrugis* was reported to infest several species of citrus, including pomelo (*C. maxima*), sweet orange (*C. sinensis*), mandarin (*C. reticulata*) and trifoliate orange (*Poncirus trifoliata*) (Chen and Jiang, 2000, cited in Xia et al., 2021). Whether the pest has a preference for some host species or cultivars is uncertain (Xia et al., 2021).

A survey of 29 small orchards in Gangzhou, Jiangxi Province, suggests that pest prevalence (fruit infestation rate) is variable, ranging from 1% to 43%, with a median of 12% (Figure 1). Other data sources report higher levels of fruit infestation, sometimes above 80% (Xia et al., 2021).

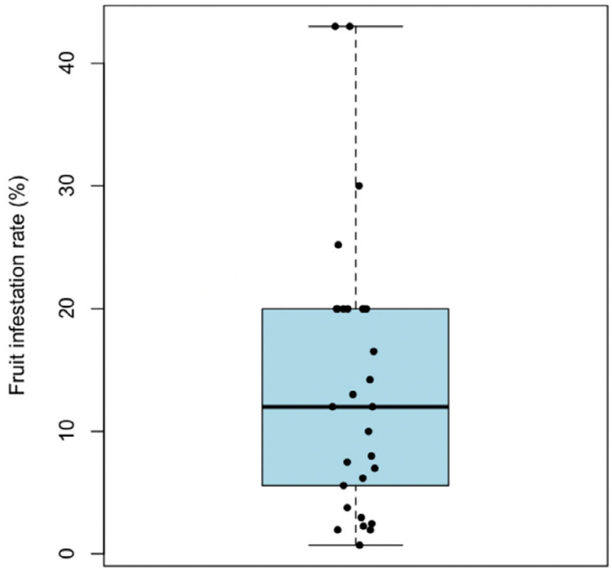

Figure 1: Prevalence of *Resseliella citrifrugis* as the rate (%) of citrus fruit infestation measured in a survey of 29 small orchards in Gangzhou, Jiangxi Province, China. Boxplot reports minimum, 1st quartile, median, 3rd quartile and maximum values. Points indicate individual observations. Data from table 5 of Xia et al. (2021)

3.1.2. Trade flow (N_{trade})

Data on yearly citrus fruit EU import from China (2016–2020) were extracted from EUROSTAT (Table 3). In the period 2016–2020, between about 83,000 and 110,000 tons of citrus fruits were imported per year into the EU (27) from China. The Netherlands is a major entry point in the EU and accounted for about 70% of EU imports of citrus fruit from China (2016–2020). Adults of *R. citrifrugis* are unlikely to be carried by fruit because adults would fly off when disturbed during harvesting and processing for shipment, and are short-lived (1–2 and 2–4 days for males and females, respectively, Huang et al., 2001). *R. citrifrugis* is most likely to move in international trade as immature stages in fruit (eggs and larvae) (EFSA PLH Panel, 2021a).

Table 3: Citrus fruit EU import from China (2016–2020) (in tons). Source: EUROSTAT, accessed February 2023

Year	2016	2017	2018	2019	2020	Average
China	82,784	108,485	102,416	110,859	109,868	102,882

3.1.3. Sorting ($p_{sorting}$)

Larvae of *R. citrifrugis* are small (up to 4 mm long for last instar larvae; EFSA PLH Panel, 2021a) and difficult to detect (Xia et al., 2021). Infestation can cause symptoms on fruit, including dark colour of entrance holes, exuding liquid, uneven yellow and brown spots on the outer layer, deformed fruit and rotting (EFSA PLH Panel, 2021a). However, damage by the pest is not always easily detected, reducing the effectiveness of harvest and post-harvest sorting and inspection at port of exit/entry (Xia et al., 2021). Although an EPPO protocol for the inspection of citrus fruit consignments is available (EPPO, 2020), it is unclear how inspection is done at the origin. In addition to the 11 interceptions of *R. citrifrugis* (December 2020–January 2021) reported in the pest categorisation (EFSA PLH Panel, 2021a), 11 additional interceptions were retrieved from the Traces database (November 2021–January 2023) in February 2023, with both sets of interceptions on pomelo fresh fruit imported from China. The several recent interceptions show that infested fruit can escape harvest and post-harvest sorting.

In relation to scenario A1 (deregulation), it should be noted that Commission Implementing Regulation (EU) 2021/2285 amended Implementing Regulation (EU) 2019/2072 in its Annex VII with a list of plants, plant products and other objects, originating from third countries and the corresponding special requirements for their introduction into the EU. In the case of fruits of *Citrus* L., *Fortunella* Swingle, *Poncirus* Raf. and their hybrids originating from areas in third countries where Tephritidae (i.e. fruit flies) are present, such as China, the Regulation lays down that no signs of Tephritidae to which those fruits are known to be susceptible, have been observed at the place of production and in its immediate vicinity since the beginning of the last complete cycle of vegetation, on official inspections carried out at least monthly during the 3 months prior to harvesting, and none of the fruits harvested at the place of production has shown, in appropriate official examinations, signs of the relevant pest and information on traceability is included in the phytosanitary certificate. ISPM 10 establishes the general requirements for the establishment of pest-free places of production, but without indicating operational details such as level of detection and sample size. Nevertheless, the damage produced by *R. citrifrugis* is less conspicuous than the one due to fruit flies. Thus, inspection for the presence of fruit flies is not likely to change substantially the probability of sorting for *R. citrifrugis*.

For scenario A0, the current situation is that *R. citrifrugis* is a regulated pest for the EU, and therefore, inspectors are more focused on this pest, so a higher number of notifications and consignment rejection is expected.

3.1.4. Transfer rate ($p_{transfer}$)

Because the species *R. citrifrugis* was not named until the early 1990s (and is still awaiting proper description, EFSA PLH Panel, 2021a), it is difficult to determine where, when and how the pest originated within China (Xia et al., 2021). The literature indicates that outbreaks of *R. citrifrugis* occurred in Guangxi as early as the 1970s, but the reliability of the early reports was questioned by Xia et al. (2021).

According to Xia et al. (2021), the pest can disperse over short distances by larval jumping and wind, and over long distances by long-range migration, human-assisted dispersal such as trade and human movement, and wind. However, no rigorous dispersal studies on the pest are available (Xia et al., 2021).

Despite the lack of available scientific studies, the transfer of the insect to host plants in the EU is facilitated because the insect can infest different *Citrus* spp. (Xia et al., 2021). Moreover, citrus fruit packinghouses are often close to citrus orchards in the EU, especially in Spain. In addition, although imports of citrus fruits from China to the EU are low during late spring and summer, they can reach high levels during early autumn, when citrus fruit still have to be harvested in EU citrus-growing areas and temperatures are still suitable for pest development (Figure 2).

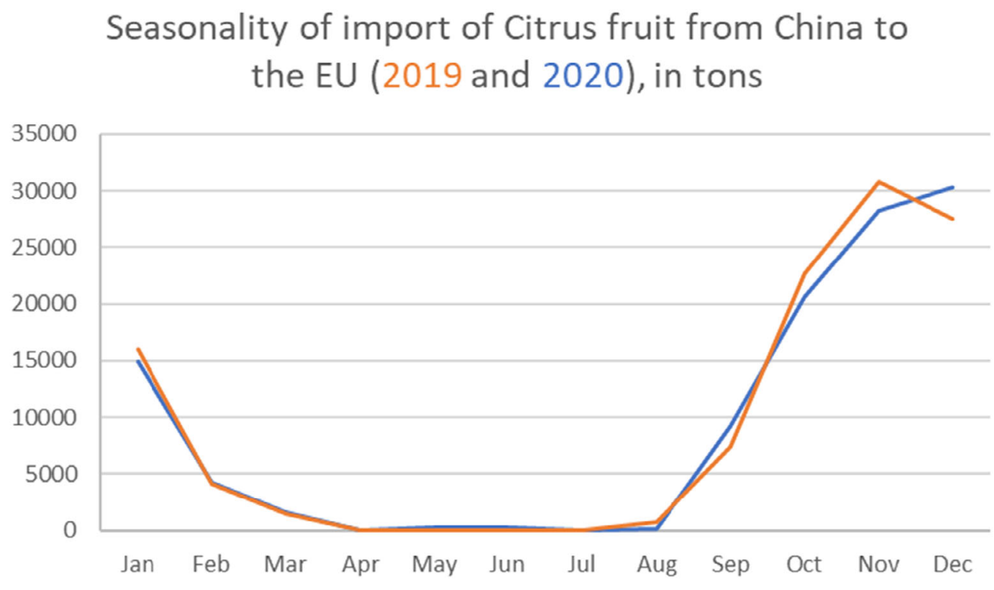

Figure 2: Seasonality of import of citrus fruit from China to the EU (2019 (orange) and 2020 (blue), data from EUROSTAT)

3.2. Entry assessment

3.2.1. Scenario recapitulation

The following scenarios for entry were considered:

- Scenario A0 (regulated pest)
- Scenario A1 (unregulated pest)
- Scenario A2 (regulated pest with additional RRO)

The additional RRO is a post-harvest cold treatment.

The current practice scenario was named A0 and the deregulation scenario was named A1 to be consistent with previous EFSA PRAs (e.g. EFSA PLH Panel, 2016, 2019b).

3.2.2. Definition of the input parameters and elicitation of their distributions

3.2.2.1. Prevalence at the origin

The prevalence at the origin ($p_{prevalence}$) is defined in Table 4.

Table 4: Definition of the parameter prevalence at the origin ($p_{prevalence}$)

Name	Definition	Sources
$p_{prevalence}$	Prevalence of *R. citrifrugis* at the origin (China) (expressed as the proportion of infested citrus fruit to all citrus fruit harvested in the areas considered)	Literature (see Section 3.1.1) and expert knowledge (see justification below)

The elicited distribution of the prevalence at the origin is reported in Table 5 and Figures 3 and 4.

Table 5: Elicited quantiles of prevalence (proportion of infested fruit) at the origin $p_{prevalence}$ (scenarios A0, A1 and A2)

Quantile	1%	25%	Median	75%	99%
A0	0.5%	5%	10%	15%	50%
A1	1%	10%	20%	30%	50%
A2	0.5%	5%	10%	15%	50%

Justification:
Scenarios A0 and A2:

The regulation of the pest should lead to reduction of prevalence (assessed with a reduction factor of two) compared to the A1 scenario (i.e. the situation before October 2022 without regulation). The current regulation of this insect should favour the development of specific measures targeting *R. citrifrugis* not available yet (including specific monitoring traps and treatments), particularly in orchards for export. Moreover, in order to avoid rejection following inspection, it is expected that exporters will collect fruits in orchards with lower pest prevalence. The Panel kept the upper boundary as 50% (same as A1) because it is uncertain whether the prevalence will be actually reduced during the time horizon of the assessment by the newly acquired regulated status of the pest in the EU (October 2022).

Scenario A1:

For the 99% value, it was considered that in some countries and some very favourable years, fruit flies can infest the majority of citrus fruit. Considering that *R. citrifrugis* is not a fruit fly, a 50% prevalence as worst situation is plausible.

Following the comparative approach described above (Section 3), for the 1% value, it was considered that the pest is not a strong flyer as the moth *C. sagittiferella* (EFSA PLH Panel, 2023), so it could take more time for the foci to expand and uniformly infest orchards as *C. sagittiferella* could do. Also, *C. sagittiferella* is a tropical pest breeding all year round, whereas *R. citrifrugis* is a temperate pest with an overwintering period, thus probably relatively less aggressive.

For the median, it was considered that there are better data for the fruit infestation rate of *R. citrifrugis* compared to *C. sagittiferella*, demonstrating the impact on several *Citrus* spp. However, there is uncertainty on whether the reported values (Xia et al., 2021) are representative for the whole of the infested area in China, or reflect the situation in most severely damaged orchards. Higher damage is to be expected where the pest is able to have more generations (up to 4 in China; Xia et al., 2021).

R. citrifrugis causes fruit drop (leading to fruit downgrading – this fruit is not harvested and thus not considered in the elicitation), but not all infested fruit fall. At the same time, the pest is less easy to detect compared to *C. sagittiferella*. However, there can be hundreds of larvae of *R. citrifrugis* per fruit, an order of magnitude higher than what was reported for *C. sagittiferella* (EFSA PLH Panel, 2023).

If bagging is consistently applied, then the pest prevalence could be lowered. Exporting orchards will tend to be large, and there it is more likely that control measures will be taken. Higher infestation rates tend to be in smaller orchards (Xia et al., 2021). Pesticide application will also reduce infestation rates of exporting orchards. Citrus fruit exported from China to the EU are subject to measures against fruit flies (see Section 3.1.3), which may also affect *R. citrifrugis*. But this is the case also for *C. sagittiferella*, which supports no difference in the elicited distribution. All this reasoning led the Panel to choose the same median prevalence value as for *C. sagittiferella*.

The 25% and 75% values were chosen as for *C. sagittiferella*, reflecting the high uncertainty (more data available, but uncertainty about their interpretation). For *C. sagittiferella*, the distribution in Vietnam was uncertain (the pest is still spreading), whereas for *R. citrifrugis*, there is evidence of a widespread presence across much of the citrus-growing areas in China.

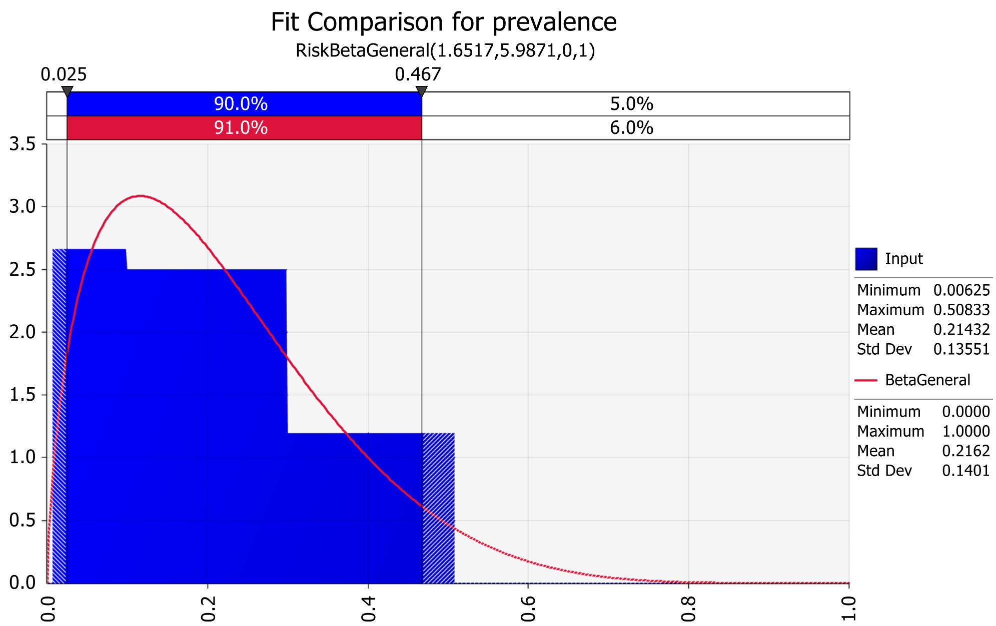

Figure 3: Fitted distribution for prevalence at the origin ($p_{prevalence}$) defined as the proportion of infested citrus fruit (scenario A1)

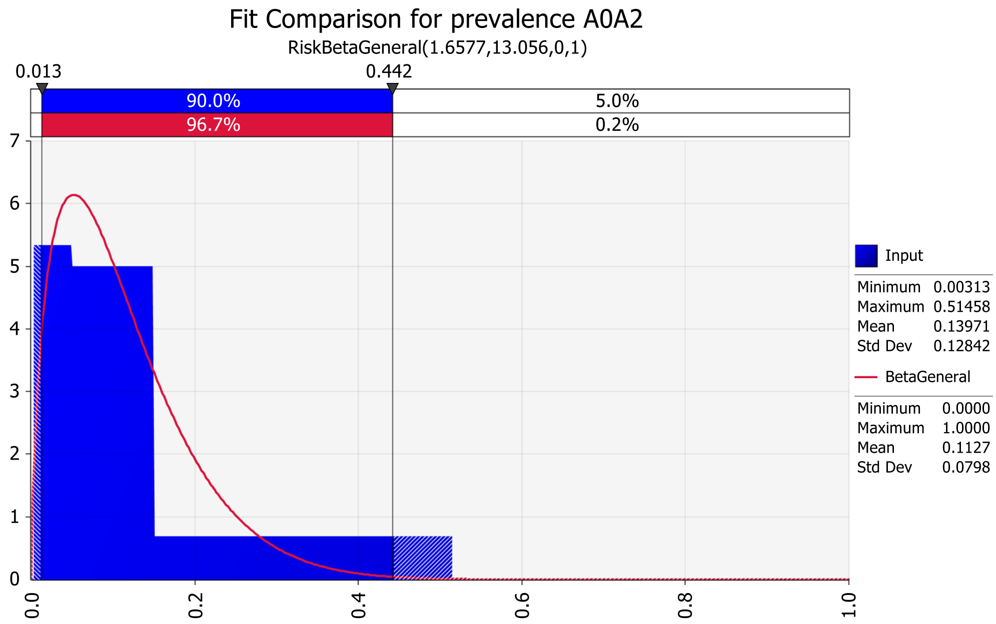

Figure 4: Fitted distribution for prevalence at the origin ($p_{prevalence}$) defined as the proportion of infested citrus fruit (scenarios A0 and A2)

3.2.2.2. Trade flow

Trade flow is defined in Table 6. A trend analysis is shown in Figure 5.

Table 6: Definition of the parameter trade flow (N_{trade})

Name	Definition	Sources
N_{trade}	Total quantity of citrus fruit (infested or not) imported by the EU from China	Eurostat and expert knowledge (see justification below)

The elicited distribution of the trade flow is reported in Table 7 and Figure 6.

Table 7: Elicitation of trade flow in metric tons (1,000 kg) of citrus fruit per year, averaged over the time horizon period 2024–2033 (all scenarios)

Quantile	1%	25%	Median	75%	99%
N_{trade}	100,000	140,000	175,000	210,000	250,000

Justification – EU imports (2016–2020) of citrus fruit from China ranged between about 83,000 tons and 110,000 tons, with an average of about 103,000 tons (EFSA PLH Panel, 2021a). Nevertheless, Figure 5 shows an increasing trend when considering data over a longer period. Pomelo is seldom grown commercially in the EU, so the growing import of fruit of this *Citrus* species from China is likely to carry on over the next years. Indeed, it seems pomelo is becoming more and more popular in the EU and this trend is likely to continue in the future (EFSA PLH Panel, 2023). For all these reasons, the upper bounds of the confidence and prediction intervals of the regression appear as relevant references for the elicitation.

The median could be set closer to the lower boundary, because citrus fruit production in China coincides with the season of EU citrus production. Moreover, the export from China to the EU is more specialised in fruit such as pomelo, it is thus a niche market that might have reached a plateau. However, again using a comparative approach, in the elicitation for the trade flow of citrus fruit for *C. sagittiferella* (trade from Vietnam and other South-East Asian countries where this pest is present), the increasing trend in trade led the Panel to set the median of the trade flow distribution closer to the upper boundary. The Panel was uncertain about whether to give more weight to the first or the second argument, so the midpoint was chosen.

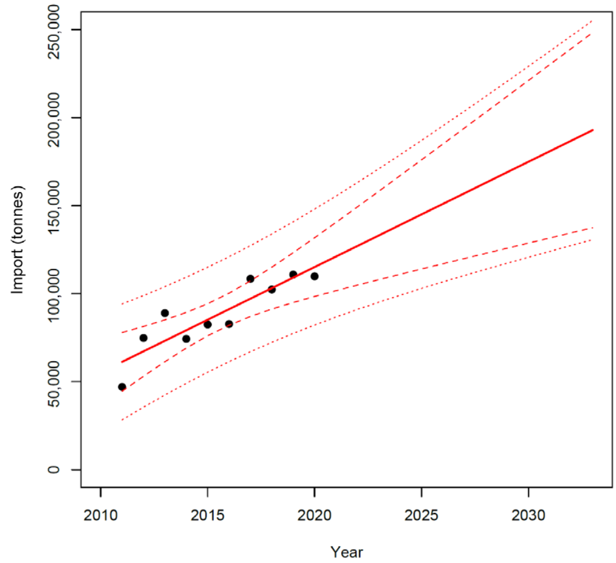

Figure 5: Trend analysis of the import into the EU of citrus fruit (tons) from China, based on 2011–2020 EUROSTAT data, over the 10 years of the PRA time horizon. Dashed and dotted lines indicate the 98% confidence and prediction intervals, respectively

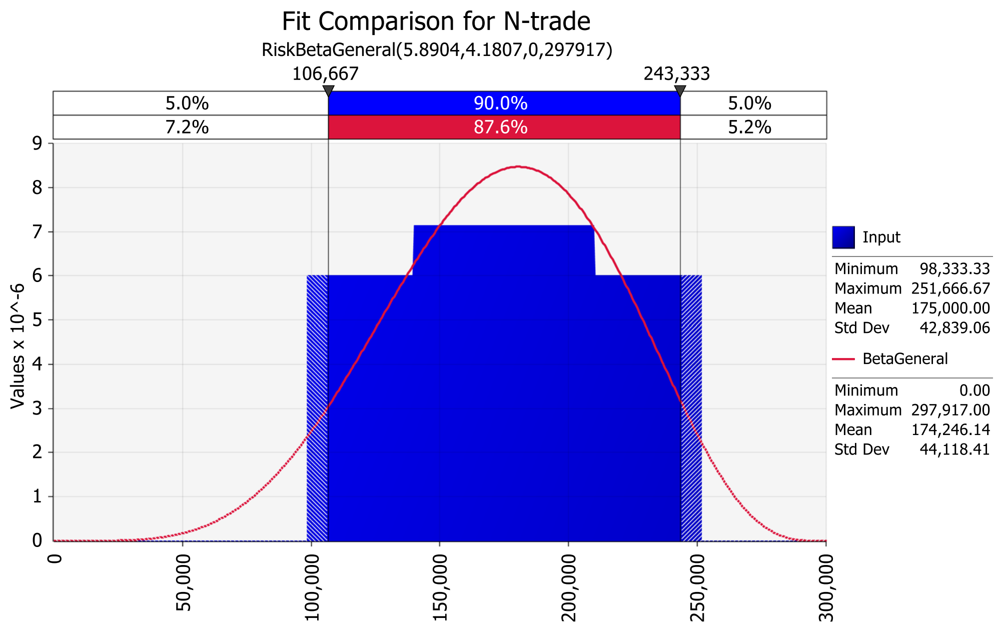

Figure 6: Fitted distribution for trade flow (N_{trade}) for citrus fruit as tons per year (all scenarios)

3.2.2.3. Sorting

The parameters $p_{sorting}$ and the RRO effectiveness are defined in Table 8.

Table 8: Definition of sorting ($p_{sorting}$) and risk reduction option (RRO) effectiveness

Name	Definition	Sources
$p_{sorting}$	Proportion of infested citrus fruit removed following pre-export inspections (identification and removal of infested fruits before entry in the EU)	Expert knowledge (see justification below)
RRO effectiveness	Reduction in the proportion of infested citrus with post-harvest cold treatment	Expert knowledge (see justification below)

The elicited distributions of $p_{sorting}$ and of the RRO effectiveness are reported in Table 9 and Figures 7–9. For $p_{sorting}$, two components were considered: (i) the proportion of infested citrus fruit removed following inspection and culling at the packinghouse ($p_{sorting\ packing}$) and (ii) the proportion of infested citrus fruit removed following inspection at the border ($p_{sorting\ border}$) in the exporting country. The two components were combined in the Monte Carlo simulation as:

$$p_{sorting} = 1-(1-p_{sorting\ packing}) \times (1-p_{sorting\ border}).$$

Table 9: Proportion of infested citrus fruit removed from trade due to sorting ($p_{sorting}$) or cold treatment (RRO effectiveness). $p_{sorting}$ was calculated as a combination of sorting at the packinghouse ($p_{sorting\ packing}$) and sorting at the border ($p_{sorting\ border}$) in the exporting country

Quantile	1%	25%	Median	75%	99%
Scenario A1					
$p_{sorting\ packing}$	0	0.08	0.15	0.30	0.50
$p_{sorting\ border}$	0.50	0.62	0.725	0.83	0.95
$p_{sorting}$*	0.447	0.701	0.789	0.862	0.966
Scenarios A0 and A2					
$p_{sorting\ packing}$	0	0.13	0.20	0.35	0.55
$p_{sorting\ border}$	0.57	0.69	0.80	0.90	0.96
$p_{sorting}$*	0.515	0.774	0.858	0.918	0.988
Scenario A2					
RRO effectiveness	0.95	0.99	0.9999	0.99994	1

*$p_{sorting} = 1 - (1 - p_{sorting\ packing}) \times (1 - p_{sorting\ border})$.

Justification – sorting. The elicitation focuses on sorting at the packinghouse and subsequent sorting at the border.

Scenario A1:

- In general, and following a comparative approach indicated above, it was considered that the sorting at the packinghouse will tend to be less efficient than for *C. sagittiferella* (EFSA PLH Panel, 2023), because the pest is smaller and its damage more difficult to detect (Anonymous, 2022). The median was set away from the upper boundary, because what is left on the trees (and thus harvested), is the fruit with low or recent damage, which is the most difficult situation for detection.
- For sorting at the border, it was considered that there will be inspection at the border for quarantine fruit flies (that may include the opening of a sample of fruits), which will lead to detection of this pest. This also reduces the overall uncertainty for the elicitation compared to *C. sagittiferella*. For the median, it was considered that, unless the fruit is opened, sorting is not likely to be effective. At the border, experts are generally better trained than in the packing houses, but the pest is still difficult to detect. Thus, the median was chosen in the middle of the distribution. The 25% and 75% values were chosen to reflect the high uncertainty on this parameter, as sample size at the border is not always known and random sampling (FAO, 2016; EPPO, 2020) might not be easily achieved.

Scenarios A0 and A2:

- Considering that the pest is currently a regulated pest for the EU, inspectors will be specifically checking for its presence in batches, thus increasing the probability of detection. On the other hand, the pest is difficult to detect, and the lower prevalence considered in scenarios A0 and A2 compared to scenario A1 could in theory make sorting less effective. However, as the median prevalence is still relatively high in A0 and A2 (10%), it was considered that the impact of a lower prevalence on sorting will be minor and, consequently, the $p_{sorting}$ at the packing house was increased by 5% for all quantiles compared to scenario A1.
- For $p_{sorting}$ at the border, it was decided to increase the probability by about 7% because of the regulated status of the pest, with exception of the 99% value (0.95 in scenario A0), which

was only increased by 1% because of the limited knowledge on how sampling at the border is performed, even for regulated pests.

Justification – RRO effectiveness

On the one hand, there are the results from the experiment at 2°C (see Section 2.2.3), but the experimental design was not published in a peer-reviewed journal and was based only on two pomelo fruits containing just 100 larvae. Nevertheless, the lower development temperature threshold is known to be rather high for *R. citrifrugis*, whereas it was not known for *C. sagittiferella* (EFSA PLH Panel, 2023). Thus, the Panel considers that the cold treatment is potentially effective.

The 1% value represented the case of not proper implementation of the cold treatment. The Panel is not completely certain of the temperature threshold, due to the limitations of the available experimental data. However, based on a comparison with *Ceratitis capitata* and *Thaumatotibia leucotreta* (Meyrick) (Lepidoptera: Tortricidae) (less thermophilic pests; EFSA PLH Panel, 2021b), for which this treatment is considered effective, the cold treatment is considered to be potentially effective for *R. citrifrugis*.

The 99% value was based on the data on the lower development threshold. USDA (2020) considers cold treatment as an effective measure (within a systems approach) and Mexico includes it in the importing protocol of citrus fruit from China.

The median value was chosen considering the development threshold for *C. capitata* and *T. leucotreta* (which are lower than for *R. citrifrugis*, thus those are more cold-tolerant pests). Since there are mortality data for *C. capitata* and *T. leucotreta* showing that cold treatment is an effective measure, the survival rate was chosen as 1 out of 10,000, as 1 out of 100,000 is the standard operating performance (= probit 9 mortality), to allow for the uncertainty in the temperature requirements for *R. citrifrugis*.

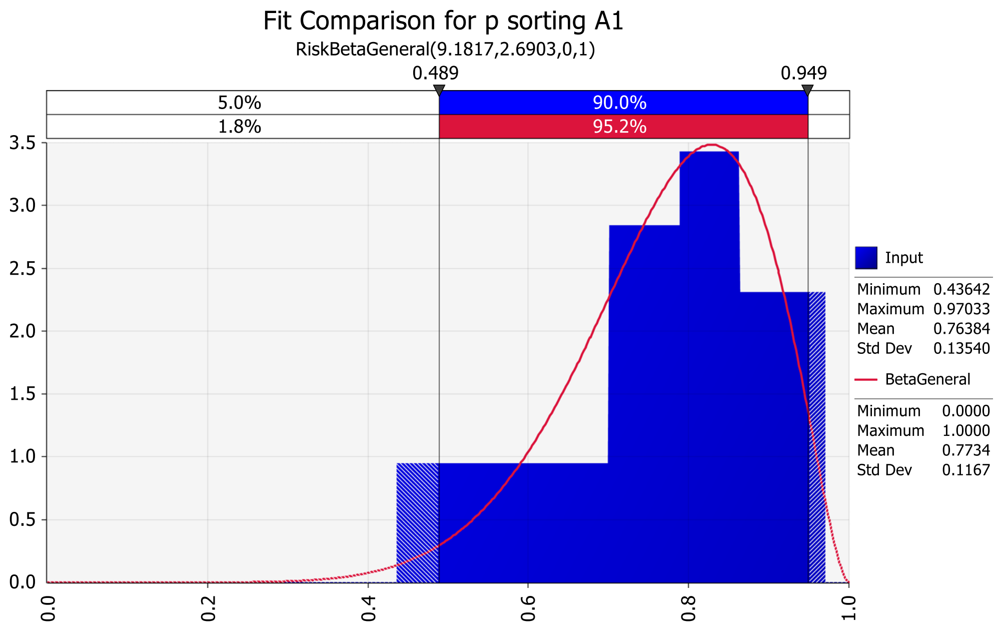

Figure 7: Fitted distribution for sorting ($p_{sorting}$) as the proportion of infested fruit (scenario A1)

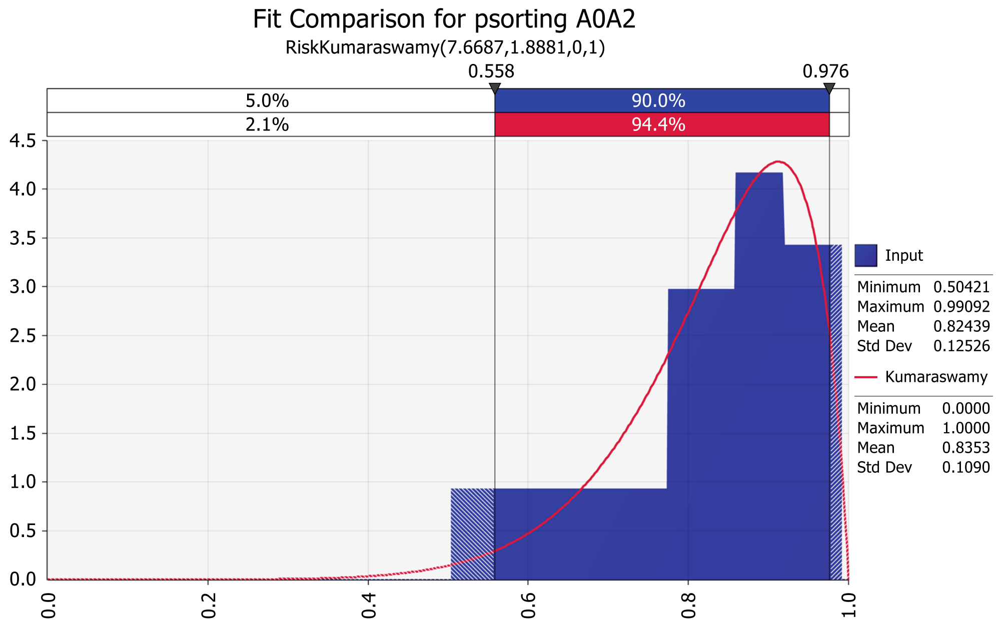

Figure 8: Fitted distribution for sorting ($p_{sorting}$) as the proportion of infested fruit (scenarios A0 and A2)

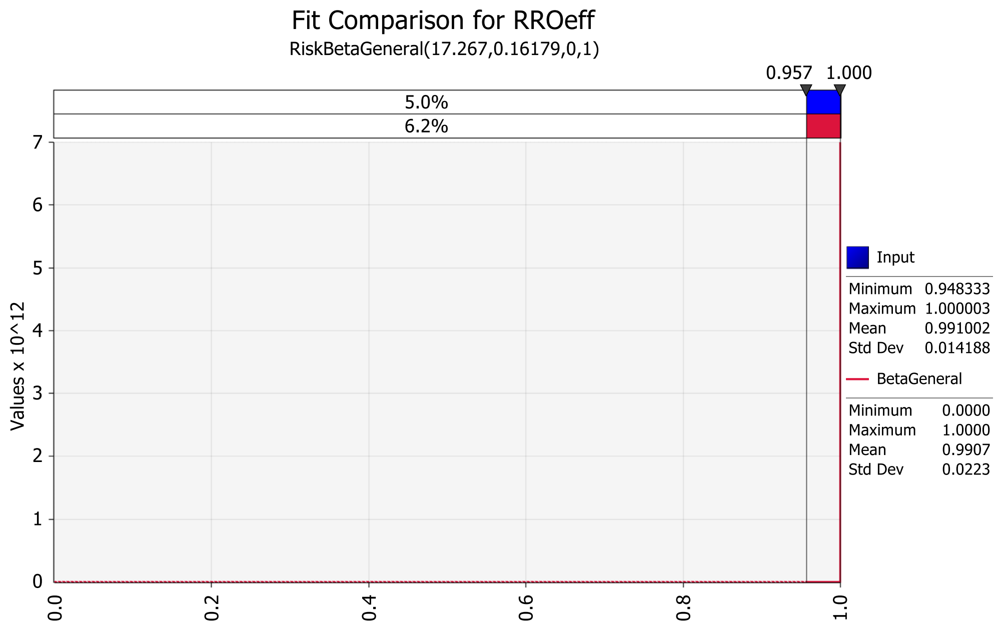

Figure 9: Fitted distribution for $RRO_{effectiveness}$ as the proportion of infested citrus fruit removed with cold treatment (scenario A2)

3.2.2.4. Disaggregation of consignments

The disaggregation of consignments is defined in Table 10.

Table 10: Definition of the parameter disaggregation factor (d)

Name	Definition	Sources
d	Disaggregation factor for one ton (1,000 kg) of infested citrus fruit, to take into account the number of locations for transfer to which one ton of infested citrus fruit is delivered. The Panel thus assumed that if there are several infested citrus fruits in one single pathway unit, they would contribute to the same potential founder population	Expert knowledge (see justification below)

The elicited distribution of the disaggregation factor is reported in Table 11 and Figure 10.

Table 11: Disaggregation factor (d) for citrus fruit (all scenarios A0, A1/A2)

	1%	25%	Median	75%	99%
d	1	6	10	50	500

Justification:

Considering the similarities between the trade pathways, and following a comparative approach, the same distribution was used as for C. sagittiferella (EFSA PLH Panel, 2023). For the 1% quantile, it was considered a whole ton of citrus fruit is delivered to one single location. For the 99% quantile, it was considered that lots of 2 kg of citrus fruits were allocated to different locations. The median was set to reflect the situation when one ton of infested citrus fruit is delivered to 10 different locations in the risk assessment area (100 kg per location).

The distribution was constrained to start from 1, because one ton of citrus fruit can go to no less than one location. The distribution was constrained up to 2,000, assuming one pomelo fruit is 500 g and a distribution of each pomelo of a one-ton-batch to a different location.

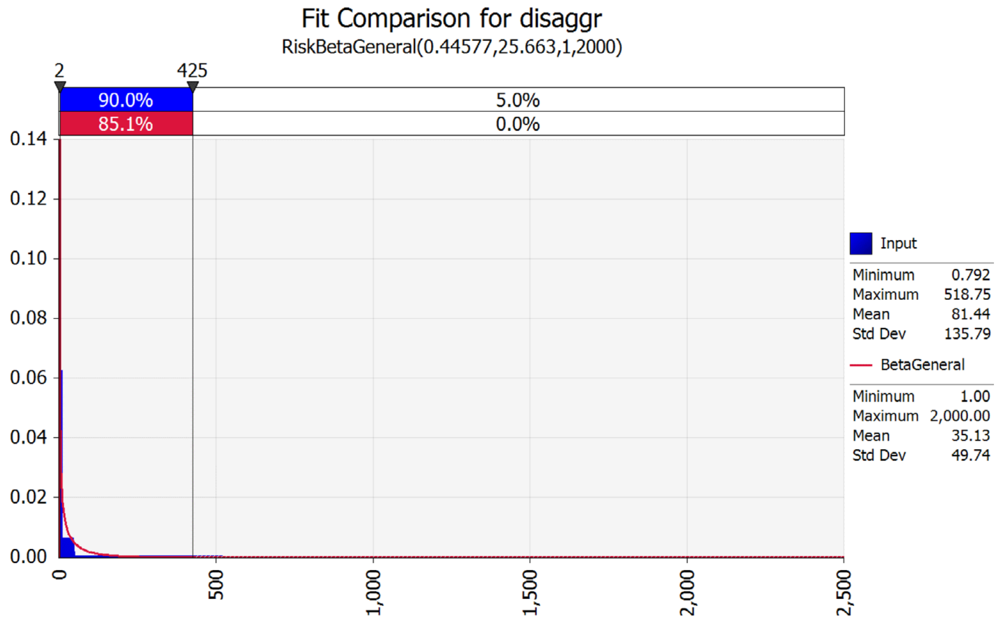

Figure 10: Fitted distribution for the disaggregation factor (d) for citrus fruit (number of suitable locations for transfer to which one ton of infested citrus fruit is delivered) (all scenarios A0, A1 and A2)

3.2.2.5. Transfer

The probability of transfer is defined in Table 12.

Table 12: Definition of the parameter transfer ($p_{transfer}$)

Name	Definition	Sources
$p_{transfer}$	Probability that the pest in one disaggregated batch of citrus fruit is transferred to suitable hosts, thus leading to a potential founder population	Expert knowledge (see justification below)

The elicited distribution of the probability of transfer is reported in Table 1 and Figure 11.

Table 13: Probability of transfer ($p_{transfer}$) for citrus fruit (all scenarios A0, A1 and A2)

Quantile	1%	25%	Median	75%	99%
$p_{transfer}$	0	0.0007	0.001	0.01	0.033

Justification

R. citrifrugis is not a strong flyer and lives for a short time (a few days), so transfer is likely to be less successful than for *C. sagittiferella*, which lives longer and is a strong flyer (EFSA PLH Panel, 2023). However, the lower development threshold of *R. citrifrugis* is relatively high. The import of citrus fruit from China takes place over autumn and winter, the less suitable season for transfer in terms of pest temperature requirements.

The 99% value was thus reduced compared to *C. sagittiferella* for the reasons mentioned above. However, if the waste is not properly disposed (e.g. discarding the unprocessed waste close to a citrus orchard), the pest could survive until the spring, when temperatures might already be suitable for transfer.

For the median value, it was considered whether wax and fungicide post-harvest treatment of citrus fruit could have a negative effect on pest survival and thus transfer, this remains to be investigated. This could be more of an issue for *R. citrifrugis*, given its minute size and its location in the outer part of the fruit, contrary to *C. sagittiferella*, which bores the whole fruit.

On the whole, following a comparative approach, the Panel decided to reduce by 10 the values elicited for *C. sagittiferella* (EFSA PLH Panel, 2023), for the reasons provided above.

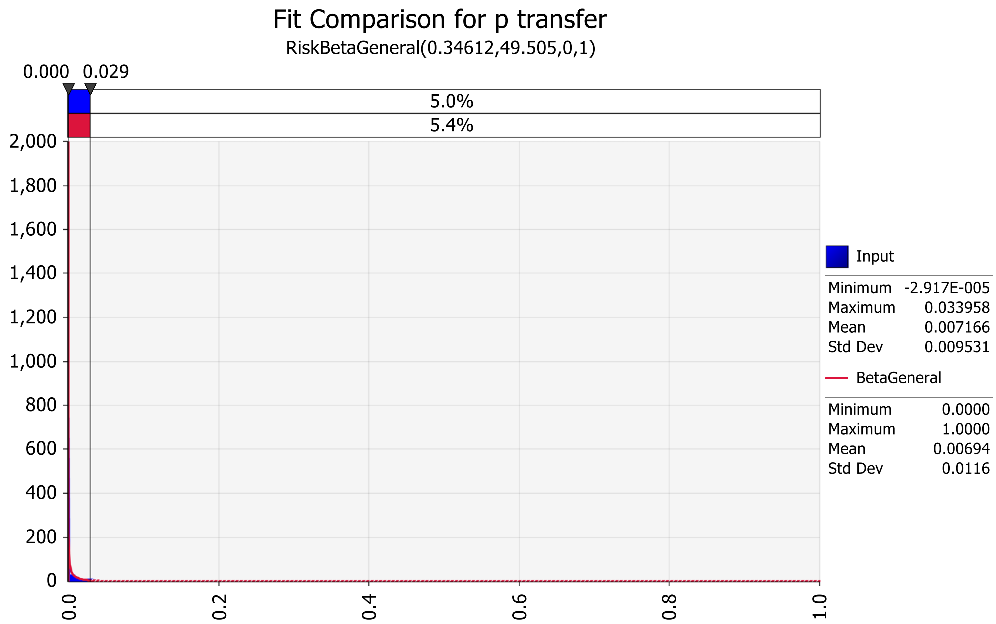

Figure 11: Fitted distribution for the probability of transfer ($p_{transfer}$) for citrus fruit (all scenarios A0, A1 and A2)

3.2.3. Entry assessment results

Table 14 shows the outcome of the model calculations (N_{inf}) expressed as the number of *R. citrifrugis* potential founder populations per year due to import into the EU of infested citrus fruit for the three considered scenarios. The results are visualised in Figures 12–14.
According to model results,

- under scenario A0 (current practice, i.e. regulated pest status), slightly less than 40 potential founder populations per year are expected (median; 90%-uncertainty interval between about one per 30 years and about 3,000 per year)
- the risk of entry increases under scenario A1 (deregulation) by about three times to about 120 potential founder populations per year (median; 90%-uncertainty interval between about one per 10 years and about 9,000 per year)
- compared to both scenarios A0 and A1, the risk of entry is orders of magnitude lower for scenario A2 (regulated pest status with additional RRO: stand-alone cold treatment) (median = about one founder population per 120 years; 90%-uncertainty interval between one founder population per about 600 million years and about two founder populations per year)

- the uncertainty is larger for scenario A2 (the 90%-uncertainty range spans nine orders of magnitude) compared to scenarios A0 and A1 (the 90%-uncertainty range spans five orders of magnitude)

Table 14: Outcome of the model calculation for the output variable N_{inf} (number of potential founder populations of *Resseliella citrifrugis* in the EU due to import of infested citrus fruit) under the considered scenarios A0 (regulated pest), A1 (deregulation) and A2 (regulated pest with additional RROs), using 10,000 simulation runs

Scenario	Mean	St. Dev.	1%	25%	Median	75%	99%
A0	720	3,300	0.0003	3.6	39	290	13,000
A1	2,000	10,500	0.001	11	120	850	29,000
A2	6.2	55	1×10^{-13}	6×10^{-5}	0.008	0.3	130

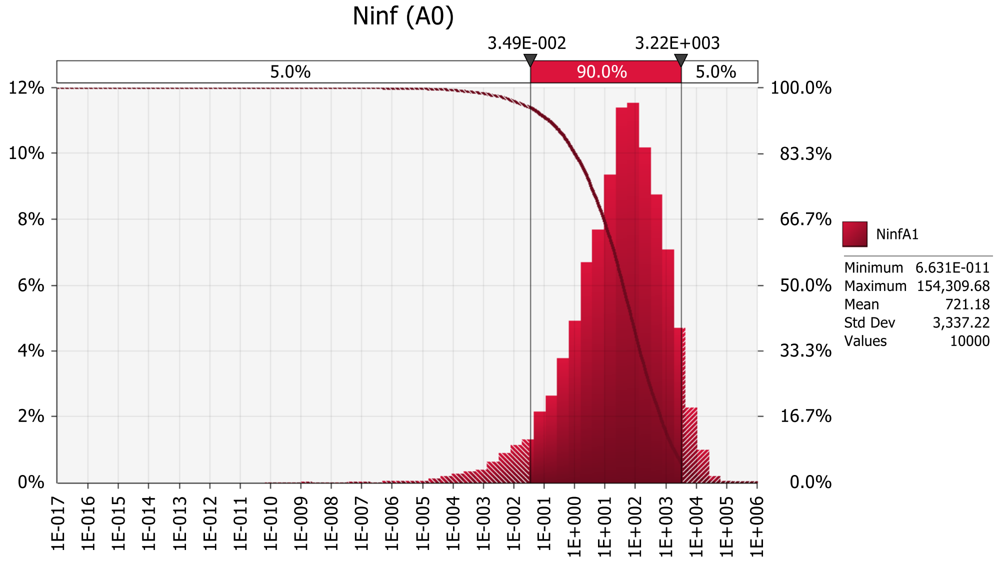

Figure 12: Outcome of the model simulations for scenario A0 (regulated pest) showing the relative frequency and cumulative descending probability; log-scale x-axis, same x-axis scale as Figures 13 and 14. The number of potential founder populations of *Resseliella citrifrugis* in the EU due to import of infested citrus fruit is estimated between about one per 30 years and about 3,000 per year with a 90% probability

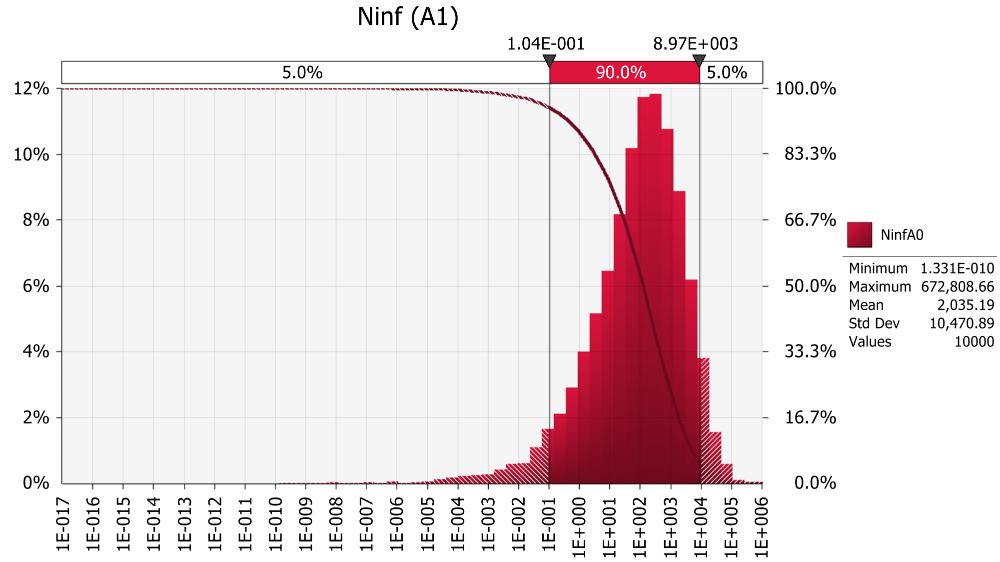

Figure 13: Outcome of the model simulations for scenario A1 (deregulation) showing the relative frequency and cumulative descending probability; log-scale x-axis, same x-axis scale as Figures 12 and 14. The number of potential founder populations of *Resseliella citrifrugis* in the EU due to import of infested citrus fruit is estimated between about one per 10 years and about 9,000 per year with a 90% probability

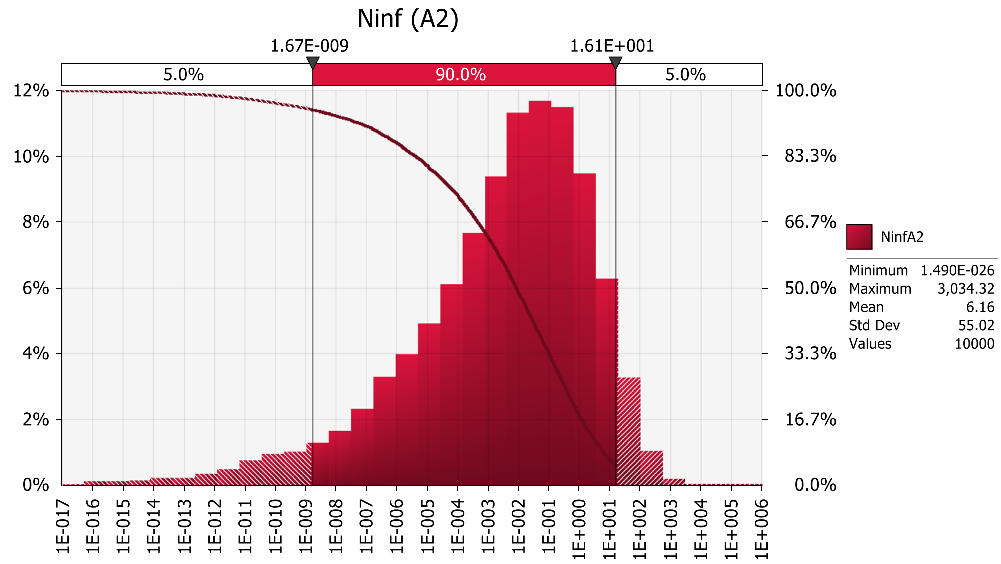

Figure 14: Outcome of the model simulations for scenario A2 (regulated status with additional RROs) showing the relative frequency and cumulative descending probability; log-scale x-axis, same x-axis scale as Figures 12 and 13. The number of potential founder populations of *Resseliella citrifrugis* in the EU due to import of infested citrus fruit is estimated between about one per 600 million years and about two per year with a 90% probability

3.3. Sensitivity analysis of the number of potential founder populations

A sensitivity analysis was conducted, where correlations between the output variable (N_{inf}) and the parameters of the entry pathway model were estimated using the Spearman rank coefficient (Figures 15–17). Spearman is non-parametric, so no assumption about the data distribution (e.g. normality) is needed. Based on the sensitivity analysis, the parameters included in the entry model most correlated with the output variable are:

- RRO effectiveness (scenario A2)
- probability of transfer
- disaggregation of consignments

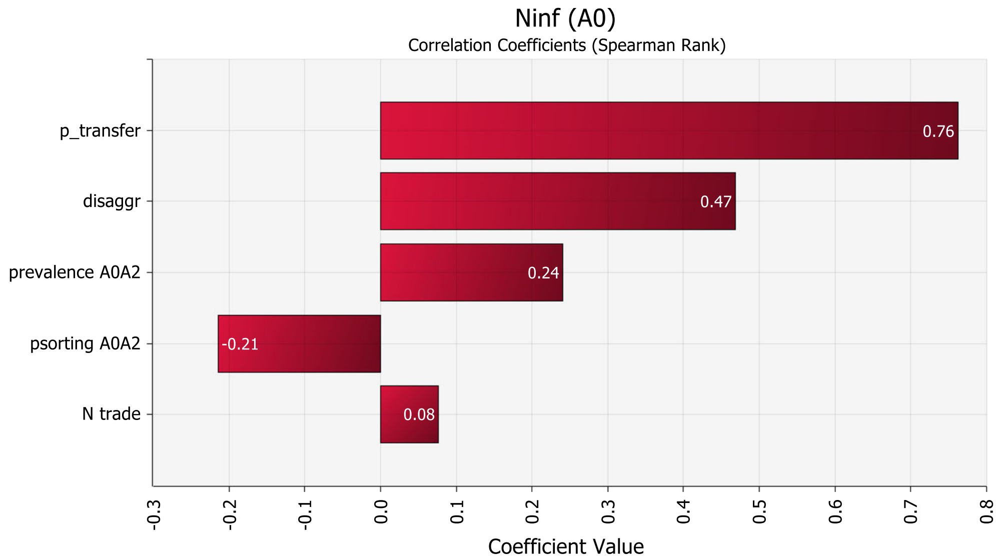

Figure 15: Correlation between the output variable (N_{inf}) and the parameters of the entry pathway model for scenario A0 (current practice, i.e. regulated status). The parameter $p_{sorting}$ has a negative correlation coefficient as it is inserted in the model as $(1 – p_{sorting})$

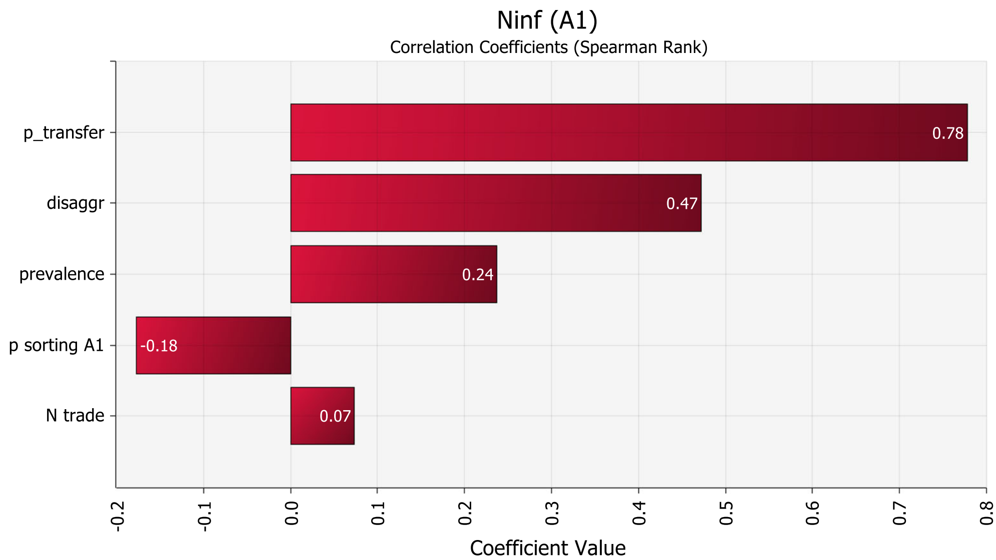

Figure 16: Correlation between the output variable (N_{inf}) and the parameters of the entry pathway model for scenario A1 (deregulation). The parameter $p_{sorting}$ has a negative correlation coefficient as it is inserted in the model as $(1 – p_{sorting})$

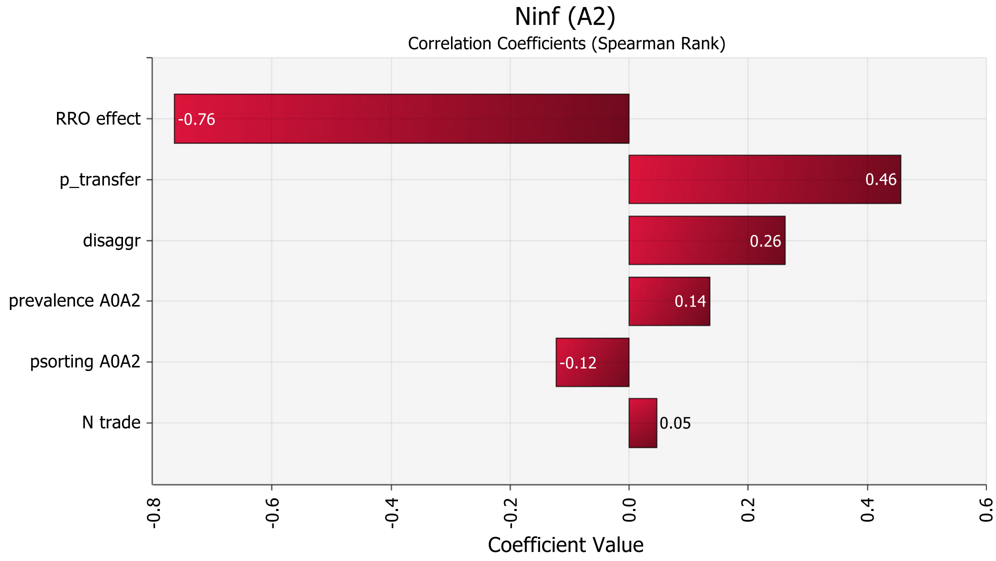

Figure 17: Correlation between the output variable (N_{inf}) of the parameters of the entry pathway model for scenario A2 (regulated status with additional RROs). $RRO_{effectiveness}$ and $p_{sorting}$ have negative correlation coefficients, as they are inserted in the model as ($1 - RRO_{effectiveness}$) and ($1 - p_{sorting}$)

3.4. Additional uncertainties

From a biological point of view, various uncertainties regarding *R. citrifrugis* coincide with those already listed by the Panel in the previous pest categorisation (EFSA PLH Panel, 2021a). These uncertainties include:

- Uncertainty on the thermal biology of the pest. Data are available, but there is uncertainty about their interpretation, when using them to explain field results.

Furthermore, there is a lack of data to accurately estimate sorting and transfer. There is also lack of experimental data supporting the effectiveness of post-harvest cold treatment.

This lack of information is reflected in the parameter distributions and in the outcomes of the entry model.

Uncertainties that were not quantified in the entry model include:

- Seasonality of pest prevalence in relation to fruit harvesting.
- The target temperature and duration of refrigeration during overseas transport.
- The susceptibility of *Citrus limon* to the pest. Even if trade volumes of lemon from China to the EU are small, the pest might be introduced on pomelo and then transfer to lemon in the RA area. Lemons are widely grown in the EU citrus-growing area, but are apparently not mentioned in the literature from China on *R. citrifrugis*, thus leading to a key knowledge gap.

The Panel expects the conclusions of the entry model not to be modified substantially by the additional uncertainties not quantified in this assessment.

3.5. Dependencies between parameters

The Panel considers the parameters of the entry model to be independent of each other, with the possible exception of prevalence at the origin and sorting (the higher the prevalence at the origin, the higher the effectiveness of sorting), but this dependency is assumed not to affect the conclusions of the assessment.

If the pathway units (clusters) are large enough, the proportion of infested pathway units should exceed the proportion of infested single fruit as every single fruit in a cluster has a chance to be infested if there is any degree of independence. If there is complete independence between the health status of individual fruits in a disaggregated ton of product (cluster), then the probability of a cluster of n fruit to be infested should equal $p_{cluster} = 1 - (1 - p_{single\ fruit})^n$ where $p_{cluster}$ is the proportion of infested clusters, $p_{single\ fruit}$ is the proportion of infested single fruit and n is the size of the pathway units (the « disaggregated » tons of product). A similar issue of aggregation applies to $p_{sorting}$ and $RRO_{effectiveness}$. For sake of simplicity and lack of specific data, the Panel did not explore these dependencies, but they are not expected to affect the conclusions of the assessment, because it was assumed that several infestations of the pest in the same pathway unit would lead to the same potential founder population (although with increased risk of transfer, which was considered in the transfer elicitation).

Increased prevalence at the origin might lead to lower trade, but exporting growers might progressively find areas for export production in other regions less affected by the pest, thus making the conclusions of this assessment robust to this potential parameter dependency.

Transfer is likely to be dependent on prevalence, as males and females are needed to mate for transfer to occur. Similarly, for transfer and disaggregation factor, if the infested ton of citrus fruit is not disaggregated, transfer is going to be more likely, but again this dependency between model parameters was taken into account during the elicitation of the probability of transfer (see Section 3.2.2.5) and should thus not affect the conclusions of the assessment.

3.6. Conclusion on the assessment of entry for the different scenarios

According to model results, under scenario A0 (current practice, i.e. regulated pest status), slightly less than 40 potential founder populations per year are expected (median; 90%-uncertainty interval between about one per 30 years and about 3,000 per year).

Under scenario A1 (deregulation), the risk of entry increases by about three times to about 120 potential founder populations per year (median; 90%-uncertainty interval between about one per 10 years and about 9,000 per year).

Compared to both scenarios A0 and A1, the risk of entry is orders of magnitude lower for scenario A2 (regulated pest status with additional RRO) (median = about one potential founder population per 120 years; 90%-uncertainty interval between one potential founder population per about 600 million years and about two potential founder populations per year).

The uncertainty is larger for scenario A2 (the 90%-uncertainty range spans nine orders of magnitude) compared to scenarios A0 and A1 (the 90%-uncertainty range spans five orders of magnitude).

In all scenarios, the uncertainty in the model outcome is due to combining the uncertainties of the model parameters. The main uncertainties in the entry assessment are the probability of transfer, the $RRO_{effectiveness}$ (for scenario A2) and the disaggregation of consignments.

4. Establishment

4.1. Background information and host distribution

In China, the area of current distribution of *R. citrifrugis*, Mediterranean climate types are not present (Csa, Csb and Csc climates are not present there; Figure 18) (Rossi et al., 2023). However, the climates in the citrus-growing areas in China with reports of the pest are mostly temperate (Anonymous, 2022). This consideration was taken into account in a pest-rating proposal for California, US, to conclude that *R. citrifrugis* could establish and spread in that region, although some uncertainties remain (Anonymous, 2022). The Express PRA published by the Netherlands (produced following several interceptions on pomelo imported from China) states that establishment in Southern Europe, i.e. EU citrus-growing areas, is most likely (Anonymous, 2020).

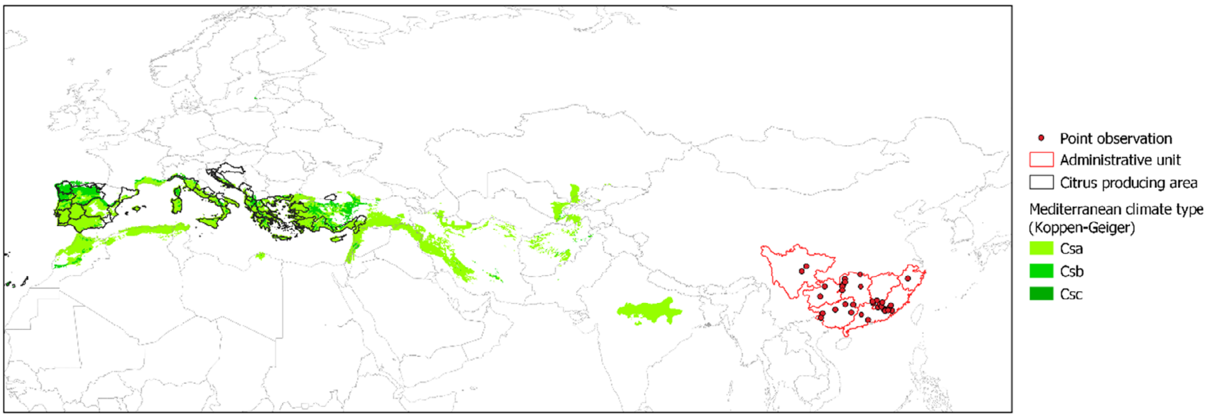

Figure 18: Distribution of Mediterranean climate types in Europe and neighbouring regions. Hot summer-Csa and warm summer-Csb occur in citrus-growing areas of the EU, whereas the cold summer-Csc Mediterranean climate type is found in scattered high-altitude locations along the west coasts of North and South America and does not occur in the EU. Note that in the area of current distribution of *Resseliella citrifrugis* (China, highlighted in red), Mediterranean climate types do not occur (Southern China is subtropical with hot summers with monsoon rains and mild winters)

To define the risk assessment area, the map for citrus production NUTS2 regions in EFSA PLH Panel (2019a) was used (Figure 19).

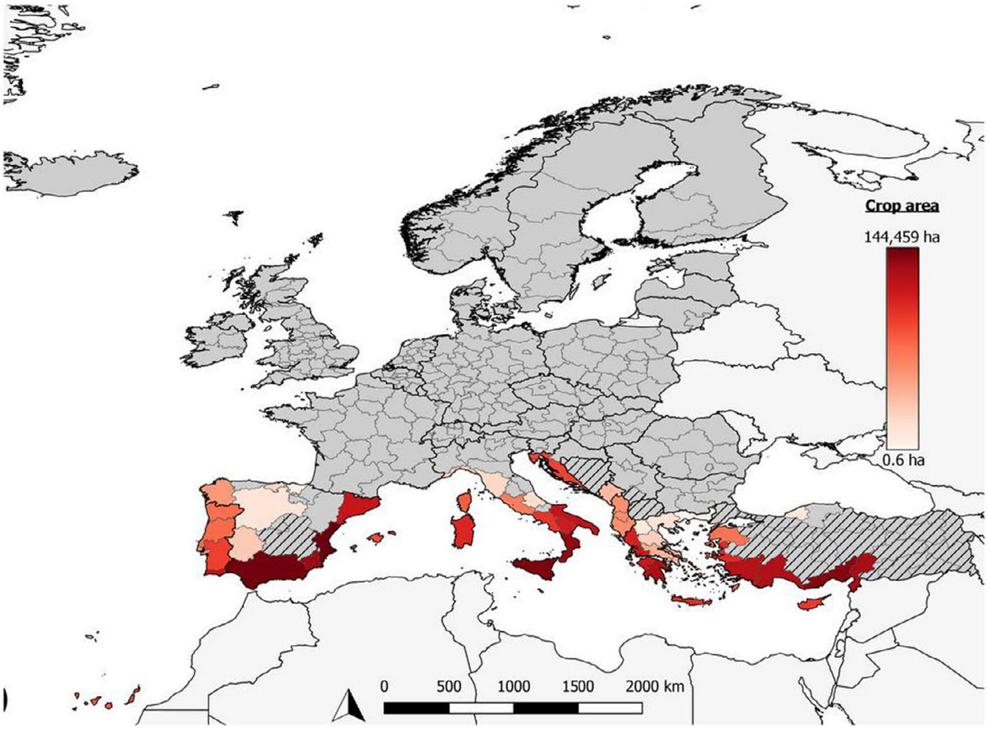

Figure 19: European citrus-growing areas based on data of crop area at NUTS 2 level (from EFSA PLH Panel, 2019a). Areas with lines indicate regions with no data. Areas in light grey are neighbouring countries not included in the analysis

4.2. Climate suitability

4.2.1. Climate suitability methodology

The number of confirmed *R. citrifrugis* presence locations is rather restricted (41 with point locations). Therefore, the use of comprehensive modelling approaches such as species distribution models and niche models is not appropriate. Since the transferability in space and time of the above-mentioned models is often limited, their use could lead to unreliable projections in large parts of the risk assessment area.

4.2.2. Köppen–Geiger climate comparison

Building on the *R. citrifrugis* pest categorisation (EFSA PLH Panel, 2021a), a more enhanced Köppen–Geiger climate comparison was performed in this PRA. For this updated analysis, additional literature was evaluated and 821 pest observations (of these, 41 were administrative units and 41 were point locations with coordinates) were selected for use. More details are available in Rossi et al. (2023). The Köppen–Geiger map suggested that climates of continental Europe (Cfa and Cfb) are suitable for pest establishment. However, those regions are outside of the EU citrus-growing area, so this approach was not pursued further.

In China, *R. citrifrugis* occurs in areas included in the 8–10 cold-hardiness zones (USDA, 2017). Therefore, by analogy, in the EU, the pest could occur in the citrus-growing area of e.g. Cyprus, Greece, Italy, Malta, Portugal and Spain, where the same cold-hardiness zones are found (Figure 20) and, as a consequence, citrus is grown (EFSA PLH Panel, 2021a).

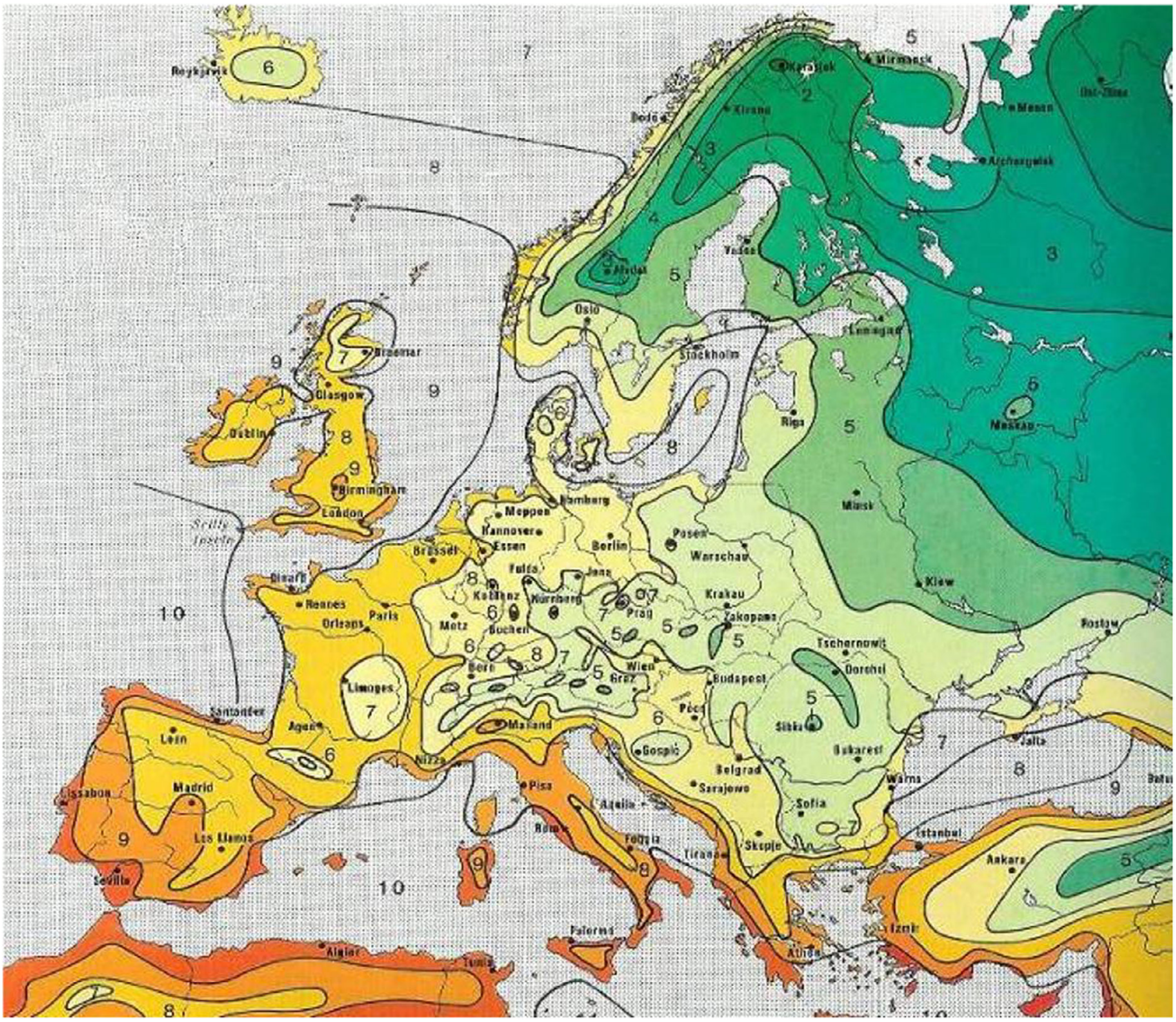

Figure 20: Cold-hardiness zones in Europe and neighbouring regions (Source: Wikimedia Commons)

4.2.3. Lower development thresholds

Based on development times (Y in days) for each temperature treatment T (°C) obtained from Xia et al. (2021), developmental rates ($R = Y^{-1}$, in $days^{-1}$) were calculated for each tested temperature T and each development stage. These rates R were plotted against temperatures for each development stage. Data showing an increasing linear trend were visually selected. Then, a linear regression model relating R to T was fitted in order to estimate lower development temperature (LDT, °C) (Logan et al., 1976), defined as the intercept of the fitted linear regression model. Based on the LDTs for different life stages, we calculated the thermal constants K (sum of temperatures, degree-day) required for completing each stage as follows (Varley et al., 1974):

$K = \Sigma[Y_i\ (T_i - LDT)]/n$, where Y_i is ith observed development time (in days) required to complete the stage considered, T_i is the ith temperature, LDT is lower development threshold obtained for the stage considered and n is the number of observations.

In this opinion, we based our analysis on the total number of days required to complete the whole cycle of females, as this stage was the one requiring the largest thermal constant, and was thus the most demanding stage in terms of temperature sum.

An attempt was then made to produce a map of the EU citrus-growing area with the expected number of generations of *R. citrifrugis*, based on a thermal constant of 146.07 DD (K) and a lower development threshold of 17.6°C for the whole life cycle from egg to egg. The resulting values seemed implausible, as for example, 14 generations were predicted for Valencia, Spain, whereas the literature in China reports only up to four generations per year (Xia et al., 2021). The Panel thus checked the modelled number of generations for three provinces in China where the number of generations per year was reported by Xia et al. (2021) (two generations in Guizhou, three generations in Fujian and four generations in Hunan). The calculated values were 5, 10 and 10, respectively, thus very different from the values reported by Xia et al. (2021), suggesting that the available thermal data (Xia et al., 2021) are not reliable and might lead to misleading results if used to study the risk of establishment of this pest in the EU or elsewhere. Nevertheless, as the sum of degree day (without thermal threshold, base temperature = 0°C) computed in EU and in citrus-growing areas in China are similar in some regions (Figure 21), the Panel expects at least as many generations in the EU citrus-growing area as in China.

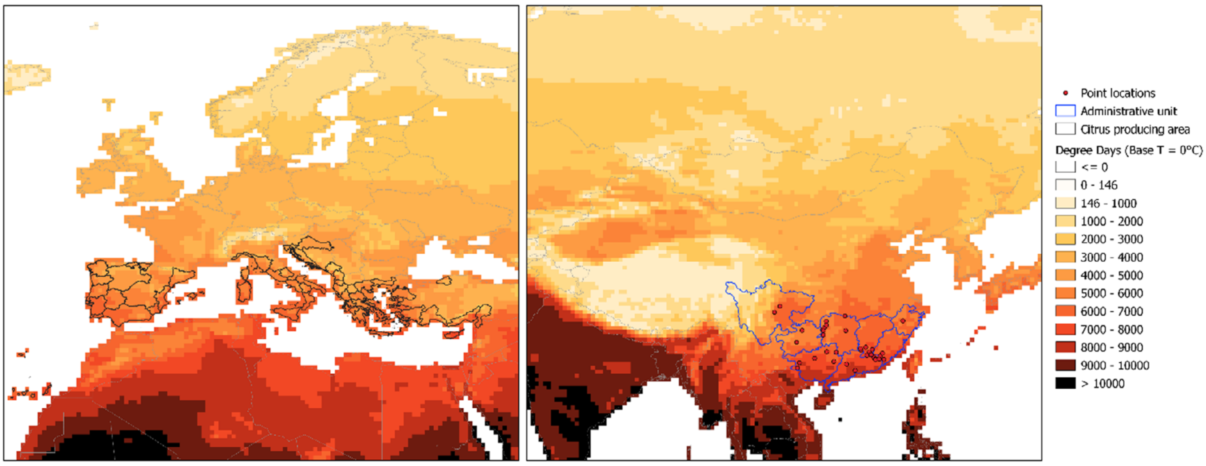

Figure 21: Comparison of sum of degree days (base temperature = 0°C) between the regions with reports of *Resseliella citrifrugis* in China (red dots, right-hand panel) and the EU citrus-growing area (left-hand panel). The map was made with CLIMEX which uses a 30-year period centred around 1995 (from 1981 to 2010). The sum of degree days is calculated as the yearly average of the yearly degree day accumulation over the 30-year period

4.2.4. Conclusions on climate suitability

Considering the lack of available information on *R. citrifrugis* distribution and its thermal biology, the evaluation of the climatic suitability of this pest is not straightforward and an EKE approach is thus required.

4.2.5. Probability of establishment

The parameter probability of establishment (p_{estab}) in the citrus-growing area in the EU is defined in Table 15.

Table 15: Definition of the parameter probability of establishment (p_{estab})

Name	Definition	Sources
p_{estab}	Probability that one founder population (from a successful entry) will establish. Once transfer occurs, the probability of establishment is the same for all founder populations	Expert knowledge (see justification below)

The elicited distribution of the probability of establishment is reported in Table 16 and Figure 22.

Table 16: Probability of establishment (p_{estab}) for citrus fruit (all scenarios)

Quantile	1%	25%	Median	75%	99%
p_{estab}	0	0.25	0.5	0.75	1

Justification

For the 1% value, the only considered limiting factor is the host presence, as the pest is able to infest different species of *Citrus*. Transfer to isolated hosts in the landscape will reduce the probability of the potential founder population to become self-sustaining and thus to establish (the pest is not a strong flyer). Seasonality in import (mainly winter) can play a role also for establishment, not just transfer. Temperatures are lower in winter, so the pest might not be able to reach the hosts. In the EU, the harvesting season starts in September, then the harvesting calendar goes on until May and even June with late maturing sweet orange cultivars, but the harvested citrus fruit is no longer available for the pest. However, in October, fruit will be on the canopy in most cultivars and will thus be available for the pest. In Valencia, Spain, heat is considered insufficient between November and February for pest development. In March, there might be no fruits available in some areas, as they have mostly been harvested, but ornamental citrus fruit might still be present. One possibility is that transfer takes place on lemon trees, which might not be the most suitable host for establishment of the founder population (lemon is here considered as host for establishment, not as the commodity on which the pest enters the EU). Following a comparative approach, the main difference with *C. sagittiferella* is that this moth is a strong flyer, so it could colonise far away orchards (EFSA PLH Panel, 2023), whereas this is not easy for a tiny midge such as *R. citrifrugis*.

For the 99% value, it was considered that establishment could take place in autumn, when temperatures are still favourable for the pest and citrus fruit not yet harvested. Also, the pest could arrive later in spring and take advantage of late-maturing varieties and milder temperatures.

The median value was set lower than for *C. sagittiferella*, given that *R. citrifrugis* is not such a strong flyer. The pest needs to fly if it transfers to a plant/orchard without fruit. Between September and November, there is fruit. If the pest transfers to a citrus fruit in late-maturing varieties, then it can survive over the winter and start colonising in spring (USDA, 2017). There are many uncertainties, so the median was chosen between the 1% and 99% values, and the 25% and 75% values were chosen to make the distribution as flat as possible.

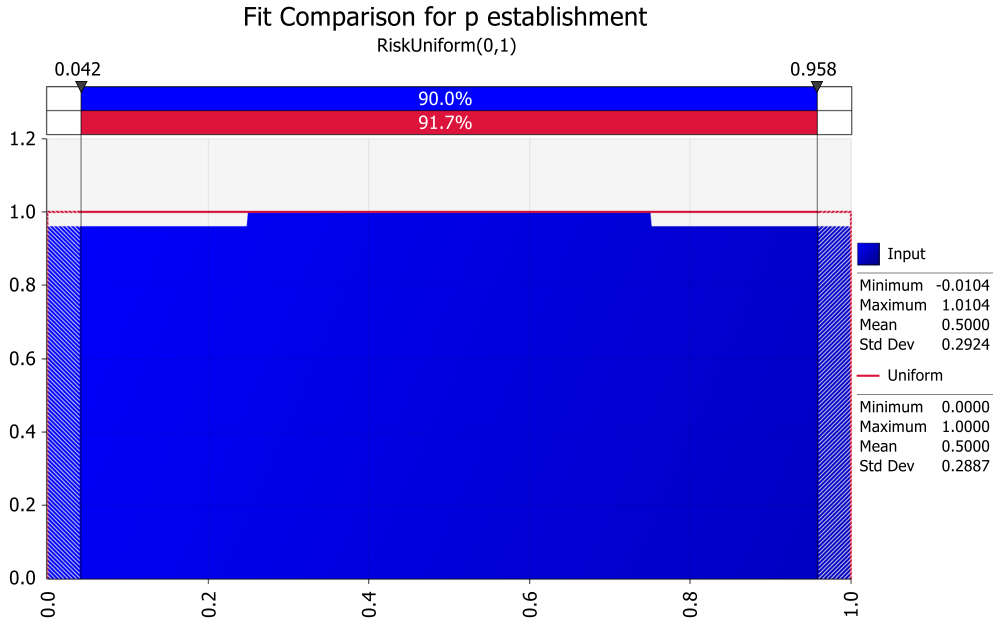

Figure 22: Fitted distribution for the probability of establishment (p_{estab}) (all scenarios)

4.2.6. Number of established populations

As a reminder (see Section 2.2.2), the output variable (N_{est}) of the establishment model is obtained through the following equation:

$$N_{est} = N_{inf} \times p_{estab}.$$

Table 17 shows the outcome of the model calculations for N_{est} (number of established *R. citrifrugis* populations due to entries). The results are visualised in Figures 23–25.
According to the model results,

- Under scenario A0 (current practice, i.e. regulated status), a median of about 15 established populations per year (90%-uncertainty range between about one every 110 years and about 1,500 per year) is expected.
- Under scenario A1 (deregulation), the risk of establishment increases by about three times to a median of about 46 established populations per year (90%-uncertainty range between about one every 30 years and about 4,400 per year).
- Under scenario A2 (regulated status with additional post-harvest cold treatment), a median of about one established population every 90 years (90%-uncertainty range between about one established populations every two billion years and about seven established populations per year) is expected.
- For all scenarios, the number of established populations is only slightly lower than the number of founder populations. In other words, establishment is not expected to be a major constraint for this pest to then spread and cause impacts.
- As is the case in the entry model, the risk of establishment is reduced under scenario A2 compared to scenario A0, but not eliminated, as cold treatment might not be fully effective.

Table 17: Outcome of the model calculation for the output variable N_{est} (the number of *Resseliella citrifrugis* established populations per year due to entries) under the considered scenarios A0 (regulated pest), A1 (unregulated) and A2 (regulated pest with additional RROs), using 10,000 simulation runs

Scenario	Mean	St. dev.	1%	25%	Median	75%	99%
A0	358	1,680	8×10^{-5}	1.1	15	110	6,400
A1	990	4,500	3×10^{-4}	3.6	46	340	18,000
A2	3.2	31	5×10^{-14}	2×10^{-5}	3×10^{-3}	0.1	68

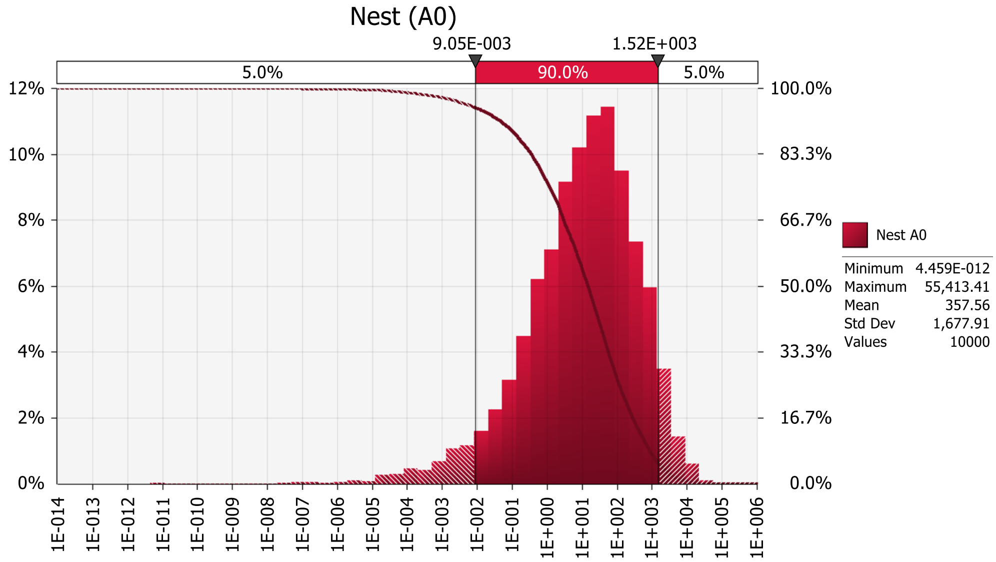

Figure 23: Outcome of the model simulations for scenario A0 (current practice, i.e. regulated status) showing the relative frequency and cumulative descending probability; log-scale x-axis (same x-scale as in Figures 24–25). The number of established *Resseliella citrifrugis* populations is estimated between about one every 110 years and about 1,500 per year with a 90% probability

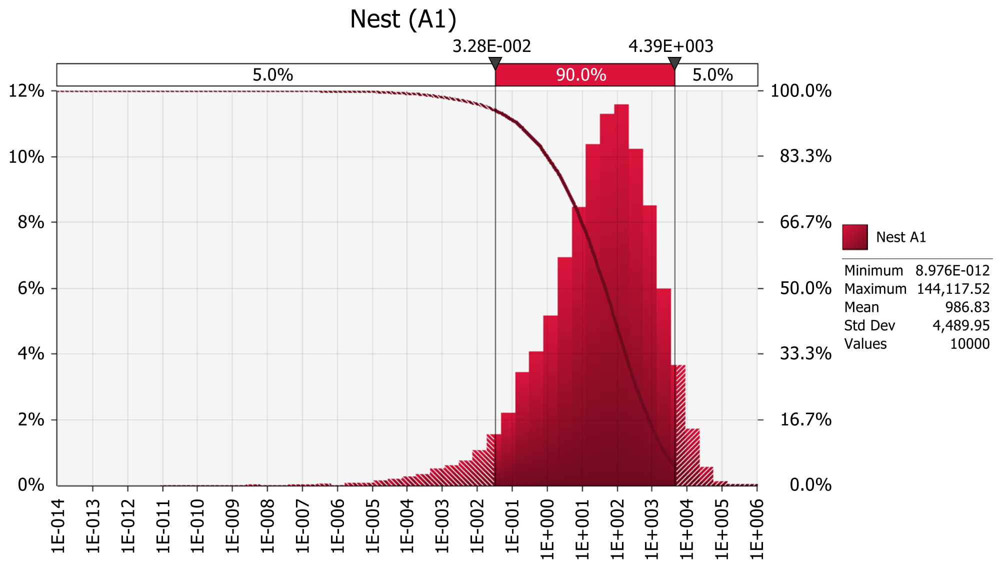

Figure 24: Outcome of the model simulations for scenario A1 (deregulation) showing the relative frequency and cumulative descending probability; log-scale x-axis (same x-scale as in Figures 23 and 25). The number of established *Resseliella citrifrugis* populations is estimated between about one every 30 years and about 4,400 per year with a 90% probability

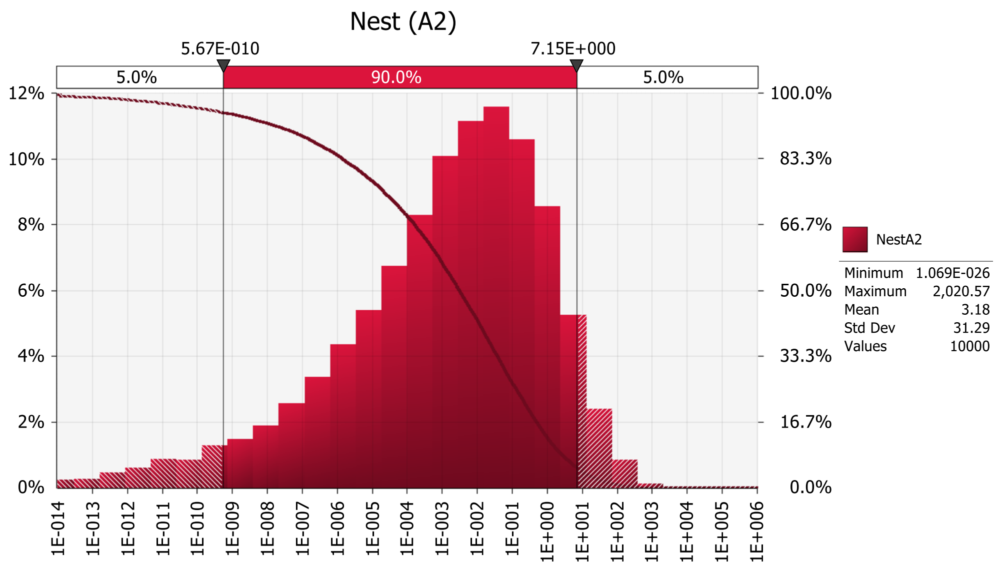

Figure 25: Outcome of the model simulations for scenario A2 (regulated status with additional RRO) showing the relative frequency and cumulative descending probability; log-scale x-axis (same x-scale as in Figures 23–24). The number of established *Resseliella citrifrugis* populations is between one every about two billion years and about seven established populations per year with a 90% probability

4.3. Sensitivity analysis of the number of established populations

Based on the sensitivity analysis (Figures 26–28), the output variable N_{est} is mainly correlated with the probability of transfer and the disaggregation of consignments. For scenario A2, N_{est}.is also strongly correlated with the effectiveness of the RROs. In all scenarios, the probability of establishment is weakly correlated with the output variable N_{est}.

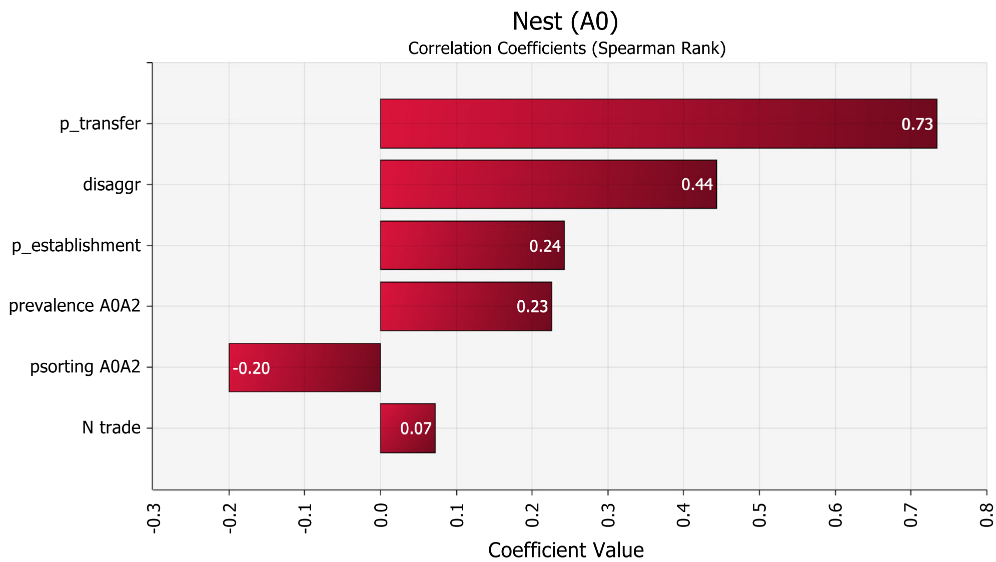

Figure 26: Correlation with the output variable (N_{est}) of the model parameters for scenario A0 (current practice, i.e. regulated status)

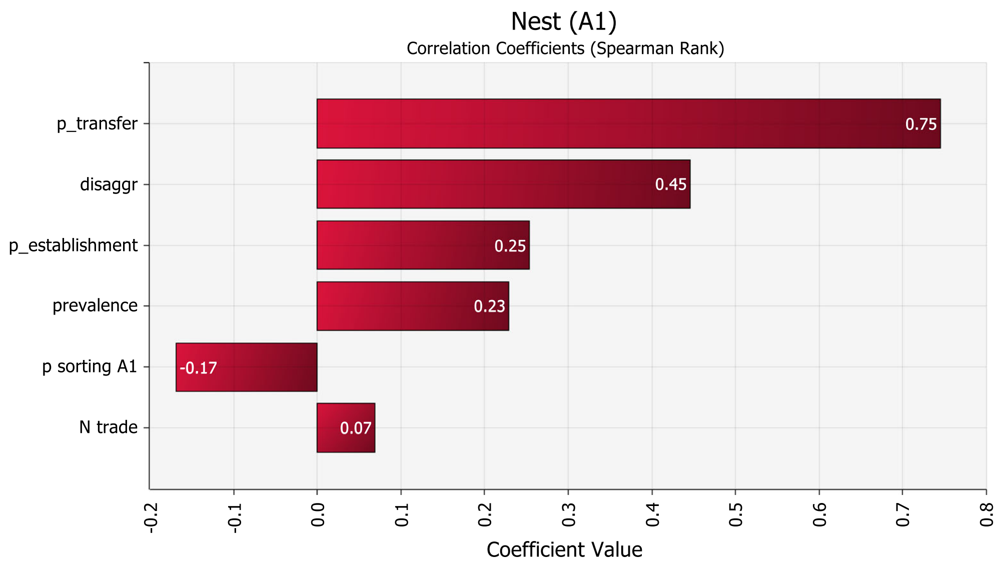

Figure 27: Correlation with the output variable (N_{est}) of the model parameters for scenario A1 (deregulation)

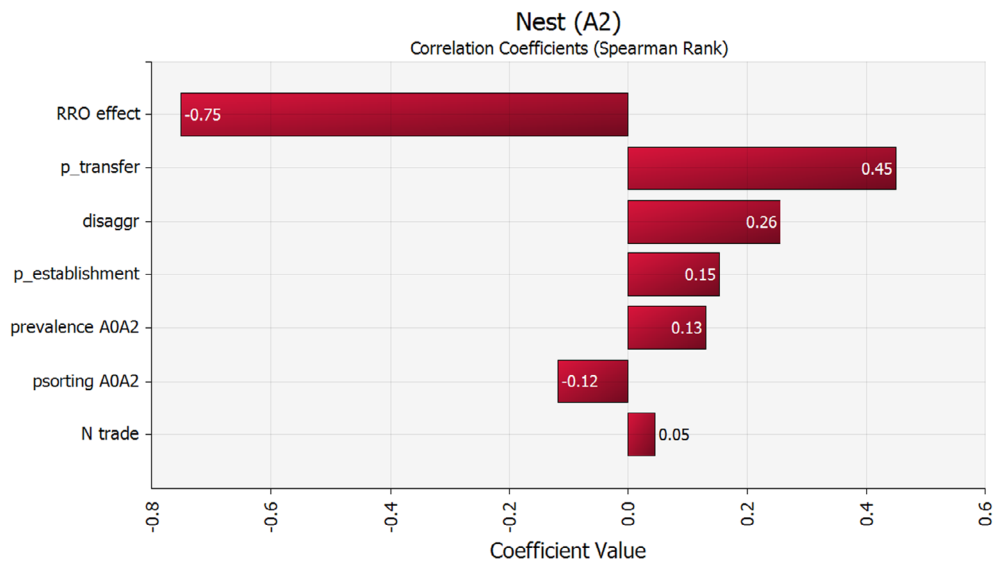

Figure 28: Correlation with the output variable (N_{est}) of the model parameters for scenario A2 (regulated status with additional RRO)

4.4. Additional uncertainties

Unquantified uncertainties in the establishment assessment include:

- The role of irrigation in making the microclimate of citrus orchards more suitable for establishment
- The role of occasional frost in making the microclimate of citrus orchards less suitable for establishment

The Panel expects the conclusions of the assessment model not to be modified substantially by the additional uncertainties not quantified in this assessment.

4.5. Dependencies between parameters

There is a possible dependency between the probability of transfer and the probability of establishment, because locations more suitable to transfer will tend to be also more suitable to establishment.

However, the Panel expects the conclusions of the establishment model not to be modified substantially by this dependency between parameters.

4.6. Conclusions on establishment

Under scenario A0 (current practice, i.e. regulated pest status), model simulations lead to a median of about 15 established populations per year (90%-uncertainty range between about one every 110 years and about 1,500 per year).

Under scenario A1 (deregulation), the risk of establishment increases by about three times to a median of about 46 established populations per year (90%-uncertainty range between about one every 30 years and about 4,400 per year).

Under scenario A2 (regulated status with additional RRO), a median of about one established population every 90 years (90%-uncertainty range between about one established populations every two billion years and about seven established populations per year) is expected.

For all scenarios, the number of established populations is only slightly lower than the number of potential founder populations. In other words, establishment is not expected to be a major constraint for this pest to then spread and cause impacts.

As is the case in the entry model, the risk of establishment is reduced under scenario A2 compared to scenario A0, but not eliminated, as cold treatment might not be fully effective.

The main uncertainties in the establishment assessment are the probability of transfer, the disaggregation of consignments and, for scenario A2, the effectiveness of the RROs. The probability of establishment is instead weakly correlated with the output variable N_{est}.

5. Spread

In the assessment of potential spread, it is assumed that the founder population of *R. citrifrugis* occupies a limited proportion of available habitat (citrus plants or orchards located in a restricted area) with a small local population size (i.e. a fraction of the habitat's carrying capacity), in agreement with previous spread assessments (EFSA PLH Panel, 2022). Similarly, it is assumed that the initial increase in population size and the initial dispersal rate of *R. citrifrugis* are limited due to (a) (epi)-genetic factors (lack of fitness of the species in a new environment) and (b) suboptimal environmental conditions reducing the fitness of the pest.

During the lag period, spread is limited and random (it can vary in different directions). At the end of this phase, the pest is expected to be better adapted to local conditions allowing it to survive, reproduce and infest enough plants to spread between orchards by natural means (flight). In the specific case of *R. citrifrugis*, an important role in the spread is likely to be played by harvesting and transport of citrus fruit to packinghouses, part of common agricultural practices, and thus considered in the estimations here (USDA, 2017).

5.1. Assessment of spread

The lag period between establishment and spread is defined as the time needed for a founder population to build up to a density enabling the colonisation of a neighbouring orchard. For *R. citrifrugis*, the median lag period is estimated to be about 18 months (90%-uncertainty interval between about 7 and 54 months).

After the lag period, the median spread rate by natural means (flying) and due to transport of harvested citrus fruit from orchards to packinghouses (part of common agricultural practices) is estimated at about 100 km/year (90%-uncertainty interval between about 40 and 500 km/year).

More details are provided in Appendix A (Tables A.1–A.2; Figure A.1–A.4).

5.2. Uncertainties

The main uncertainties affecting the assessment of the lag period include:

- the extent to which natural enemies (other arthropods, entomopathogens, birds, etc.) could hamper the build-up of the population, as adaptation to a new host can take time
- climatic conditions disrupting or delaying establishment in new areas
- unknown effects of pesticide applications in the orchard – these would decrease the speed of population build-up
- unknown differences in susceptibility of different *Citrus* species and cultivars

The main uncertainties affecting the assessment of the spread rate include:

- quantitative data about the spread rate in China are not available
- whether gaps in the distribution of citrus orchards in the landscape would affect the natural spread of the pest
- the climate suitability of the initial spread focus

5.3. Conclusions

The median lag period between establishment and spread, defined as the time needed for a founder population to build up to a density enabling the colonisation of a neighbouring orchard, is estimated for *R. citrifrugis* to be about 18 months (90%-uncertainty interval between about 7 and 54 months).

After the lag period, the median spread rate by natural means (flying) and due to transport of harvested citrus fruit from orchards to packinghouses (part of common agricultural practices) is estimated (using EKE, see Appendix A) at about 100 km/year (90%-uncertainty interval between about 40 and 500 km/year).

6. Impact

6.1. Assessment of impact

Estimation of yield losses is performed in terms of the proportion of infested fruits among total fruits produced within the EU citrus-growing regions. Infested fruit may not be harvested, so the total produced fruits in the estimation also include the potentially harvestable fruit that are not harvested due to pest infestation. The estimation is done for citrus in general, without differentiating between *Citrus* species and cultivars or production for fresh consumption and juice.

RROs already in place are taken into account and also possible additional RROs for this pest (e.g. those applied in the countries of origin that could be applied in the EU). In an assessment for the continental US, it was concluded that fruit-infesting cecidomyiid flies are not among the important pests of citrus in that area. Thus, *R. citrifrugis* may require control measures in addition to those already in place for other citrus pests (USDA, 2017).

The elicited median impact of *R. citrifrugis* in the EU citrus-growing area as the proportion of infested citrus fruit among the harvested (i.e. harvestable) citrus fruit is estimated at about 10% (90%-uncertainty range between about 2% and 25%).

More details are provided in Appendix A (Tables A.3; Figures A.5–A.6).

6.2. Uncertainties

Uncertainties affecting the impact assessment include:

- the susceptibility of different *Citrus* species and cultivars.
- differences in potential yield loss between fresh fruit and juice production.
- the effect of the citrus fruit harvesting season in the EU (mainly winter, which is most probably the less suitable season for the pest).

Most factors affecting the impact assessment are fraught with uncertainty. Further uncertainties are listed in Appendix A.

6.3. Conclusions on impact

The pest is reported to cause significant damage in China (Xia et al., 2021). This PRA confirms the potential negative impact of *R. citrifrugis* in the EU citrus-growing area. The median impact of *R. citrifrugis* in the EU citrus-growing area as the proportion of infested citrus fruit out of the harvested citrus fruit is estimated at about 10% (90%-uncertainty interval between about 2% and 25%).

7. Conclusions of the PRA

In a study of new pests likely to be introduced into Europe with the fruit trade, *R. citrifrugis* was assessed as a pest with high economic importance, more likely to transfer and emerge/spread (Suffert et al., 2018). In agreement with the EFSA pest categorisation (EFSA PLH Panel, 2021b), this PRA confirms the potential for entry, establishment, spread and impact of *R. citrifrugis*. The PRA also shows the effectiveness of (1) regulation of *R. citrifrugis* and (2) cold treatment as a stand-alone post-harvest additional RRO.

Entry

Based on the outputs of the entry model, under scenario A0 (current practice, i.e. regulated pest status), slightly less than 40 potential founder populations per year are expected (median; 90%-uncertainty interval between about one per 30 years and about 3,000 per year).

Under scenario A1 (deregulation), the risk of entry increases by about three times to about 120 potential founder populations per year (median; 90%-uncertainty interval between about one per 10 years and about 9,000 per year). In this scenario, the prevalence at the origin is higher than under current practice, and the sorting less effective.

Compared to both scenarios A0 and A1, the risk of entry is orders of magnitude lower for scenario A2 (regulated pest status with additional RRO) (median = about one potential founder population per 120 years; 90%-uncertainty interval between one per about 600 million years and about two per year). The only difference with scenario A0 under scenario A2 is the inclusion in the model of the RRO.

The uncertainty is larger for scenario A2 (the 90%-uncertainty range spans nine orders of magnitude) compared to scenarios A0 and A1 (the 90%-uncertainty range spans five orders of magnitude).

In all scenarios, the uncertainty in the model outcome is due to combining the uncertainties of the model parameters. The main uncertainties in the entry assessment are the probability of transfer, the $RRO_{effectiveness}$ (for scenario A2) and the disaggregation of consignments (a parameter reflecting the distribution of one ton of infested citrus fruit to different locations in the risk assessment area).

Establishment

When including the probability of establishment in the model, under scenario A0 (current practice, i.e. regulated status), model simulations lead to a median of about 15 established populations per year (90%-uncertainty range between about one every 110 years and about 1,500 per year).

Compared to scenario A0, under scenario A1 (deregulation), the risk of establishment increases by about three times to a median of about 46 established populations per year (90%-uncertainty range between about one every 30 years and about 4,400 per year).

Under scenario A2 (regulated status with additional RRO), a median of about one established population every 90 years (90%-uncertainty range between about one established populations every two billion years and about seven established populations per year) is expected.

For all scenarios, the number of established populations is only slightly lower than the number of potential founder populations. In other words, establishment is not expected to be a major constraint for this pest to then spread and cause impacts.

As is the case in the entry model, the risk of establishment is reduced under scenario A2 compared to scenario A0, but not eliminated, as cold treatment might not be fully effective.

The main uncertainties in the establishment assessment are the probability of transfer, the disaggregation of consignments, and, for scenario A2, the effectiveness of the RROs.

Spread

The median lag period between establishment and spread, defined as the time needed for a founder population to build up to a density enabling the colonisation of a neighbouring orchard, is estimated for *R. citrifrugis* to be about 18 months (90%-uncertainty interval between about 7 and 54 months).

After the lag period, the median spread rate by natural means (flying) and by transport of harvested citrus fruit from orchards to packinghouses (part of common agricultural practices) is estimated at about 100 km/year (90%-uncertainty interval between about 40 and 500 km/year).

The main uncertainties in the assessment of the lag period include climatic conditions disrupting or delaying establishment in new areas and unknown differences in susceptibility of different citrus cultivars in the EU. The main uncertainties in the assessment of the spread rate include the lack of available data about the spread rate in China and the climate suitability of the initial spread focus.

Impact

The median impact of *R. citrifrugis* in the EU citrus-growing area as the proportion of infested citrus fruit out of the harvested citrus fruit is estimated at about 10% (90%-uncertainty interval between about 2% and 25%).

Uncertainties affecting the impact assessment include the susceptibility of different citrus cultivars and the effect of the citrus fruit harvesting season in the EU (mainly winter, which is the less suitable season for the pest).

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Abbreviations

A0	scenario reflecting current requirements
A1	scenario reflecting deregulation (not considered in this assessment)
A2	scenario with risk reduction options
EPPO	European and Mediterranean Plant Protection Organisation
FAO	Food and Agriculture Organisation of the United Nations
IPM	Integrated Pest Management
IPPC	International Plant Protection Convention
MS	Member State
N_{est}	number of established populations

N_{inf}	number of potential founder populations
N_{trade}	trade flow
$P_{prevalence}$	prevalence at the origin
$p_{sorting}$	sorting
$p_{transfer}$	probability of transfer
PLH	Plant Health
PRA	pest risk assessment
RRO	risk reduction option
USDA	United States Department of Agriculture

Appendix A – Overview of the evaluation of spread and impact

SPREAD

Overview of the results of the Expert Knowledge Elicitation (1st EKE question)															
Parameter	**Duration of the lag period (months)**														
Stratification	Citrus-growing area in the EU (see Figure 19)														
Question	How long is the average duration of the lag period, i.e. the time from the first infested plant(s) present in a citrus orchard to the spread between orchards by natural means, e.g. by flight of the pest? [months]														
Results	P1%	P5%	P10%	P15%	P20%	P25%	P35%	P50%	P65%	P75%	P80%	P85%	P90%	P95%	P99%
Elicited values	6					12		18		33					48
EKE results	4.7	6.8	8.4	9.7	10.9	12.1	14.5	18.6	23.9	28.9	32.3	36.6	42.9	53.8	80.4
Fitted distribution	Invgauss (22.922, 47.913)														

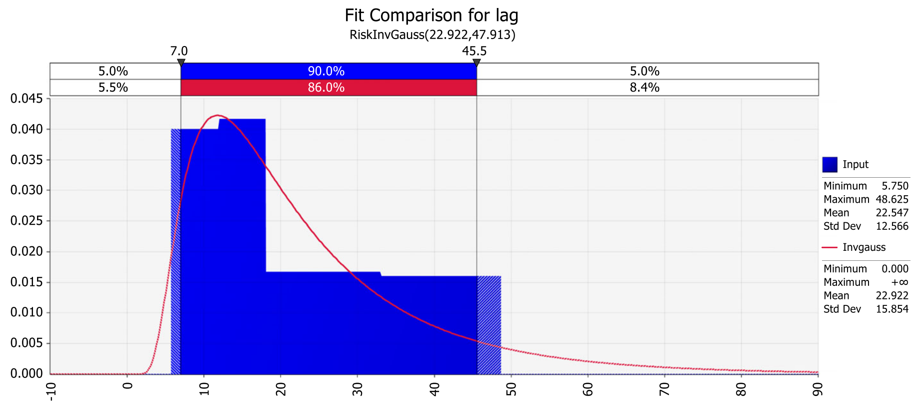

Figure A.1: Comparison of elicited and fitted values/density function to describe the remaining uncertainties of the parameter

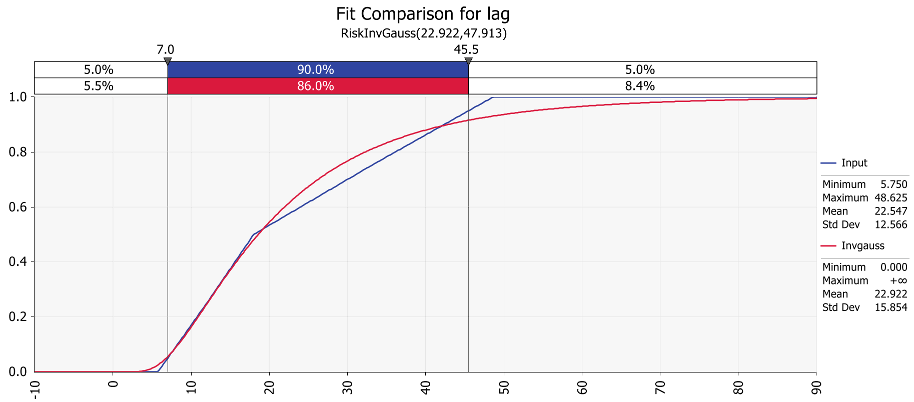

Figure A.2: Cumulative distribution function (CDF) of the parameter

Table A.1: Lag period

Summary of the evidence used for the evaluation
The experts considered several factors influencing the presence and the length of a lag period, especially: • Size of the founder population • Size of the orchard • Generation time needed for descendants to be able to spread • As the population has established, temperature would be suitable for establishment, but it could still be more or less suitable for the spread to begin (e.g. due to the presence of fruit) • Timing of the process start (winter arrival would delay the process, whereas summer arrival would proceed immediately)
Main uncertainties
• The extent to which natural enemies (other insects, entomopathogens, birds, etc.) could hamper the build-up of the population as adaptation to a new pest can take time • Climatic conditions could disrupt or delay the development • Unknown effect of pesticide applications in the orchard would decrease the speed of population build-up • Uncertain differences in susceptibility of different *Citrus* species and cultivars to *R. citrifrugis*

Reasoning for a scenario which would lead to a reasonable high duration	The judgement on the upper limit considers that: • several generations are needed to produce a population able to spread beyond the limits of the orchard. • more time compared to *C. sagittiferella* is needed for *R. citrifrugis* for population build-up (due to the known temperature requirements – *C. sagittiferella* is also likely to be a thermophilic species, but no specific data are available) • colonisation of the initial focus, particularly for large citrus orchards, could take several years
Reasoning for a scenario which would lead to a reasonable low duration	The judgement on the lower limit considers that: • if a relatively high number of individuals arrive, they could spread in a matter of months, particularly for small orchards • however, this pest is not a strong flyer, so more time than for *C. sagittiferella* is expected to be required
Fair estimate as judgement on the weighted evidence	The judgement on the median considers that: • the most frequent situation would be that relatively few individuals arrive, which have to reproduce before spreading, which will take at least 1 year • however, *R. citrifrugis* is less of a strong flyer than *C. sagittiferella* • as *R. citrifrugis* is smaller than *C. sagittiferella*, natural enemies could prey more easily on *R. citrifrugis*, thus delaying spread
Precision of the judgement as description of remaining uncertainties	The judgement on the interquartile range considers that: • after 18 months, a suitable season is likely to have occurred • uncertain susceptibility of different *Citrus* species and cultivars • it could take time for the pest to adapt to the EU conditions and citrus cultivars

Overview of the results of the Expert Knowledge Elicitation (2nd EKE question)															
Parameter	**Spread rate after the lag period (km/year)**														
Stratification	Citrus-growing area in the EU (see Figure 19)														
Question	Assuming that human-assisted spread between citrus orchards is excluded by perfect sanitary measures or prohibited exchange of tools, but taking into account the possible movement of harvested citrus fruit from orchards to packinghouses (as this is part of common agricultural practices), what is the 95th percentile of the distance newly infested orchards have to the nearest existing one already infested 1 year before? [km/year]														
Results	P1%	P5%	P10%	P15%	P20%	P25%	P35%	P50%	P65%	P75%	P80%	P85%	P90%	P95%	P99%
Elicited values	0					70		100		200					1,000
EKE results	27	37	46	53	60	66	81	107	146	189	221	267	345	520	1,268
Fitted distribution	Pearson5 (1.9505, 174.66)														

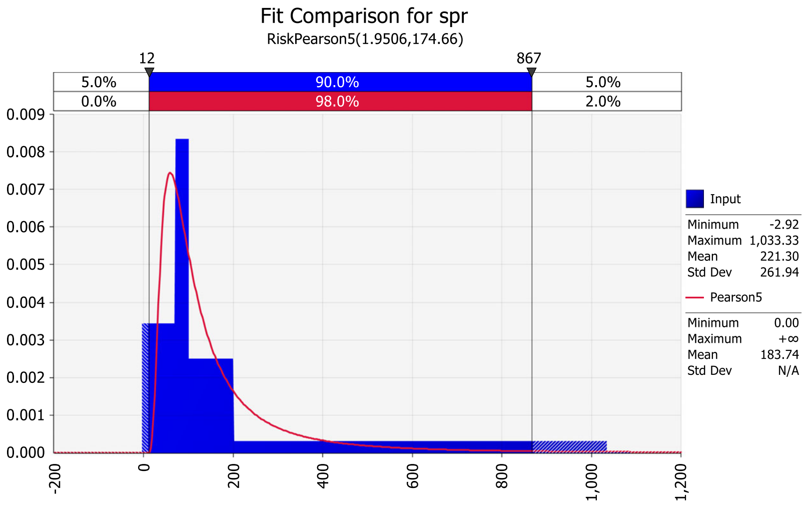

Figure A.3: Comparison of elicited and fitted values/density function to describe the remaining uncertainties of the parameter

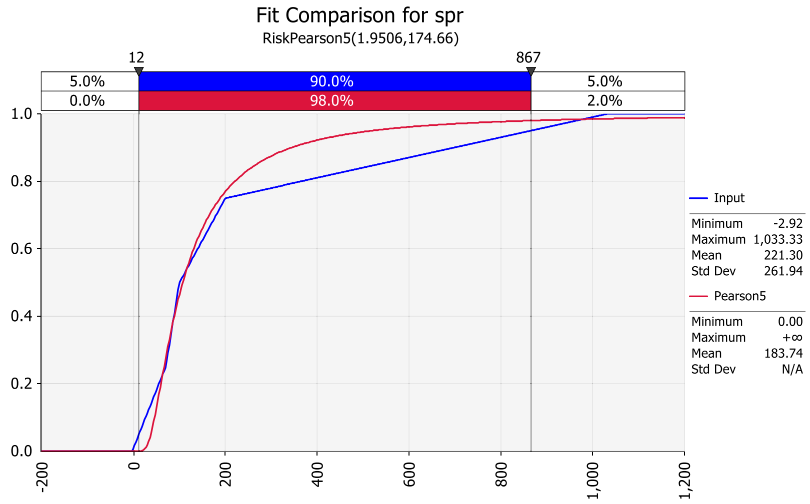

Figure A.4: Cumulative distribution function (CDF) of the parameter

Table A.2: Spread rate after lag period

Summary of the evidence used for the evaluation	
The experts considered several factors influencing the rate of spread, including: • *R. citrifrugis* is not a strong flyer (in contrast with *C. sagittiferella*) • The values in the literature for other citrus pests (e.g. *Phyllocnistis citrella*) may not be due only to natural spread • Spreading across whole regions takes years only for wingless mites. If citrus pests can fly, then it is normally a relatively fast process • *R. citrifrugis* is a pest of fruits, not of other organs of the plant. Fruit movement is part of common agricultural practices, so it is considered here • Continuity of citrus orchards in the landscape	
Main uncertainties • Quantitative data of the spread rate are not available • Lack of knowledge of the spread rates for midges • Whether gaps in the distribution of citrus orchards in the landscape would affect the natural spread of the pest • Climate suitability of initial spread focus	
Reasoning for a scenario which would lead to a reasonable high spread rate	The judgement on the upper limit considers that: • considering fruit movement, the spread rate would be increased by jumps between far-away locations • a jump from e.g. Huelva to Valencia provinces (Spain) due to movement of fruit boxes before processing at packinghouse would not be surprising in 1 year • even after processing at the packinghouse, there could still be viable eggs and larvae in the traded fruit
Reasoning for a scenario which would lead to a reasonable low spread rate	The judgement on the lower limit considers that: • in 1 year, if there is only one generation, each midge would live maximum 5 days and would fly less than 1 km (*R. citrifrugis* is not a strong flyer) • however, in case of an isolated citrus orchard, or under protected cultivation, then the pest would not spread much and the outbreak could remain relatively localised
Fair estimate as judgement on the weighted evidence	The judgement on the median considers that: • if the judgement was just on natural spread, with more than one generation per year, then about 1 km per year would be a suitable median • but here we consider fruit movement, so hundreds of km is more realistic • to reduce transport costs, harvested fruit mostly goes to the nearest packinghouses
Precision of the judgement as description of remaining uncertainties	The judgement on the interquartile range considers that: • a peak around 100 km is likely because fruit movement is an efficient means of spread, but most of the times not over extremely long distances • juice-processing facilities are not so many, thus extending the possible spread rate, but even in that case distance travelled by the harvested fruit will be kept as low as possible for cost reasons. Juice is anyway a side-product, at least in Spain, where production is oriented towards fresh consumption

IMPACT

Overview of the results of the Expert Knowledge Elicitation (3rd EKE question)															
Parameter	**Incidence in citrus fruit (proportion)**														
Stratification	Citrus-growing area in the EU (see Figure 19)														
Question	What is the proportion of infested fruits out of harvested fruits within the EU citrus production regions (i) once the pest has spread to the entire citrus-growing area in the EU, (ii) for citrus in general, without differentiating between citrus cultivars for production for fresh consumption and juice and (iii) taking into account RROs already in place as well as possible additional RROs for this pest (e.g. those applied in the countries of origin that could be applied in the EU)?														
Results	P1%	P5%	P10%	P15%	P20%	P25%	P35%	P50%	P65%	P75%	P80%	P85%	P90%	P95%	P99%
Elicited values	0					0.05		0.10		0.15					0.25
EKE results	0.008	0.019	0.029	0.038	0.046	0.054	0.070	0.095	0.12	0.15	0.17	0.18	0.21	0.25	0.34
Fitted distribution	BetaGen (1.8790, 15.259, 0.1)														

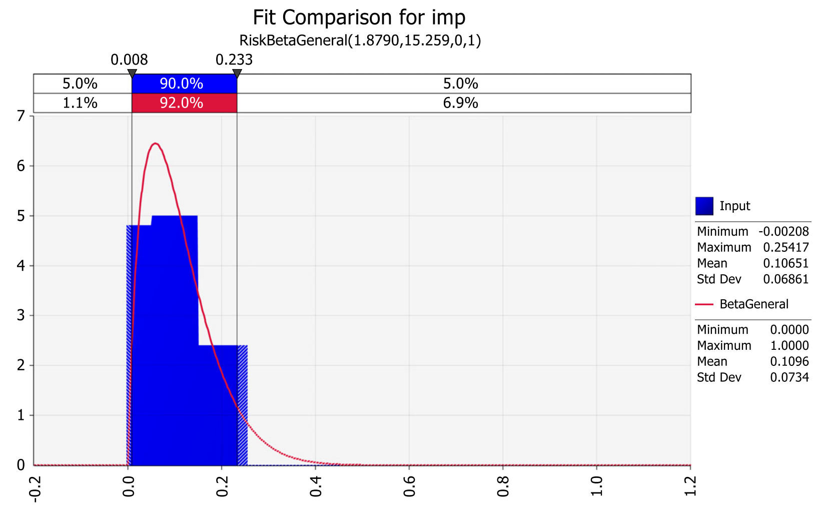

Figure A.5: Comparison of elicited and fitted values/density function to describe the remaining uncertainties of the parameter

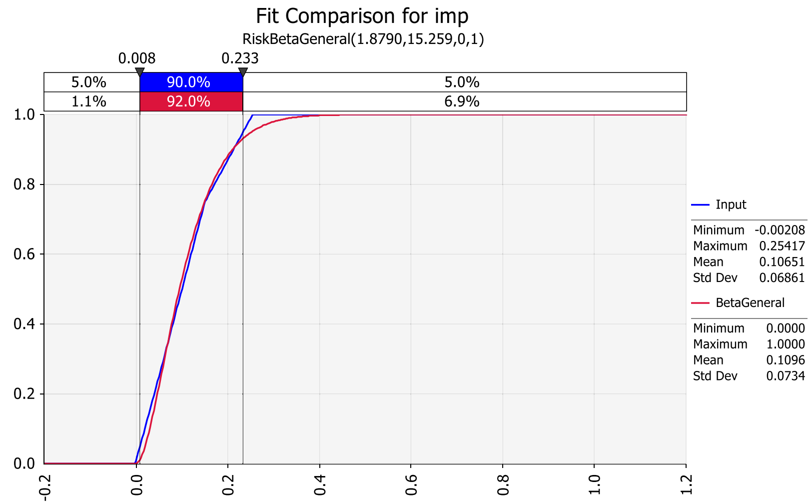

Figure A.6: Cumulative distribution function (CDF) of the parameter

Table A.3: Yield loss

Summary of the evidence used for the evaluation	
The experts considered several factors influencing the yield loss, in particular: • Susceptibility of different *Citrus* species and cultivars • Environmental conditions (e.g. presence of frost, low relative humidity) • Control measures applied against other pests (especially *Ceratitis capitata*) • Natural enemies (generalists) already present in the EU • Number of generations (voltinism may be lower than at the area of current distribution) • Number of larvae per fruit (it may be lower than in the area of current distribution)	
Main uncertainties • A potential mismatch between host phenology and pest development (although citrus fruit is available most of the year also in the EU) • Susceptibility of different *Citrus* species (it is unknown whether lemon is affected) and cultivars • Differences in crop value between fresh fruit and juice production (in some cases infested fruit might go to juice production, with a lower price) • Effect of the harvesting season in the EU (mainly winter, which is likely the less suitable season for the pest)	
Reasoning for a scenario which would lead to a reasonable high impact	The judgement on the upper limit considers that: • the pest has high prevalence at the origin, similarly as for *C. sagittiferella*
Reasoning for a scenario which would lead to a reasonable low impact	The judgement on the lower limit considers that: • if conditions are unsuitable for the pest, yield loss would be zero or close to zero
Fair estimate as judgement on the weighted evidence	The judgement on the median considers that: • the skew towards the left of the distribution reflects the elicited distribution for the prevalence at the origin (see Section 3.2.2.1)
Precision of the judgement as description of remaining uncertainties	The judgement on the interquartile range considers that: • the microclimatic conditions will not be similarly suitable for the pest in all citrus orchards • the values elicited for the prevalence at the origin were halved