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Popillia japonica
Pest Report to support ranking of EU candidate priority pests

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1. Introduction to the report

This document is one of the 28 Pest Reports produced by the EFSA Working Group on EU Priority Pests under task 3 of the mandate M-2017-0136. It supports the corresponding Pest Datasheet published together on Zenodo[1] and applies the methodology described in the Methodology Report published on the EFSA Journal (EFSA, 2019a).

This Pest Report has five sections. In addition to this introduction, a conclusion and references, there are two key sections, sections 2 and 3.

Section 2 first summarises the relevant information on the pest related to its biology and taxonomy. The second part of Section 2 provides a review of the host range and the hosts present in the EU in order to select the hosts that will be evaluated in the expert elicitations on yield and quality losses. The third part of Section 2 identifies the area of potential distribution in the EU based on the pest's current distribution and assessments of the area where hosts are present, the climate is suitable for establishment and transient populations may be present. The fourth part of Section 2 assesses the extent to which the presence of the pest in the EU is likely to result in increased treatments of plant protection products. The fifth part of section 2 reviews additional potential effects due to increases in mycotoxin contamination or the transmission of pathogens.

In Section 3, the expert elicitations that assess potential yield losses, quality losses, the spread rate and the time to detection are described in detail. For each elicitation, the general and specific assumptions are outlined, the parameters to be estimated are selected, the question is defined, the evidence is reviewed and uncertainties are identified. The elicited values for the five quantiles are then given and compared to a fitted distribution both in a table and with graphs to show more clearly, for example, the magnitude and distribution of uncertainty. A short conclusion is then provided.

The report has two appendices. Appendix A contains a host list created by amalgamating the host lists in the EPPO Global Database (EPPO, online) and the CABI Crop Protection Compendium (CABI, 2018). Appendix B provides a summary of the evidence used in the expert elicitations.

It should be noted that this report is based on information available up to the last day of the meeting[2] that the Priority Pests WG dedicated to the assessment of this specific pest. Therefore, more recent information has not been taken into account.

For *Popillia japonica*, the following documents were used as key references: the EPPO diagnostic protocol (EPPO, 2006), the pest risk assessment for the UK territory (Korycinska et al., 2015), the pest categorization by EFSA PLH Panel (2018), the pest survey card by EFSA (2019b).

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[1] Open-access repository developed under the European OpenAIRE program and operated by CERN, https://about.zenodo.org/

[2] The minutes of the Working Group on EU Priority Pests are available at http://www.efsa.europa.eu/sites/default/files/wgs/plant-health/wg-plh-EU_Priority_pests.pdf

2. The biology, ecology and distribution of the pest

2.1. Summary of the biology and taxonomy

The Japanese beetle, *Popillia japonica*, is a single taxonomic entity. It is a polyphagous species with over 300 hosts in 79 plant families. It defoliates plants, skeletonises leaves and adults can also feed on fruits. Larvae live and develop underground, feeding on roots. The main factors limiting the spread are temperature and soil moisture (Fleming, 1972). In the area of origin, Japan, there is one generation per year but in cold northern regions the pest has a 2-year life cycle. The same duration can be observed in USA and Canada (Fleming, 1972). Adults usually fly for short distances, from plant to plant. The spread rate was estimated at 2 to 20 miles (3.7 – 37 km) per year with the average of 5 miles (9.3 km) annually (Fox, 1932).

In the USA (USDA, 2015):

- Larvae of *P. japonica* are pests of turf, especially in lawns, golf courses and sports pitches. Larval feeding on grass roots causes drought stress and browning which often requires replacement of the turf.
- Adults are often found feeding in gardens, on rose plants and other ornamentals. They are attracted to diverse plant odours, especially blends of feeding-induced volatiles, and have gut enzymes able to detoxify a myriad of secondary compounds (Loughrin et al., 1995).

2.2. Host plants

2.2.1. List of hosts

Popillia japonica is a polyphagous pest with over 300 host species belong to 79 families in USA (EFSA PLH Panel, 2018). Tree hosts include: *Acer, Betula, Fagus, Larix decidua, Malus, Populus, Prunus, Quercus, Tilia* and *Ulmus.* Some shrubs such as: *Althaea rosea*, *Rhododendron*, *Rosa*, *Rubus idaeus*, *Vaccinium*, *Viburnum* and *Vitis* are also a host for the pest. *Asparagus officinalis, Fragaria*, *Trifolium* and *Zea mays* are also attacked by insect. *Vitis* and *Zea* mays could represent the main crops of concern for the EU together with grassland species in *Festuca*, *Poa* and *Lolium* (EPPO, 2006). The larval activity can represent a threat for nurseries, seedbeds, orchards, field crops, landscape plants, turf and garden plants. Impacts on forest trees are not expected as *P. japonica* attacks flowers and fruits but does not kill trees.

Appendix A provides the full list of hosts.

2.2.2. Selection of hosts for the evaluation

At the Ticino Valley outbreak site in Italy, *P. japonica* was observed on wild *Rubus*, *Ulmus*, *Urtica*, *Rosa*, *Populus* and *Parthenocissus* and cultivated soybean (*Glycine max*) (EPPO, 2014).

Crucial factors in host selection by the beetle are the host plant’s odour and if it is located in direct sun. Usually, the beetles feed in groups, starting at the top of a plant and working downwards (Vieira, 2008).

Popillia japonica’s impact on hazelnut (*Corylus avellana*) has not been assessed although impacts have been observed in Italy which is potentially relevant from an environmental point of view.

The following table shows the plant parts of different crops that are attacked by *P. japonica*.

	roots	leaves	fruits	flowers
raw crops (soybean, **maize**, etc)	X	X		X
Shrubs (e.g. hazelnuts)		X		
Large fruit (e.g. stone fruit, apple)		X	X	
Soft fruit/berries		X	X	
Ornamentals		X		X
Turf/grassland	X			
Grapevine		X		

For the impact assessments, the hosts were grouped based on the expected amount and type of damage

- Turf production
- Soft fruit (the timing of maximum damage coincides with the ripening period)
- Stone fruit (excluding kiwi fruit)
- Maize and soybean
- Grapevine

2.2.3. Conclusions on the hosts selected for the evaluation

The complete list of hosts is produced by merging:

- the list of host plants defined by EPPO (online),
- the list of host species reported by CABI (2018)

The hosts on which impacts were assessed are:

- turf, in terms of percentage infested area of turf that requires replacement, including sports fields
- soft fruit such as blueberries, strawberries and blackberries
- stone fruits, including edible species, ornamentals and wild species
- soybean and maize (excluding forage maize)
- grapevine

2.3. Area of potential distribution

2.3.1. Area of current distribution

Popillia japonica, is an insect native to Japan which has spread in eastern states of United States since 1911. It is also known to occur in eastern Canada (Ontario, Quebec, New Brunswick, Nova Scotia and Prince Edward Island) and in Vancouver, British Columbia (CFIA, 2019). Its presence in Far East Russia is limited to Kunashir island, less than 30 km to the east of Hokkaido (northern Japan). In the EU the pest occurs in the Azores, where it was introduced in the early 1970s, and in Italy (in Piedmont and Lombardy Regions), where it was reported in October 2014 (EPPO, 2014). It is unknown how *P. japonica* arrived in Italy, but two airports are close to the sites of detection (EPPO, 2016). In spite of the immediate application of control measures, eradication in the EU remains unfeasible due to the extent of the infestation and the well-established population. In June 2017, Switzerland reported finding *P. japonica* adults in a pheromone trap near the border with Italy, a few km from an outbreak site in Italy (EPPO, 2017).

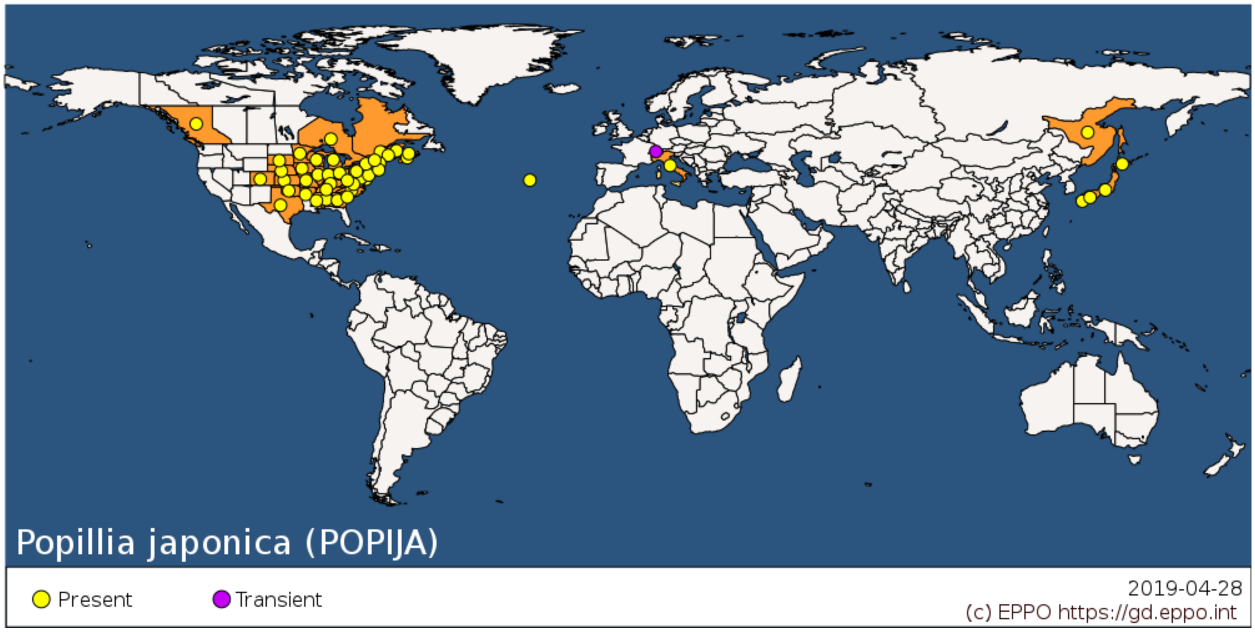

Figure 1 Distribution map of *Popillia japonica* from the EPPO Global Database accessed 28/04/2019.

2.3.2. Area of potential establishment

Popillia japonica can occur in locations with degree days above 1422 (10 °C threshold) where the insect can complete its life cycle in one year, or in places with degree days above 711 (10 °C threshold) where the life cycle takes two years (Table 1). In Italy, *P. japonica* has been observed completing its cycle in 1 year (EPPO, online)

Eggs are not cold hardy (Fleming, 1972):

- viability decreases at temperatures below 10° C, reaching zero after 28 days at 3-5°C
- 7 days at 0°C or 1 day to -20°C led to 100% egg mortality
- eggs do not hatch below 15°C
- only 42% hatched at 15°C

- more than 75% hatch at temperatures between 17.5 and 34°C
- no eggs hatch above 34°C
- adult mortality observed was: 42% after 60 minutes at -5°C, 84% at -10°C and 100% at -15°C

Other key abiotic factors are

- soil temperature: the insect requires 17.5-27.5°C in summer, and > -9.4°C in winter (Fleming, 1972).
- soil moisture: the insect requires fairly uniform precipitation during the year and at least 250 mm during the summer (although the Milan summer rainfall of 234 mm did not impede establishment)

Bourke (1961; in Fleming, 1972) concluded that the Mediterranean region was unsuitable for the establishment of *P. japonica* due to the lack of summer rainfall. Establishment in northern Europe was judged less likely because of lower summer temperatures. The most suitable climatic conditions for establishment in Europe were identified to be in central France, southern Germany, and parts of Switzerland, Austria,the Czech Republic, Hungary, Poland, Romania and Slovakia where summer rainfall is abundant and temperature is favourable. However, extensive irrigation applied in southern Europe could make some areas also suitable for its establishment there (EFSA PLH Panel, 2018).

The role of soil moisture for oviposition and temperature for development are taken into account as uncertainties.

Calculations based on air temperature from Lombardy (Boriani, personal communication):

- 460 degree days min 10°C MAX 34 °C for the first adult male
- 520 degree days min 10°C MAX 34 °C for the first adult female

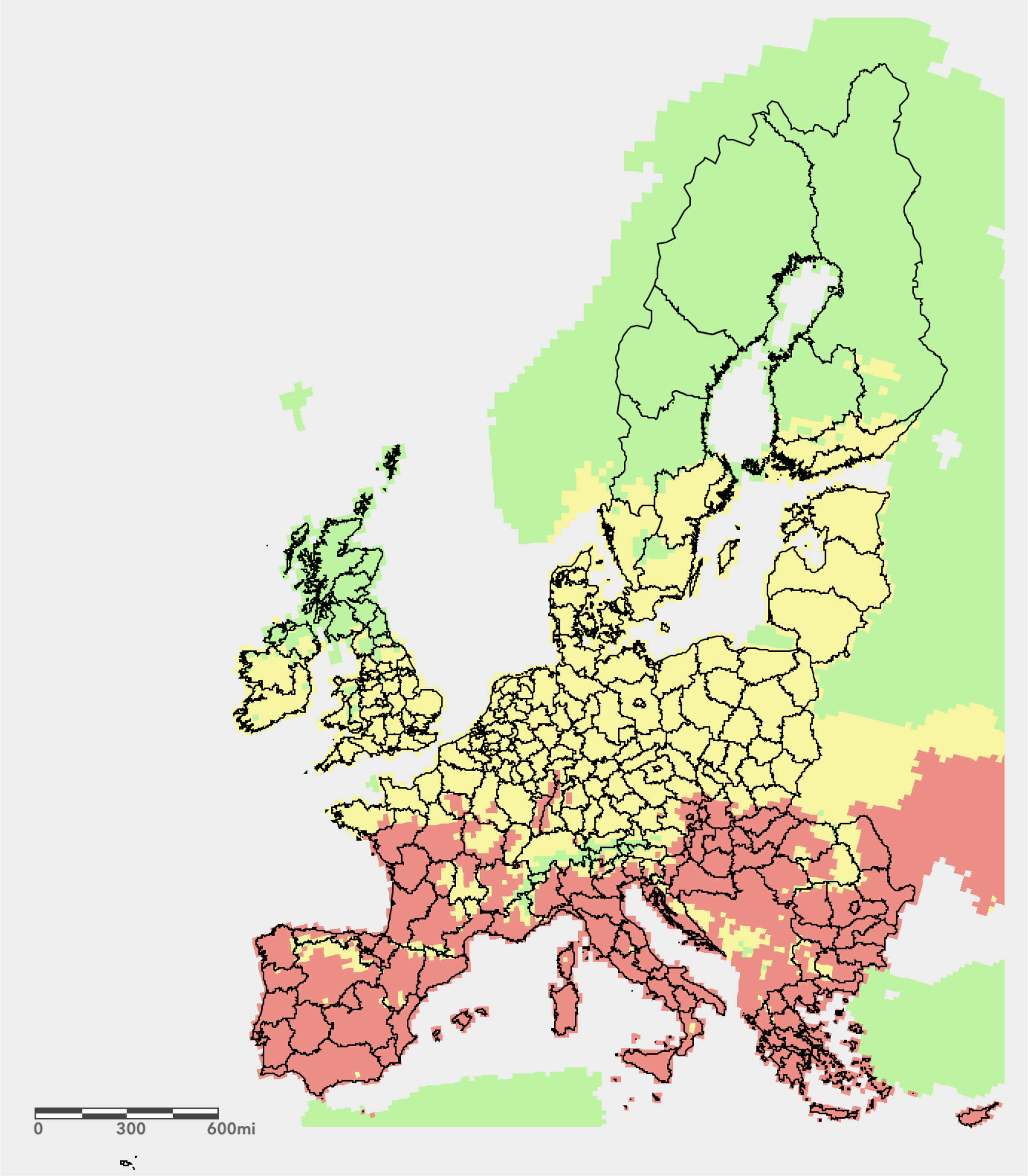

Figure 2 Climatic suitability for *Popillia japonica* development based on degree days above 711 (for a two year life cycle) and 1422 (for a one year life cycle) with a threshold of 10°C (climatic data 1997-2017) based on Korycinska and Baker (2017). Colour indicates where accumulated temperature is or is not suitable for development of *P. japonica*: red indicates the life cycle can be completed in one year; yellow indicates the life cycle will require two years; green colour indicates temperature does not favour the successful development of *Popillia japonica*. Note that soil moisture – which corresponds with rainfall – is not considered here but is important, since precipitation and soil moisture should be taken into account when considering establishment of *P. japonica*. Overlaying this figure with precipitation data would more clearly identify where temperature and summer precipitation support the establishment of *P. japonica*. This link provides an online interactive version of the map that can be used to explore the data further: https://arcg.is/PbS8i

Table 1: Thermal requirements for the development of *Popillia japonica* in rearing experiments (Korycinska et al., 2015).

Minimum threshold for development	**Degree days**	**Details**	**Reference**
Between 13 and 15°C (depending on life stage)	1317.1	At a temperature of 20°C, egg-adult	Ludwig (1928)
	1596.5	At 22.5°C, egg-adult	
	1970.9	At 25°C, egg-adult	
10°C	1305	Egg-adult	Régnière et al. (1981)
10°C	1422	Egg-egg	Régnière et al. (1981)
Not stated	Min: 1029 Max: 2154	"Growing degree days" but no details of what is being measured, or the threshold temperature. Location: Long Island, New York using a 20-year dataset.	Johnson (2000)
50°F (= 10°C)	970	From Jan 1, cumulative degree days before adult emergence in Ohio	Herms (2004)
50°F (= 10°C)	1030	From Jan 1, cumulative degree days before adult emergence in Iowa	Hodgson and Kuntz (2013)

P. japonica is adapted to regions were the mean soil temperature is between 17.5 and 27.5°C during the summer, and above -9.4°C in the winter (Hawley and Dobbins, 1941; CABI, 2018). This species feeds on clear summer days when the temperature is between 21 °C and 35 °C, and the relative humidity is above 60%, the beetle feeds less on cloudy and windy days and does not feed on rainy days (CFIA, 2017).

Since the Japanese beetle has a broad host range, host plants are not the limiting factor for its establishment. It is expected to be able to establish in all Member States where climatic conditions are suitable (Figure 2). The beetle has established in the Azores (Portugal) and in Milan (Italy). However, temperature and the soil moisture are key parameters limiting the potential spread of the Japanese beetle into new areas.

2.3.3. Transient populations

Popillia japonica is not expected to form transient populations in the EU (for "transient" see the definition in EFSA, 2019a).

2.3.4. Conclusions on the area of potential distribution

The area of potential establishment includes all the areas in the EU where degree days are greater than 711 with a minimum threshold of development of 10°C. The map of the area of potential establishment is shown in Figure 3 based on climatic data from JRC for the period 1998-2017.

For this species, since transient populations are not considered, the assessment is limited to the area of potential establishment.

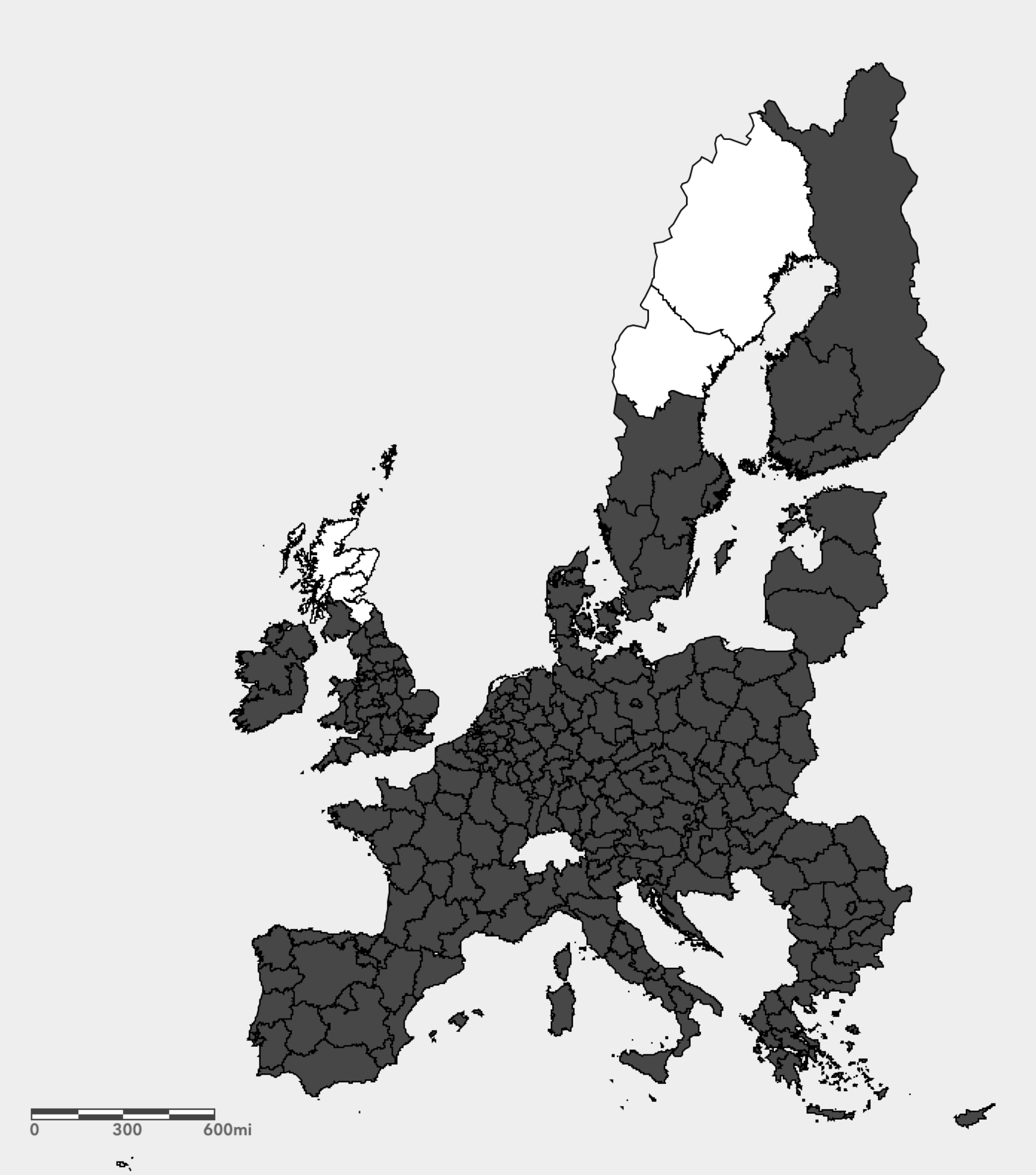

Figure 3 The potential distribution of the pest in the EU NUTS2 regions based on the scenarios established for assessing the impacts of the pest by the EFSA Working Group on EU Priority Pests (EFSA, 2019a). This link provides an online interactive version of the map that can be used to explore the data further: https://arcg.is/PbS8i

2.4. Expected change in the use of plant protection products

Potter and Held (2002) note that there is substantial insecticide use, especially on private lawns, golf courses, and in urban landscapes, to control adults of *P. japonica* that is applied to the foliage and flowers of susceptible plants.

In the USA, large amounts of pesticides are applied to grasslands to manage *P. japonica* (USDA, 2015). The bacterial pathogen *Bacillus papillae* has been used to control the larval stage.

Oliver et al., 2017 compared a series of plant protection products and control strategies against third instar larvae for nurseries.

The brown marmorated stink bug (*Halyomorpha halys*), *Diabrotica* and *Ostrinia* treatments could limit the observed damage on maize and soybeans.

In conclusion, based on the table below, this pest belongs to Case "D" and category "2", as an increase in the number of treatments is not expected to be sufficient to control *P. japonica* in most of the crops and more integrated strategies are required (e.g. soft fruit, grapevine). In case of soybean and maize an increase in the number of treatments could be sufficient (Case "C" and category "1").

Table 2: Expected changes in the use of Plant Protection Products (PPPs) following *Popillia japonica* establishment in the EU in relation to four cases (A-D) and three level score (0-2) for the expected change in the use of PPPs

Expected change in the use of PPPs	**Case**	**PPPs indicator**
PPPs effective against the pest are not available/feasible in the EU	A	0
PPPs applied against other pests in the risk assessment area are also effective against the pest, without increasing the amount/number of treatments	B	0
PPPs applied against other pests in the risk assessment area are also effective against the pest but only if the amount/number of treatments is increased	C	1
A significant increase in the use of PPPs is not sufficient to control the pest: only new integrated strategies combining different tactics are likely to be effective	**D**	**2**

2.5. Additional potential effects

2.5.1. Mycotoxins

The species is not known to be related to problems caused by mycotoxins.

2.5.2. Capacity to transmit pathogens

The species is not known to vector any plant pathogens.

3. Expert Knowledge Elicitation report

3.1. Yield and quality losses

3.1.1. Structured expert judgement

3.1.1.1. Generic scenario assumptions

All the generic scenario assumptions common to the assessments of all the priority pests are listed in the section 2.4.1.1 of the Methodology Report (EFSA, 2019a).

3.1.1.2. Specific scenario assumptions

- turf: damage at production sites is not taken into account as it is considered to be integrated with damage caused by other similar pests. The damage is considered instead at the final user's level in terms of % of infested area of turf that requires replacement. The turf area taken into account includes sports fields
- stone fruits: include edible *Prunus* species, ornamentals and wild species
- soybean and maize (excluding forage maize, due to expected limited damage) are assessed together; in sweetcorn the expected damage is to cobs, in soybean the expected damage is to leaves and flowers (with a reduction in bean production)

3.1.1.3. Selection of the parameter(s) estimated

The yield losses are caused both by the larval and adult feeding.

On turf the replacement rate is used to assess the impact considering the percentage of turf in sports fields replaced every year due to *P. japonica* infestations.

In case of soybean and maize production the damage takes into account the plant decline and reduction of harvested volumes.

In case of grapevine production, the damage is quantified in terms of plant decline, rejected and unharvested fruit.

3.1.1.4. Defined question(s)

What is the percentage yield loss in turf in sports fields under the scenario assumptions in the area of the EU under assessment for *Popillia japonica*, as defined in the Pest Report?

What is the percentage yield loss in soft fruit production under the scenario assumptions in the area of the EU under assessment for *Popillia japonica*, as defined in the Pest Report?

What is the percentage yield loss in stone fruit production under the scenario assumptions in the area of the EU under assessment for *Popillia japonica*, as defined in the Pest Report?

What is the percentage yield loss in soybean and maize production under the scenario assumptions in the area of the EU under assessment for *Popillia japonica*, as defined in the Pest Report?

What is the percentage yield loss in grapevine production under the scenario assumptions in the area of the EU under assessment for *Popillia japonica*, as defined in the Pest Report?

3.1.1.5. *Evidence selected*

The experts reviewed the evidence obtained from the literature (see Table B.1 in Appendix B) selecting the data and references used as the key evidence for the EKE on impact. A few general points were made:

- Soft fruit
  - Only the fruit which is present when high density adult populations occur (an 8 week period) will be affected,
  - In Italy the maximum fruit loss damage observed in a few fields was > 60%. However, when the damage is very high (due to the direct damage caused by *P. japonica* and the indirect effect of secondary pests) it could result in a 100% loss since picking the crop becomes uneconomic
  - All varieties of blueberries are susceptible
  - Ribes, blackberry and raspberry are attacked
  - Adults can also eat green fruits, although they are less attractive to the insect.
  - The use of netting as a control option for other pests, in particular against *Drosophila suzukii,* could limit the damage by *P. japonica*
  - netting is currently applied in only a very small area of the EU used for soft fruit production
- Stone fruits
  - Current agricultural practices are expected to have some controlling effect on *P. japonica* attacks
  - Observations in Italy indicate that the pest prefers foliage and ripe fruits. However, in commercial orchards the fruits are harvested relatively unripe.
- Maize and soybean:
  - Insecticide treatments against *Ostrinia nubilalis* and *Diabrotica virgifera virgifera* in maize during the summer (beginning of July) are also effective against *P. japonica*.
  - Adults are mainly found at the edges of the field
  - Damage caused by larvae to maize plantlets are not frequent observed in the Italian outbreak
  - In soybean at the end of summer, *Halyomorpha halys* causes damage and it is treated but this does not occur during the early summer when impacts by *P. japonica* are expected.
  - a consistent defoliation threshold of 30% (before flowering) and 20% (after flowering) is used in the USA as a threshold before economic impact is observed (Illinois College of ACES, online).
- grapevine:
  - Adult grapevine has high tolerance to defoliation, to the point that defoliation is an agricultural practice used for improving the quality of wine grapes. Defoliation levels up

to 50% are reported as even having positive consequences on quality, i.e., sugar content (e.g. Peña-Olmos et al., 2013).

  - Young plants are more susceptible to *P. japonica* attacks
  - Large variation in impact is observed in Piedmont: defoliation from 10 to 100%, yield losses from 0 to 80%. The large variation probably depending on the proximity of the vineyard to infested fields of other crops (e.g., soybean)
  - *Vitis* seems to be very attractive to *P. japonica* which will fly for several km in order to reach a vineyard
  - Treatments currently applied against *Scaphoideus titanus* (1/year, where flavescence dorée is present) and *Eupoecilia ambiguella* (1/year) can have an effect on *P. japonica* although they have a short persistence
  - Treatments are more frequent on young vines (up to 3 treatments against *S. titanus*)
  - Carlson 2016 indicates that varieties with thin, smooth leaves are preferred

3.1.1.6. Uncertainties identified

- The damage observed is also driven by host presence/prominence in a given area. For example, damage to apple was not observed in Italy probably due to its very low production compared to other host species in the outbreak area
- Frequency of replacement of turf in different sports fields
- Soft fruit
  - % of area where netting is used
  - Differences in the insect's preference for leaves and fruits
  - Frequency and pattern of dispersal behaviour from the attacked plant
- Stone fruits
  - Attractiveness of green fruits
- Grapevine
  - Relationship between defoliation and yield losses

3.1.2. Elicited values for yield losses on turf of sport fields

What is the percentage yield loss in turf in sports fields under the scenario assumptions in the area of the EU under assessment for *Popillia japonica*, as defined in the Pest Report?

The five elicited values on yield loss on turf of sport fields on which the group agreed are reported in the table below.

Table 3: The 5 elicited values on yield loss (%) on turf of sport fields

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	1%	4%	7%	11%	20%

3.1.2.1. Justification for the elicited values for yield loss on turf of sport fields

Reasoning for a scenario which would lead to high yield loss (99th percentile / upper limit)

Two thirds of the EU are favourable due to irrigated conditions.

In sports fields the damage is most likely to be spotted immediately after appearance and treatments will then be applied.

The damage caused by the pest could be worsened by the action of predators.

Reasoning for a scenario which would lead to low yield loss (1st percentile / lower limit)

In the least favourable climatic conditions (e.g. Northern EU where 2 years are needed to complete one generation; areas with dry conditions) some impacts are still expected in sport fields since they are often irrigated. This scenario takes into account a low-density population.

Reasoning for a central scenario equally likely to over- or underestimate the yield loss (50th percentile / median)

The median value of yield loss is justified by the conclusion that the situation encountered by *P. japonica* in Italy is quite exceptional compared to the whole EU and many sports fields are not in very suitable areas for the pest.

Sports fields are however very attractive to this species as they are irrigated, whatever the prevailing climate, and intensively managed.

Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile / interquartile range)

The intermediate quantiles reflect a higher uncertainty in the lower part of the curve and low probability of reaching the upper values.

3.1.2.2. Estimation of the uncertainty distribution for yield loss

The comparison between the fitted values of the uncertainty distribution and the values agreed by the group of experts is reported in the table below.

Table 4: Fitted values of the uncertainty distribution on turf of sport fields

Percentile	**1%**	**2.5%**	**5%**	**10%**	**17%**	**25%**	**33%**	**50%**	**67%**	**75%**	**83%**	**90%**	**95%**	**97.5%**	**99%**
Expert elicitation	1%					4%		7%		11%					20%
Fitted distribution	0.5%	0.9%	1.4%	2.2%	3.1%	4.1%	5.1%	7.0%	9.4%	10.8%	12.7%	14.8%	17.4%	19.8%	22.7%

Fitted distribution: Weibull(1.6156,0.08833), @RISK7.5

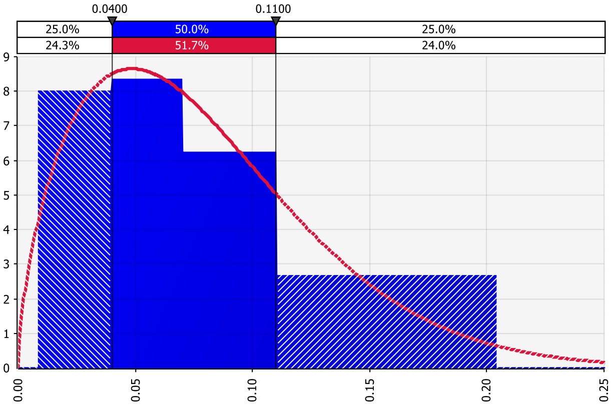

Figure 4 Comparison of judged values (histogram in blue) and fitted distribution (red line) for yield loss on turf of sport fields.

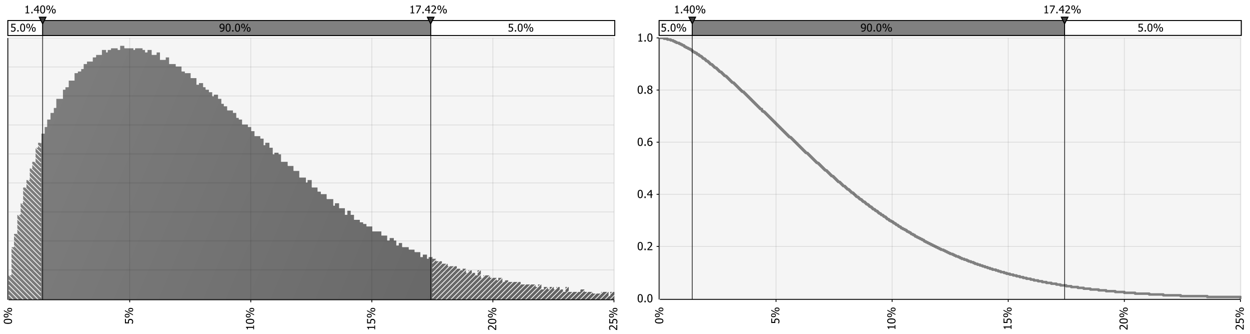

Figure 5 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for yield loss on turf of sport fields.

3.1.3. Elicited values for yield losses on soft fruit

What is the percentage yield loss in soft fruit production under the scenario assumptions in the area of the EU under assessment for *Popillia japonica*, as defined in the Pest Report?

The five elicited values on yield loss on soft fruit on which the group agreed are reported in the table below.

Table 5: The 5 elicited values on yield loss (%) on soft fruit

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	2%	9%	15%	22%	50%

3.1.3.1. Justification for the elicited values for yield loss on soft fruit

Reasoning for a scenario which would lead to high yield loss (99th percentile / upper limit)

Evidence from the Italian outbreak is taken into account. The full crop loss is considered to be an extreme situation but an average scenario for the upper value takes into account the effect of a high density population, the insect's long flight period, netting not being used as a control tactic, and the absence of effective treatments. The loss in production is expected to still be limited due to the fact that the adults do not stay very long in the same place and are likely to prefer leaves to fruits.

Reasoning for a scenario which would lead to low yield loss (1st percentile / lower limit)

The lower value of yield loss is supported by the fact that in parts of the EU production area for soft fruit the beetle has only 1 generation every two years resulting in low density populations. In soft-fruit production areas of the EU where one generation/year is expected, part of the area is also very dry and crops are irrigated, resulting in an environment that is not very suitable for the pest.

Reasoning for a central scenario equally likely to over- or underestimate the yield loss (50th percentile / median)

The median value of yield loss takes into account the scarce use of nets for soft fruit production in the EU. Although a large part of the area of soft fruit production is not very favourable to this pest, the hosts are very attractive to *P. japonica* and the probability of adults encountering fruits at the time of emergence is high.

Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile / interquartile range)

The uncertainty is mainly in the lower part of the curve and the probability to reach extreme high values is considered to be low.

3.1.3.2. Estimation of the uncertainty distribution for yield loss

The comparison between the fitted values of the uncertainty distribution and the values agreed by the group of experts is reported in the table below.

Table 6: Fitted values of the uncertainty distribution on soft fruit

Percentile	**1%**	**2.5%**	**5%**	**10%**	**17%**	**25%**	**33%**	**50%**	**67%**	**75%**	**83%**	**90%**	**95%**	**97.5%**	**99%**
Expert elicitation	2%					9%		15%		22%					50%
Fitted distribution	2.0%	2.9%	4.0%	5.6%	7.3%	9.1%	11.0%	14.7%	19.3%	22.3%	26.2%	30.9%	37.0%	42.8%	50.2%

Fitted distribution: Gamma(2.5830,0.065249), @RISK7.5

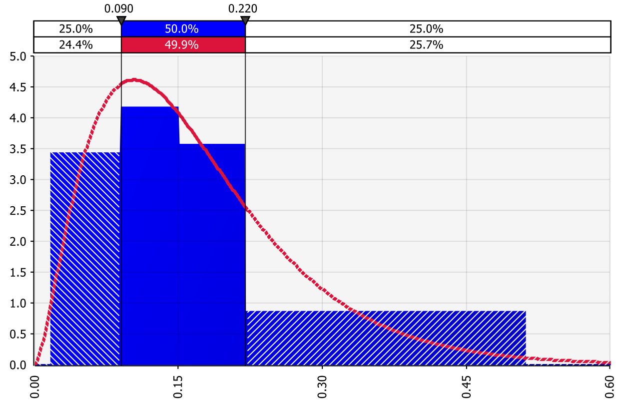

Figure 6 Comparison of judged values (histogram in blue) and fitted distribution (red line) for yield loss on soft fruit.

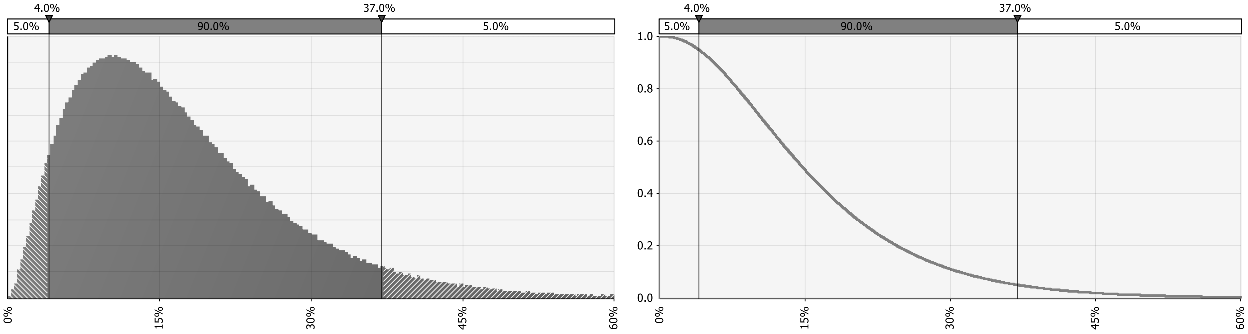

Figure 7 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for yield loss on soft fruit.

3.1.4. Elicited values for yield losses on stone fruit

What is the percentage yield loss in stone fruit production under the scenario assumptions in the area of the EU under assessment for *Popillia japonica*, as defined in the Pest Report?

The five elicited values on yield loss for stone fruit on which the group agreed are reported in the table below.

Table 7: The 5 elicited values on yield loss (%) on stone fruit

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	1%	3%	5%	10%	20%

3.1.4.1. Justification for the elicited values for yield loss on stone fruit

Reasoning for a scenario which would lead to high yield loss (99th percentile / upper limit)

Evidence from the Italian outbreak is taken into account. The scenario for the upper value takes into account the effect of a high-density population, a long flight period, the limited use of nets, and the limited availability of treatments (a limited number of PPPs are available and effective against this type of pest on stone fruits). However, the production loss is expected to be limited because adults do not stay very long in the same place and are likely to prefer leaves to fruits. Stone fruits are also frequently harvested before full ripening, when they are less attractive to the pest. High defoliation is expected to have an impact on next year's production.

Observations from the USA show that *Prunus* is often attacked.

Reasoning for a scenario which would lead to low yield loss (1st percentile / lower limit)

The lower value of yield loss is supported by the fact that in the EU production area for stone fruits only 1 generation every two years of the pest is expected. This would result in the development of low density populations. In the zone where one generation/year is possible, part of the area is also very dry and crops are irrigated, resulting in an environment that is not very suitable for the pest.

Organic stone fruit production is expected to suffer higher damage than conventional orchards

Reasoning for a central scenario equally likely to over- or underestimate the yield loss (50th percentile / median)

The median value of yield loss takes into account the expected effect of current agricultural practices in stone fruit orchards; the pest is not expected to build high population densities in these conditions. A large part of the area of stone fruit production is not very favourable to this pest, but these hosts are very attractive to this species and the probability of adults encountering available fruits at the time of emergence is high. In addition, attacks can happen over a very short time period (24-48 h to cause significant defoliation) requiring a very rapid control response.

Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile / interquartile range)

The uncertainty is mainly in the lower part of the curve and the probability of reaching extreme high values is considered to be low.

3.1.4.2. Estimation of the uncertainty distribution for yield loss

The comparison between the fitted values of the uncertainty distribution and the values agreed by the group of experts is reported in the table below.

Table 8: Fitted values of the uncertainty distribution on stone fruit

Percentile	**1%**	**2.5%**	**5%**	**10%**	**17%**	**25%**	**33%**	**50%**	**67%**	**75%**	**83%**	**90%**	**95%**	**97.5%**	**99%**
Expert elicitation	1%					3%		5%		10%					20%
Fitted distribution	0.2%	0.5%	0.8%	1.4%	2.1%	2.9%	3.7%	5.6%	7.8%	9.3%	11.2%	13.5%	16.4%	19.1%	22.5%

Fitted distribution: Weibull(1.354,0.072942), @RISK7.5

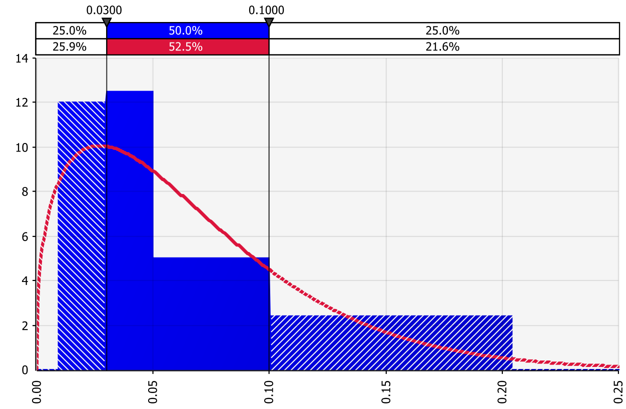

Figure 8 Comparison of judged values (histogram in blue) and fitted distribution (red line) for yield loss on stone fruit.

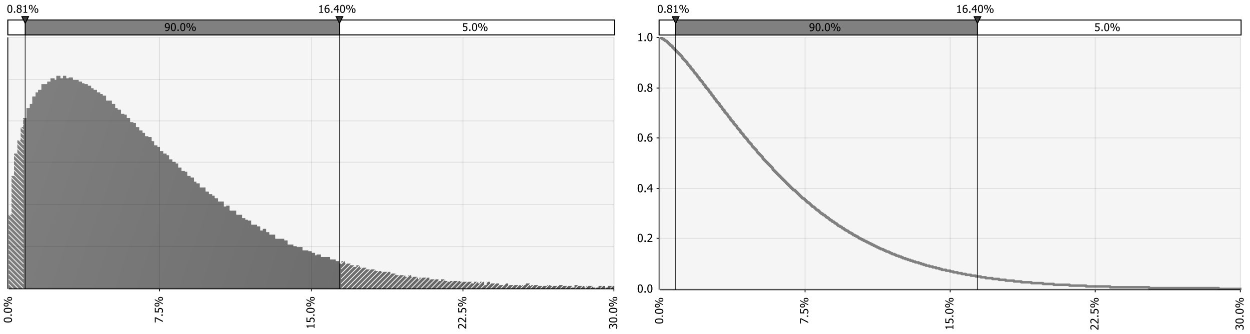

Figure 9 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for yield loss on stone fruit.

3.1.5. Elicited values for yield losses on soybean and maize

What is the percentage yield loss in soybean and maize production under the scenario assumptions in the area of the EU under assessment for *Popillia japonica*, as defined in the Pest Report?

The five elicited values on yield loss on soybean and maize on which the group agreed are reported in the table below.

Table 9: The 5 elicited values on yield loss (%) on soybean and maize

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	0%	1.5%	3%	5%	10%

3.1.5.1. *Justification for the elicited values for yield loss on soybean and maize*

Reasoning for a scenario which would lead to high yield loss (99th percentile / upper limit)

The evidence available is very limited. *Popillia japonica* is considered to be an economic pest in the US, but less so in the EU. However, the ecoclimatic conditions of maize and soybean fields are suitable for *P. japonica*.

Reasoning for a scenario which would lead to low yield loss (1st percentile / lower limit)

In Italy damage has been observed on leaves of these hosts, but the population density is not expected to exceed the threshold needed to produce an economic damage.

Reasoning for a central scenario equally likely to over- or underestimate the yield loss (50th percentile / median)

The expected impact is higher than that observed in the US. The cost of one additional treatment could be considered to be roughly equivalent to the value of 5% of the production, and the median losses are not expected to reach this threshold.

Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile / interquartile range)

The precision is mainly affected by the left part of the curve.

3.1.5.2. *Estimation of the uncertainty distribution for yield loss*

The comparison between the fitted values of the uncertainty distribution and the values agreed by the group of experts is reported in the table below.

Table 10: Fitted values of the uncertainty distribution on soybean and maize

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	0%					1.5%		3%		5%					10%
Fitted distribution	0.1%	0.3%	0.4%	0.7%	1.1%	1.5%	2.0%	3.0%	4.2%	4.9%	6.0%	7.2%	8.8%	10.2%	12.0%

Fitted distribution: Weibull(1.3519,0.038872), @RISK7.5

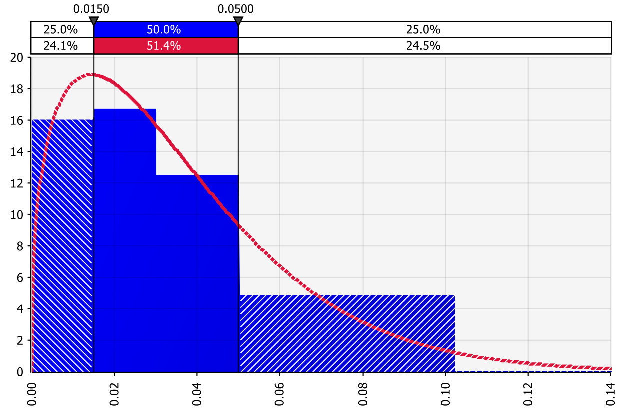

Figure 10 Comparison of judged values (histogram in blue) and fitted distribution (red line) for yield loss on soybean and maize.

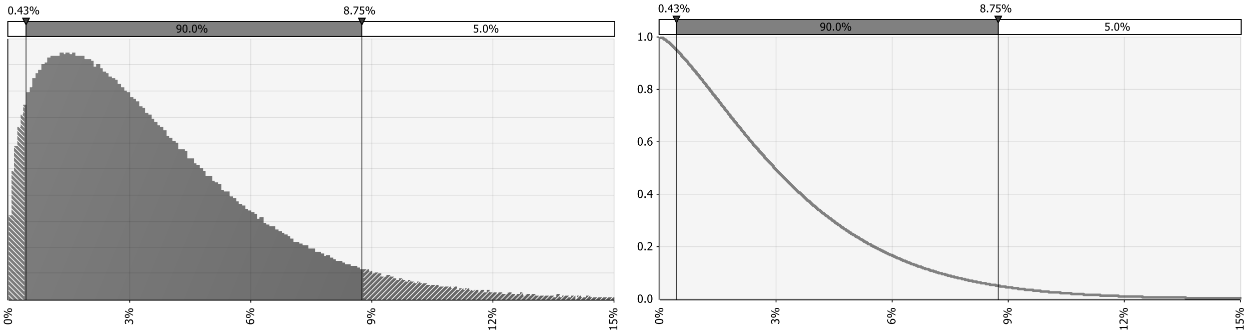

Figure 11 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for yield loss on soybean and maize.

3.1.6. Elicited values for yield losses on grapevine

What is the percentage yield loss in grapevine production under the scenario assumptions in the area of the EU under assessment for *Popillia japonica*, as defined in the Pest Report?

The five elicited values for yield loss on grapevine on which the group agreed are reported in the table below.

Table 11: The 5 elicited values on yield loss (%) on grapevine

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	1%	4%	6%	11%	20%

3.1.6.1. Justification for the elicited values for yield loss on grapevine

Reasoning for a scenario which would lead to high yield loss (99th percentile / upper limit)

There is a lack of substantial evidence but there are observations from the Italian outbreak. Observations on damage from the literature are frequently given in reference to non-EU varieties that are likely to be less attractive to the insect due to the thickness of their leaves.

Susceptible vines (hybrids, French varieties, etc) are strongly preferred by the insect. There is lower use of pesticides where *Scaphoideus titanus* and *Eupoecilia ambiguella* are absent. The upper value is lower than that for other hosts mainly due to the fact that *P. japonica* does not frequently attack fruit.

Reasoning for a scenario which would lead to low yield loss (1st percentile / lower limit)

The lower value of yield loss is mainly due to effective insecticide applications.

Reasoning for a central scenario equally likely to over- or underestimate the yield loss (50th percentile / median)

The median value of yield loss is arrived at from the fact that grapevine is a very attractive crop and the defoliation can be very rapid (very heavy defoliation can occur after 24-48h). This requires a very rapid reaction, which is not always feasible (e.g. due to the poor timing of treatments). Compared to stone fruit the attack is expected to have less on an effect on fruit.

Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile / interquartile range)

The uncertainty is mainly in the lower part of the curve and lower likelihood around the upper extremes is expected.

3.1.6.2. Estimation of the uncertainty distribution for yield loss

The comparison between the fitted values of the uncertainty distribution and the values agreed by the group of experts is reported in the table below.

Table 12: Fitted values of the uncertainty distribution on grapevine

Percentile	**1%**	**2.5%**	**5%**	**10%**	**17%**	**25%**	**33%**	**50%**	**67%**	**75%**	**83%**	**90%**	**95%**	**97.5%**	**99%**
Expert elicitation	1%					4%		6%		11%					20%
Fitted distribution	0.4%	0.7%	1.2%	1.9%	2.7%	3.7%	4.6%	6.6%	8.9%	10.4%	12.3%	14.5%	17.2%	19.8%	22.9%

Fitted distribution: Weibull(1.5217,0.083874), @RISK7.5

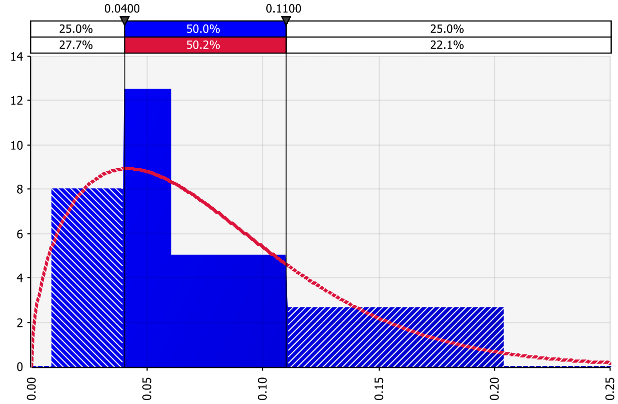

Figure 12 Comparison of judged values (histogram in blue) and fitted distribution (red line) for yield loss on grapevine.

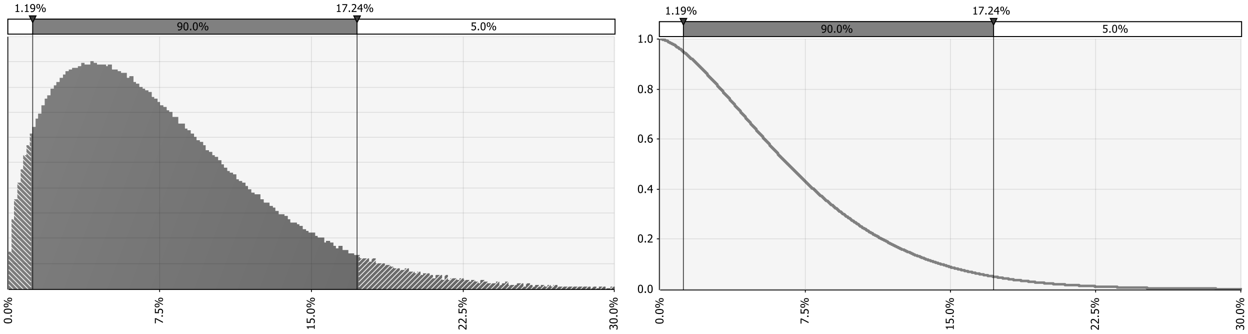

Figure 13 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for yield loss on grapevine.

3.1.7. Conclusions on yield and quality losses

Based on the general and specific scenario considered in this assessment, the percentage yield losses is estimated to be:

- 7% (with a 95% uncertainty range of 0.9-19.8%) in turf in sports fields
- 14.7% (with a 95% uncertainty range of 2.9-42.8%) in soft fruit
- 5.6% (with a 95% uncertainty range of 0.5-19.1%) in stone fruit
- 3% (with a 95% uncertainty range of 0.3-10.2%) in soybean and maize
- 6.6% (with a 95% uncertainty range of 0.7-19.8%) in grapevine

Quality losses have not been included in the assessment because they are considered to be negligible compared to the yield losses.

3.2. Spread rate

3.2.1. Structured expert judgement

3.2.1.1. Generic scenario assumptions

All the generic scenario assumptions common to the assessments of all the priority pests are listed in the section 2.4.2.1 of the Methodology Report (EFSA, 2019a).

3.2.1.2. Specific scenario assumptions

No specific assumptions are introduced for the assessment of the spread rate.

3.2.1.3. Selection of the parameter(s) estimated

The spread rate has been assessed as the number of metres per year.

3.2.1.4. Defined question(s)

What is the spread rate in 1 year for an isolated focus within this scenario based on average European conditions? (units: m/year)

3.2.1.5. Evidence selected

The experts reviewed the evidence obtained from the literature (see Table B.2 in Appendix B) selecting the data and references used as the key evidence for the EKE on spread rate. A few general points were made:

- Adults prefer to fly on warm, sunny days with temperatures of 29-35°C, relative humidity >60% and wind <20 km/h (Kreuger and Potter, 2001; CABI, 2018), but, if disturbed, they can also take off at 21°C (Fleming, 1972).

- Most adult flights fly for short distances but can fly up to 8 km, though this rarely occurs. Their flight is aimless and usually of short duration. In the absence of chemotropic stimulus, the beetles tend to drift with wind (Fleming, 1972).
- Sara et al. (2013) found that the adult density decreased significantly with increasing distance from a field edge.
- In Italy, the initial demarcated area was significantly increased as a sign of *P. japonica* spread from the initial point of detection (European Commission, 2016).

3.2.1.6. Uncertainties identified

- The duration of the lag phase under the different environmental conditions present in the EU
- That it is difficult using historical observations to discriminate between the spread caused by natural dispersal and that caused by human assisted movement, such as with plants for planting.

3.2.2. Elicited values for the spread rate

What is the spread rate in 1 year for an isolated focus within this scenario based on average European conditions? (units: m/year)

The five elicited values for spread rate on which the group agreed are reported in the table below.

Table 13: Summary of the 5 elicited values on spread rate (m/y)

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	300	1,000	1,500	2,300	5,000

3.2.2.1. Justification for the elicited values of the spread rate

Reasoning for a scenario which would lead to wide spread (99th percentile / upper limit)

Wind-assisted dispersal. The presence of particularly attractive hosts stimulates long distance flights for feeding and the search for attractive locations to lay eggs. These values are supported by observations coming from the current spread of the Italian outbreak (at least 4 years after detection).

Reasoning for a scenario, which would lead to limited spread (1st percentile / lower limit)

Females tend to fly short distances moving between suitable feeding and oviposition sites. A large variety of suitable hosts is available nearby. Cool temperatures, lower population densities with longer cycles (1 generation with a 2 year life cycle), no favourable winds.

Reasoning for a central scenario, equally likely to over- or underestimate the spread (50th percentile / median)

The adults can initially find suitable hosts in the surroundings (e.g. *Urtica* along the edge of the grass field) but then, due to the increasing thickness of wild host leaves, they are required to move further to find more suitable hosts.

Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile / interquartile range)

There is a good level of confidence around the median value while the upper limit is considered less likely to be reached.

3.2.2.2. Estimation of the uncertainty distribution for the spread rate

The comparison between the fitted values of the uncertainty distribution and the values agreed by the group of experts is reported in the table below.

Table 14: Fitted values of the uncertainty distribution on the spread rate (m/y)

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	300					1,000		1,500		2,300					5,000
Fitted distribution	240	344	458	621	794	983	1,163	1,534	1,978	2,264	2,640	3,087	3,659	4,207	4,903

Fitted distribution: Gamma(2.9064,594.51), @RISK7.5

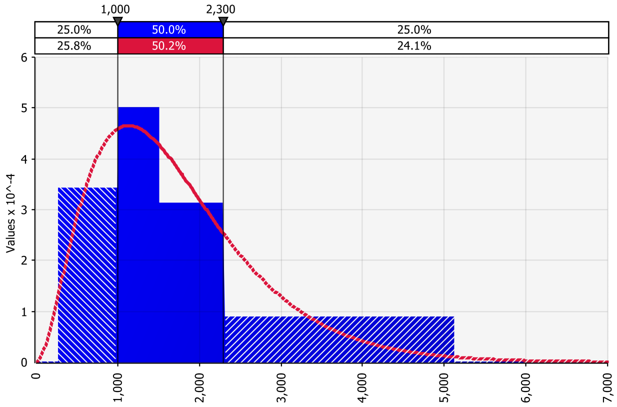

Figure 14 Comparison of judged values (histogram in blue) and fitted distribution (red line) for spread rate.

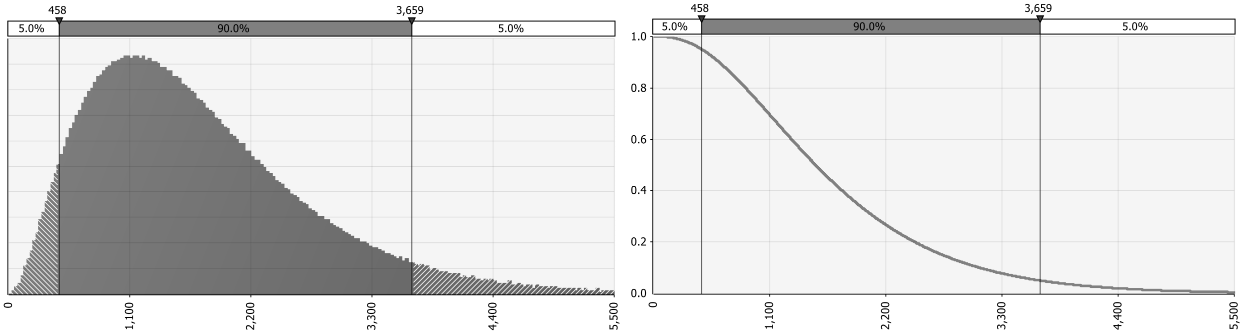

Figure 15 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for spread rate.

3.2.3. Conclusions on the spread rate

Based on the general and specific scenarios considered in this assessment, the maximum distance expected to be covered in one year by *P. japonica* is approximately 1.5 km (with a 95% uncertainty range of 350 m to 4 km).

3.3. Time to detection

3.3.1. Structured expert judgement

3.3.1.1. Generic scenario assumptions

All the generic scenario assumptions common to the assessments of all the priority pests are listed in the section 2.4.2.1 of the Methodology Report (EFSA, 2019a).

3.3.1.2. Specific scenario assumptions

No specific assumptions are introduced for the assessment of time to detection.

3.3.1.3. Selection of the parameter(s) estimated

The time for detection has been assessed as the number of months between the first event of pest transfer to a suitable host and its detection.

3.3.1.4. Defined question(s)

What is the time between the event of pest transfer to a suitable host and its first detection within this scenario based on average European conditions? (unit: months)

3.3.1.5. Evidence selected

The experts reviewed the evidence obtained from the literature (see Table B.2 in Appendix B) selecting the data and references used as the key evidence for the EKE on time to detection. A few more points were made:

- 4-5 years passed before detection (by a naturalist) in the Ticino Valley (the Italian outbreak)
- skeletonised leaves are a not very specific symptom
- larvae are difficult to detect and identify
- not as evident as other invasive insects
- The adult flight period extends from late May throughout early November, with peak numbers caught during the last half of July and the first half of August, accounting for 82% of the total number of beetles captured (Vieira, 2008). Odour and location of the host in direct sun seem to be very important factors in plant selection. The beetles usually feed in groups, starting at the top of a plant and working downwards.

3.3.1.6. *Uncertainties identified*

No main uncertainties were noted.

3.3.2. Elicited values for the time to detection

What is the time between the event of pest transfer to a suitable host and its first detection within this scenario based on average European conditions? (unit: months)

The five elicited values for time to detection on which the group agreed are reported in the table below.

Table 15: Summary of the 5 elicited values on time to detection (months)

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	28	60	90	110	150

3.3.2.1. *Justification for the elicited values of the time to detection*

Reasoning for a scenario which would lead to a long time for detection (99th percentile / upper limit)

This scenario takes into account locations for establishment that are not very suitable: adults would then move each year to find an adequate area to develop a population that is sufficiently large to be noticed. This is expected to happen mainly in the Northern EU where the pest would require 2 years to develop a new generation. A longer time would be required if the outbreak starts on wild vegetation. If *P. japonica* must compete with other phytophagous species present in the same area, the pest could need an even longer time to build up sufficiently large populations.

Reasoning for a scenario which would lead to a short time for detection (1st percentile / lower limit)

The presence of traps in hotspots (i.e. places where introduction is likely, such as airports) could detect the pest very quickly. If the outbreak occurs in other landscapes much more time would be needed to develop a population that is sufficiently large to be detected.

Twenty-eight months could be an average among different EU situations, where two years plus several months for identification is considered to be the minimum time to identify a new outbreak.

Reasoning for a central scenario, equally likely to over- or underestimate the time for detection (50th percentile / median)

The median value also takes into account conditions that are less suitable for population development (a 2 year cycle plus fewer hosts) than those observed for *P. japonica* in Italy. However, the effect of citizen science is taken into account, due to the recently increased level of awareness concerning this species.

Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile / interquartile range)

Uncertainty on the lower values and more confidence on the median than on the upper value.

3.3.2.2. Estimation of the uncertainty distribution for the time to detection

The comparison between the fitted values of the uncertainty distribution and the values agreed by the group of experts is reported in the table below.

Table 16: Fitted values of the uncertainty distribution on the time to detection (months)

Percentile	**1%**	**2.5%**	**5%**	**10%**	**17%**	**25%**	**33%**	**50%**	**67%**	**75%**	**83%**	**90%**	**95%**	**97.5%**	**99%**
Expert elicitation	28					60		90		110					150
Fitted distribution	26	31	36	44	53	62	71	87	103	112	122	132	141	147	152

Fitted distribution: BetaGeneral(1.7937,1.9325,20,160), @RISK7.5

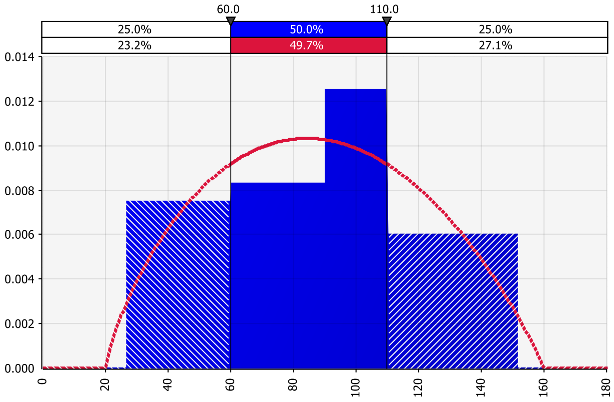

Figure 16 Comparison of judged values (histogram in blue) and fitted distribution (red line) for time to detection.

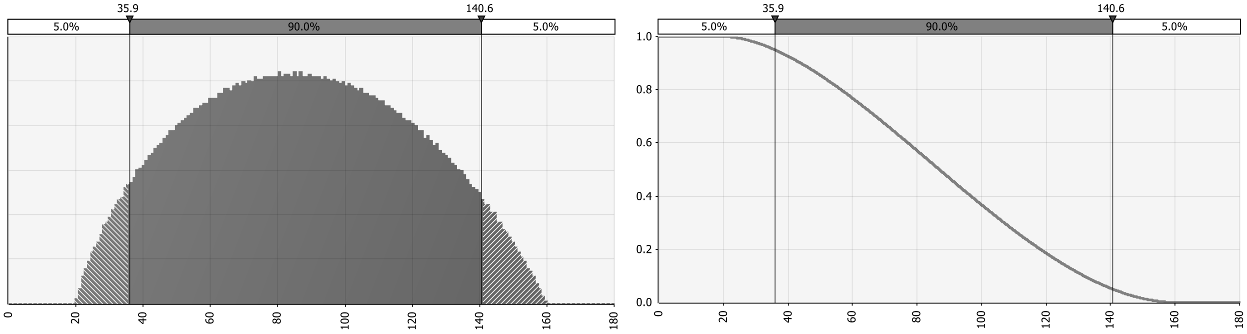

Figure 17 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for time to detection.

3.3.3. Conclusions on the time to detection

Based on the general and specific scenarios considered in this assessment, the time between the event of pest transfer to a suitable host and its detection is estimated to be more than 7 years (with a 95% uncertainty range of 2.5-12 years).

4. Conclusions

Hosts selection

The hosts on which impacts were assessed are:

- turf, in terms of percentage infested area of turf that requires replacement, including sports fields
- soft fruit such as blueberries, strawberries and blackberries
- stone fruits, including edible species, ornamentals and wild species
- soybean and maize (excluding forage maize)
- grapevine

Area of potential distribution

The area of potential establishment includes all the areas in the EU where degree days are greater than 711 with a minimum threshold of development of 10°C. For this species, since transient populations are not considered, the assessment is limited to the area of potential establishment.

Increased number of treatments

This pest belongs to Case “D” and category “2”, as an increase in the number of treatments is not expected to be sufficient to control *P. japonica* in most of the crops and more integrated strategies are required (e.g. soft fruit, grapevine). In case of soybean and maize an increase in the number of treatments could be sufficient (Case “C” and category “1”).

Yield and quality losses

Based on the general and specific scenario considered in this assessment, the percentage yield losses is estimated to be:

- 7% (with a 95% uncertainty range of 0.9-19.8%) in turf in sports fields
- 14.7% (with a 95% uncertainty range of 2.9-42.8%) in soft fruit
- 5.6% (with a 95% uncertainty range of 0.5-19.1%) in stone fruit
- 3% (with a 95% uncertainty range of 0.3-10.2%) in soybean and maize
- 6.6% (with a 95% uncertainty range of 0.7-19.8%) in grapevine

Quality losses have not been included in the assessment because they are considered to be negligible compared to the yield losses.

Spread rate

Based on the general and specific scenarios considered in this assessment, the maximum distance expected to be covered in one year by *P. japonica* is approximately 1.5 km (with a 95% uncertainty range of 350 m to 4 km).

Time for detection after entry

Based on the general and specific scenarios considered in this assessment, the time between the event of pest transfer to a suitable host and its detection is estimated to be more than 7 years (with a 95% uncertainty range of 2.5-12 years).

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Appendix A – CABI/EPPO host list

The following list, defined in the Methodology Report (EFSA, 2019a) as the full list of host plants, is compiled merging the information from the most recent PRAs, the CABI Crop Protection Compendium and the EPPO Global Database. Hosts from the CABI list classified as 'Unknown', as well as hosts from the EPPO list classified as 'Alternate', 'Artificial', or 'Incidental' have been excluded from the list.

Genus	**Species epithet**
Acer	
Aesculus	
Althaea	
Asparagus	*officinalis*
Betula	
Castanea	
Cyperaceae	
Fragaria	*ananassa*
Glycine	*max*
Hibiscus	
Juglans	
Juglans	*nigra*
Lagerstroemia	*indica*
Malus	
Malus	*domestica*
Medicago	*sativa*
Parthenocissus	*quinquefolia*
Plants	
Platanus	
Poaceae	
Polygonum	
Populus	
Prunus	
Prunus	*domestica*
Prunus	*persica*
Rheum	*hybridum*
Rosa	
Rosa	*large-flowered*
Rubus	
Salix	
Sassafras	*albidum*

Sorbus	*americana*
Tilia	
Tilia	*cordata*
Trifolium	
Turfgrasses	
Ulmus	
Vitis	
Vitis	*vinifera*
Woody	*plants*
Zea	*mays*

Appendix B – Evidence tables

B.1 Summary on the evidence supporting the elicitation of yield and quality losses

Susceptibility	**Infestation**	**Symptoms**	**Impact**	**Additional information**	**Reference**
	Incidence	***Severity***	***Losses***		
Zea mays	Beetles per plant:	0 beetles/plant	Kernels per ear: 411.2(Missouri); 601.7 (Tennessee); Kernels wt/ear [g]: 124.2 (M); 181.3 (T)	Tennesee, Missouri, USA GM corn: DeKalb DKC 64 Đ 83 VT Triple Pro containing Cry1A.105, Cry2Ab2, and Cry3Bb1	Steckel et al., 2013
		2 beetles/plant	Kernels/ear: 399.8(M); 581.2(T); Kernels wt/ear: 123.2(M); 169.4(T)		
		4 beetles/plant	Kernels/ear: 331.9(M); 569.0(T); Kernels wt/ear: 107.1(M); 173.9(T);		
		8 beetles/plant	Kernels/ear: 268.9(M); 555.2(T); Kernels wt/ear: 83.9(M); 175.1(T)		
Betula spp.	Percentage of leaf skeletonization		Data presented in Table 2 of the article	Fayetteville, Arkansas, USA	Gu et al., 2008
Malus spp.	Percentage of defoliation of 28 flowering crabapple cultivars by Japanese beetles in the field, 1992-1993.		Data presented in Table 1 of the article	Lexington, KY, USA	Potter et al., 1998
Tilia spp.	Relative defoliation of selected species and cultivars of Tilia by Japanese beetles in the field, 1992-1996		Data presented in Table 2 of the article	Lexington, KY, USA	Potter et al., 1998
Rosa spp.	Relative defoliation of 33 cultivars of hybrid tea roses by Japanese beetles during a year with very heavy beetle activity (1992)		Data presented in Table 3 of the article	Lexington, KY, USA	Potter et al., 1998

Sambucus canadensis, S. nigra	For 2014, 2015, and 2016, densities of adult *Popillia japonica* and feeding damage (expressed as percentages) on 60 perimeter-row elderberry plants at the Lincoln- University George Washington Carver farm (Jefferson City, Missouri, USA), according to sampling date	2014: mean no. adult beetles/plant = 0.5 2015: mean no. adult beetles/plant – 3.7 2016: mean no. adult beetles/plant = 1.9	2014 mean defoliation/plant = 2.5% 2015 mean defoliation/plant = 8.2% 2016 mean defoliation/platn = 9.7	Jefferson City, Missouri, USA	Pinero and Dudenhoeffer, 2018
Grapes		Defoliation of grapevines by natural populations in Virginia did not significantly reduce fruit quality, yield, or shoot growth	*P. japonica* facilitates feeding by the obligate fruit-feeding native green June beetle, Cotinis nitida, by biting into intact grape berries that C. nitida is otherwise unable to exploit, due to blunt spatulate mandibles	Hammons et al., 2009	
Vaccinium corymbosum	For 2014, 2015, and 2016, densities of adult *Popillia japonica* and feeding damage (expressed as percentages) on 200 blueberry plants at the Lincoln University Alan T. Busby organic farm (Jefferson City, Missouri, USA), according to sampling date	2014: mean no. adult beetles/plant = 0.06 2015 mean no adult beetles/plant = 0.07 2016 mean no adult beetles/plant = 0.01	2014 mean defoliation/plant = 0.3% 2015 mean defoliation/plant = 0.07% 2016 mean defoliation/plant = 0.02	Jefferson City, Missouri, USA	Pinero and Dudenhoeffer, 2018
blueberries	Defoliation on blueberry plants treated with 4 insecticides		Result presented in Figure 2 of the article	Hulbert et al., 2012	

B.2 Summary on the evidence supporting the elicitation of the spread rate

Spread	**Additional information**	**Reference**
3.2 – 16 km/year	Outward movement of the periphery of the infestation.	Fox, 1932
From 1.29 km^2 to 198 000 km^2 in 36 years (mean 5500 km^2/yr)	Spread in USA in years 1916 – 1952.	Fleming, 1972
16 – 24 km/year	Avarage outward spread or the beetle from the point of introduction in New Jersey.	Smith and Hadley, 1926 in Fleming, 1972

70% of recaptured beetles were caught within 50 m of the release point. Less than 1% were recaptured at 1 km.	Mark–release–recapture study in the Azores	Lacey et al. 1994, 1995
7.7 – 11.9 km/year	Spread in USA at constant rate of 7.7 km/yr during 1927-1938, and at constant rate of 11.9 km/yr during 1939-1951.	Allsopp, 1996

B.3 Summary on the evidence supporting the elicitation of the time to detection

Category of factors	**case**	**Evidence**	**Additional information**	**Reference**
Detection methods	Diagnostic protocols	The EPPO phytosanitary standard diagnostic protocol provides a key to the European families within the superfamily Scarabaeoidea and enables the identification of the *Popillia* genus.	Detailed morphological descriptions of each life stage of the species are provided to allow its identification to species level.	EPPO, 2006
Detection methods	Visual symptoms	very similar in appearance and habits to *Popillia quadriguttata* which occurs in Korea and China		Lee et al., 2014
Detection methods	Visual symptoms	Larvae and adults are the life stages that can be detected by visual examination in a distinguishable way. The larvae live in the fibrous root zone of the plants; therefore they can be detected by examination of the soil and roots.	Survey cards	EFSA, 2018
Detection methods	Visual symptoms	Symptoms of adults: feeding holes in host leaves. In case of high numbers of adults, leaves can be skeletonised. Symptoms of larvae: discoloured grass patches, expanding over time or the death of turf grass.		EPPO, 2006
Detection methods	Larval detection	It requires soil sampling. Larval populations are aggregated and often occur in the vicinity of plants that had had adults aggregating on them to feed and mate during the summer; well drained moderately textured soils in sunlight also favour higher densities of larvae. Soil with high levels of organic matter tends to have lower larval densities		Dalthorp et al., 2000; Potter and Held, 2002

Detection methods	Larval detection	Based on the European situation in Milan (Italy), the larval monitoring should be carried out in grassy meadows, especially irrigated ones, located in the infested area. Number of core samples (cubic portions of soil, 20 cm in depth, width and height) depends on surface area: • < 0.5 ha → 4 samples • 0.5-1 ha → 6 samples • > 1 ha → 2 additional samples Distance between one core and the next should not be less than 20 m	According to USDA APHIS (2016) a larval survey should be conducted if the turf damage indicates a large number of grubs in the soil.	ERSAF, 2016
Detection methods	Traps	Properly constructed trap caught about 75% of the beetles. The zone of attraction depends on the environment: in rural areas up to 1500 feet (457 m).	Some experiments showed that traps caught from 8 to 97% of marked insects.	Fleming, 1972
Detection methods	Traps	Commercially available lures are available. Lures combine the female produced sex attractant((R,Z)-5-(1-decenyl)dihydro-2(3H)-furanone) with a mixture of 2-phenethyl propionate, eugenol andgeraniol (3:7:3). The lure is very attractive to both sexes (Ladd et al., 1981). Traps baited with a lure are useful for detecting new infestations and mass trapping can be used to suppress pest populations (Porter and Held, 2002).		
Detection methods	Adults identification	by visual examination of green parts of plants. if a suspected specimen is collected in North America or Italy, there is high confidence that a correct morphological identification will be made. However, the genus is large and species in Asia could be confused with *P. japonica* morphologically.		EFSA, 2019b
Detection methods	Timing	Six years after the import plants with soil and grubs the insect was detected.		Frank, 2016
Detection methods	Timing	The timing of survey is important because of the natural decimation of the soil population of grubs.	In Pennsylvania and New Jersey the peak of the grub population occurred during the first half of September.	Fleming, 1972
Biology of the pest	Pest life cycle	The beetle might need one or two years to complete the development to adults.	See 1.2.1	Fleming, 1972

Biology of the pest	Pest life cycle	3 larval instars: - 1st: 2–3 weeks; - 2nd: 3–4 weeks; - 3rd: instar burrows deeper and overwinters at depths of 10–20 cm, presumably to avoid cooler or freezing temperatures. In the spring, as the soil warms, larvae rise to shallower depths in the soil where they form a chamber in which they pupate and emerge in mid-summer to repeat the cycle. In cases where development takes 2 years, second and third instars overwinter during the first and second winters, respectively.		Vittum, 1986
Biology of the pest	Pest life cycle	Lag phase		Allsopp, 1996; Fleming, 1972
Biology of the pest	Feeding and flying behaviour	Adults tend to aggregate to feed and mate on individual host plants, with the result that in the same place there will be plants of the same species heavily infested whilst others not attacked. Adults usually begin to feed at the top of a host and working down (Fleming, 1972).		Campbell et al., 1989
Biology of the pest	Feeding and flying behaviour	Larvae feed on decaying matter and on roots of grasses, ornamentals, garden and field crops, in the upper 7.5 cm of soil. Adults feed on the foliage and fruit of hosts		Metcalf and Metcalf, 1993
Biology of the pest	Feeding and flying behaviour	Adults are most active, feeding and flying, on warm sunny days. In Italy, whilst adults peak in July, some adults can be active until September and rarely in October. In the Azores, adults can be found between May and November.		EPPO, 2016
Biology of the pest	Lifespan	Adults live for 30–45 days during which time there can mate more than once.		
Biology of the pest	Host preference	Larvae are most abundant in lawns, pastures and golf courses, i.e. areas of abundant grass.		
Biology of the pest	Pest life cycle	Eggs usually hatch after about 2 weeks, but the timing is influenced by temperatures		