APPROVED: 17 May 2019
Doi: 10.5281/zenodo.2786697

Bactericera cockerelli Pest Report to support ranking of EU candidate priority pests

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Requestor: European Commission
Question number: EFSA-Q-2018-00382
Output number: EN-1640
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Acknowledgements: EFSA wishes to acknowledge the contribution of Chris Malumphy, Panagiotis Milonas and the review conducted by Lucia Zappalà.

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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 *Bactericera cockerelli*, the following documents were used as key references: pest risk analyses by EPPO (2012a) and Biosecurity Australia (2009).

[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

Bactericera cockerelli is a single taxonomic entity, known as potato psyllid, primarily found on plants within the family Solanaceae. Under favourable conditions, the life cycle takes four weeks to be completed, within a single season the pest can have from 1 to 5 generation depending on climate (Liu et al., 2006; Abdullah, 2008). The short life cycle in combination with a high oviposition rates support extremely fast population growth in presence of favourable conditions (Liu and Trumble, 2004).

Its migratory behaviour allows overwintering in the warmer areas of its distribution range (Mexico and Southern USA) and in spring and summer moving north in Western USA and up to southern Canada.

Bactericera cockerelli is considered the causal agent of the psyllid yellows disease of potato and tomato, probably produced by a toxin injected to the plant by the feeding nymphs, although its harmfulness is mainly associated to the capacity of vector the bacterium '*Candidatus* Liberibacter *solanacearum'* (EPPO, 2013).

2.2. Host plants

2.2.1. List of hosts

Bactericera cockerelli primarily feeds on species of the Solanaceae family, although it can be found on other 19 families and is able to reproduce on other two (Convolvulaceae and Lamiaceae). Its preferred hosts are *Solanum melongena* (eggplant), *Capsicum* sp. (peppers), *Solanum lycopersicum* (tomato) and *Solanum tuberosum* (potato).

Appendix A provides the full list of hosts.

2.2.2. Main hosts in the European Union

Eggplant, pepper, tomato and potato are among the main hosts of *B. cockerelli* and are widely grown in the EU (EPPO, 2012a). They are grown in open-air and, in case of eggplant, pepper and tomato, big part of the European production is also as protected cultivation.

2.2.3. Selection of host for evaluation

The hosts on which the impact is assessed are potato, tomato, pepper and eggplant. Pepper and eggplant were grouped together in the assessments of impact. For each host, the losses are considered together under open-air and greenhouse conditions.

2.3. Area of potential distribution

2.3.1. Area of current distribution

Figure 1 provides an overview of the current area of distribution of the pest. In the EU no outbreaks have yet been reported.

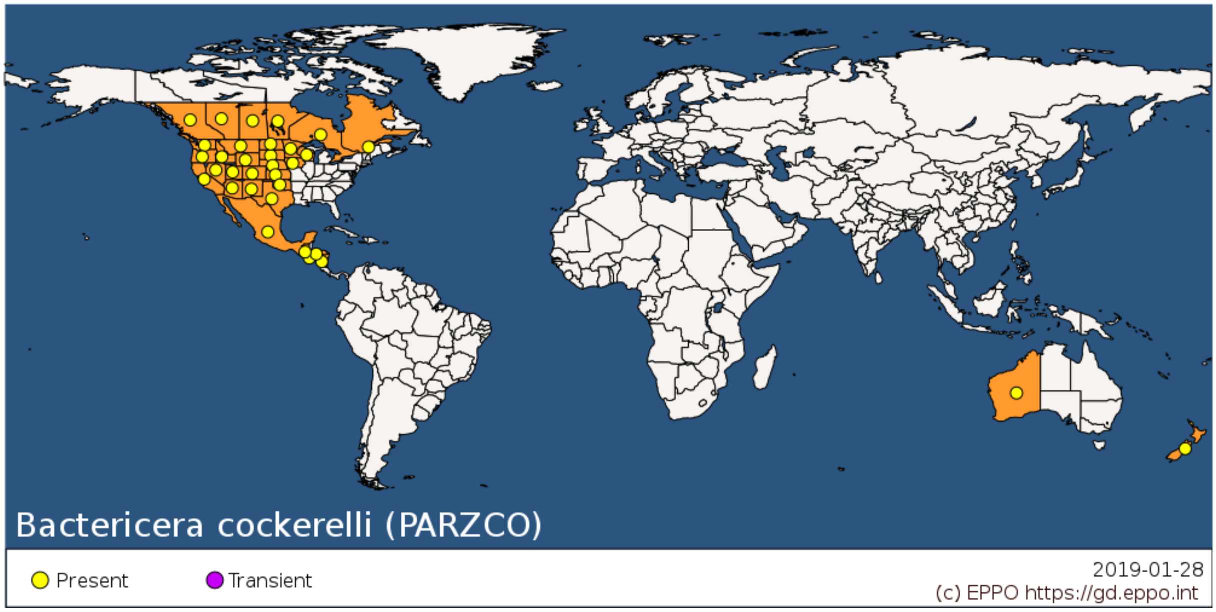

Figure 1 Distribution map of *Bactericera cockerelli* from the EPPO Global Database accessed 28/01/2019.

2.3.2. Area of potential establishment

The climate classification of Köppen-Geiger indicates that *B. cockerelli* is present in very different types of climates, some of which are included in the assessment area (EPPO, 2012b), and under protected conditions, such as greenhouses, it can extend further its area of potential establishment.

Key life cycle and temperature requirements are provided by EPPO (2012b).

In the same document, a climatic suitability study for *B. cockerelli* (performed using CLIMEX) is included. The parameters were set according to the biology of *B. cockerelli* and adjusted considering the known geographical distribution of the pest in North America and New Zealand. The model was run for the assessment area currently under evaluation. The resulting map (Figure 2) shows that *B. cockerelli* would be able to establish and overwinter outdoors in the Southern and Central European part of the assessment area, as well as in areas with mild winters in the Northern part of the assessment area, while it is unlikely to establish in the Eastern part of the region (east of Poland).

2.3.3. Transient populations

Migrations of *B. cockerelli* do occur and as a result, transient populations of *B. cockerelli* can be present in areas where they apparently cannot survive all year round. In Europe, populations might also migrate to more northern areas to escape high temperatures during summer. However, the distance reached by migrating populations is below the threshold for assessing them as transient population (see section 2.2.3.3. of EFSA, 2019), therefore in this assessment *B. cockerelli* is not expected to form transient populations in the EU.

2.3.4. Conclusions on the area of potential distribution

The area of potential distribution has been defined on the basis of the results of a climatic suitability analysis for *B. cockerelli* (performed using CLIMEX). The model proposed in EPPO (2012b) has been re-run considering the JRC dataset of climatic data for period 1998-2017. The resulting map (Fig. 2) shows that *B. cockerelli* would be able to establish and overwinter outdoors in the Southern and Central European part of the assessment area, as well as in areas with mild winters in the Northern part of the assessment area. The mean abundance of the pest, the main driver of the pest impact, is considered to be the same throughout the whole area of potential distribution.

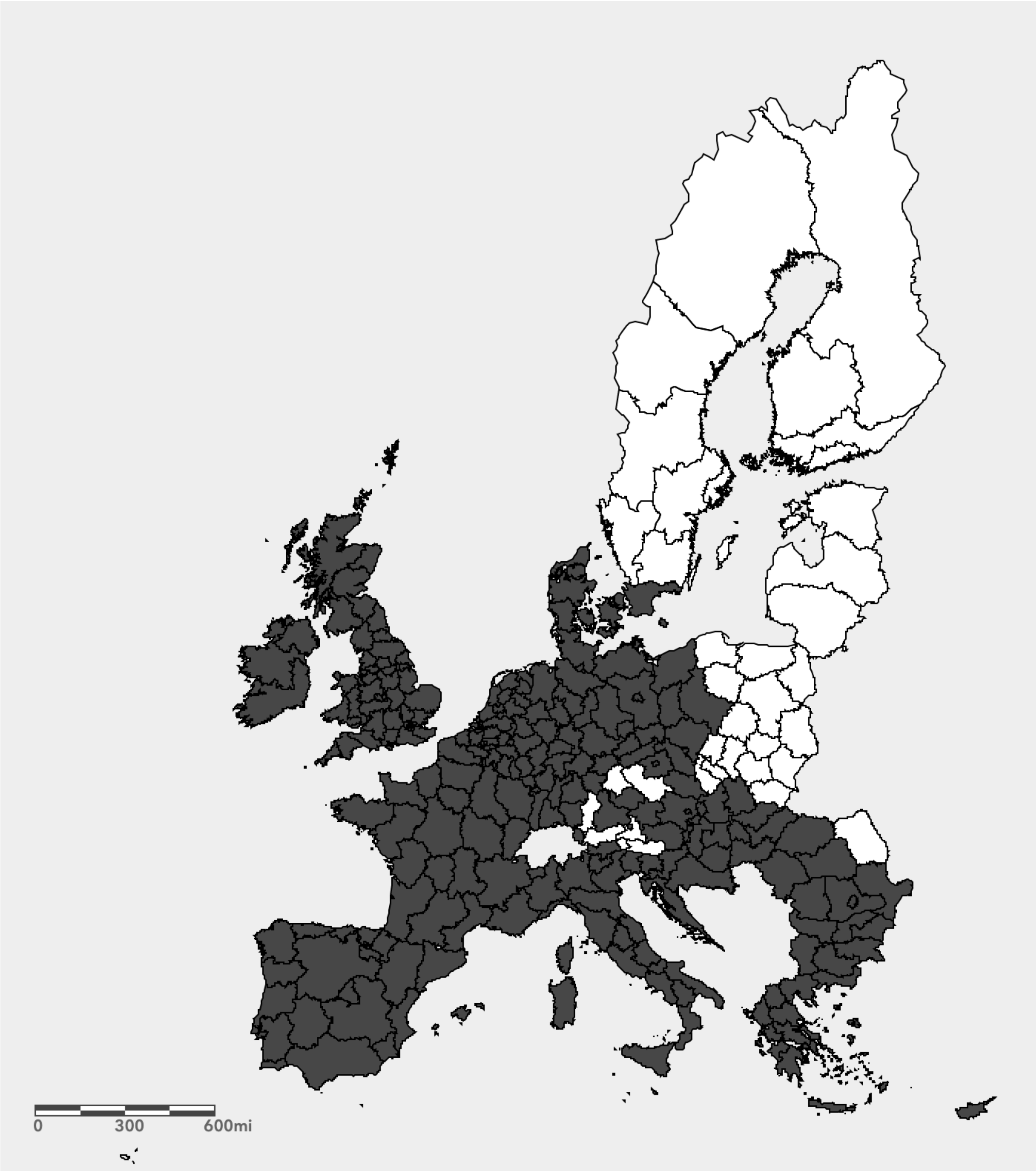

Figure 2 The potential distribution of the pest in the EU NUTS2 regions based on the scenarios established for assessing the impacts of the pest by the EFSA Working Group on EU Priority Pests (EFSA, 2019). This link provides an online interactive version of the map that can be used to explore the data further: https://arcg.is/0iH1Sq0.

2.4. Expected change in the use of plant protection products

The control strategy of *B. cockerelli* is mainly based on the application of plant protection products, in spite of the many limitations caused by the biology of this species:

- Thanks to the high fecundity rate and short generation time it can easily develop resistance to insecticides
- The numerous and overlapping generations require multiple applications and cause difficulty in identifying the most suitable moment for control.
- The products effective against adults are not necessarily effective against juveniles, therefore a single application, even when provided in the right moment, could not be able to eliminate all the life stages of the pest.
- Psyllids are commonly located on the lower side of the leaves, where they are hardly reached by treatments.
- Its vectoring capacity may not be stopped by insecticide treatments, as the disease could be still transmitted by a reduced population.

Example on the effectiveness of plant protection products against *B. cockerelli* are provided by Goolsby et al., 2007; Berry et al., 2009; Gharalari et al., 2009; Yang et al., 2010; Butler et al., 2011; Peng et al., 2011; Guenthner et al., 2012; Butler and Trumble, 2012a; Munyaneza, 2012; Munyaneza and Henne, 2012.

Due to the fact that PPPs applied against other pests in the risk assessment area are also potentially effective against *B. cockerelli* but only if the amount/number of treatments is increased, the most suitable PPP indicator is Case "C" and the category is "1" based on Table 2.

Table 1: Expected changes in the use of Plant Protection Products (PPPs) following *Bactericera cockerelli* 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	Existing 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

Bactericera cockerelli has been found to be able to vector the bacterium *Candidatus* Liberibacter *solanacearum* (EPPO, 2013).

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, 2019).

3.1.1.2. Specific scenario assumptions

No specific assumptions are introduced for the assessment of the yield losses.

3.1.1.3. Selection of the parameter(s) estimated

The assessment of yield loss for potato considers misshaped tubers, smaller tubers, green potatoes, that are all symptoms reported as caused by psyllid.

The assessments of yield loss for eggplant, pepper and tomato considers fruits expressing symptoms to be a full loss as excluded from the market.

3.1.1.4. Defined question(s)

What is the percentage yield loss in potato production under the scenario assumptions in the area of the EU under assessment for *Bactericera cockerelli*, as defined in the Pest Report?
What is the percentage yield loss in tomato production under the scenario assumptions in the area of the EU under assessment for *Bactericera cockerelli*, as defined in the Pest Report?
What is the percentage yield loss in eggplant and pepper production under the scenario assumptions in the area of the EU under assessment for *Bactericera cockerelli*, 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. The following points were noted:

- This species tends to have a patchy distribution in the field
- Sengoda et al., 2010 tried to separate the damage caused by the psyllid from that caused by *C.* Liberibacter
- Some chemical control could have an effect on psyllid population
- Damage on tomato is similar to potato for misshaped leaves, but there is also damage on the fruit
- Tomato is produced in open field and glasshouses, all year around

3.1.1.6. Uncertainties identified

- Overwintering stage is not clear
- It is very difficult to distinguish in the observed damage described from literature the component due to the direct impact of the pest from the indirect component due to the transmitted pathogen. This difficulty could lead to an overestimation due to a misinterpretation of the symptoms

- The level of susceptibility of different varieties to the pest
- In case of cultivations in the Mediterranean area (in particular tomato, pepper, eggplant), there could be an effect of high temperatures
- Less evidence is available for pepper and eggplant impact

Table 2: Summary of the main drivers for the yield losses

	Yield losses	
	Low	**High**
Infection time (in relation to plant phenology)	Late	Early
Population ecology	Low abundance Susceptibility to unfavourable climatic conditions Low availability of alternative hosts (e.g. *Solanum dulcamara*)	High abundance Capacity to adapt to unfavourable climatic conditions (e.g. overwintering) High availability of alternative hosts (e.g. *Solanum dulcamara*)
Spatial occurrence	Scattered	Homogeneous
Chemical control against other pests	High efficacy	Low efficacy
Natural enemies	High control	Low control
Host plants susceptibility	Tolerant varieties	Susceptible varieties
Relationship between population abundance on the plant and symptoms expression (e.g. including foliar damage, earlier sprouts, misshaped tubers) and connected impact	Low	High
Variability in the crop phenology and harvesting time	Early cultivation	Main crop at late harvest
Recovering capacity of the plant	High	Low

3.1.2. Elicited values for yield loss on potato

What is the percentage yield loss in potato production under the scenario assumptions in the area of the EU under assessment for *B. cockerelli*, as defined in the Pest Report?

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

Table 3: Summary of the 5 elicited values on yield loss (%) on potato

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	1%	5%	8%	13%	25%

3.1.2.1. Justification for the elicited values for yield loss on potato

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

The scenario for the upper value is based on: (i) early infection of the crop (with respect to plant phenology), (ii) high population abundance due to the capacity to adapt to unfavourable climatic conditions (e.g. overwintering), high availability of alternative hosts (e.g. *Solanum dulcamara*) and homogeneous spatial occurrence, (iii) highly susceptible varieties, (iv) low recovery capacity of the plant, (v) relationship between population abundance on the plant and symptoms expression (e.g. including foliar damage, earlier sprouts, misshaped tubers) is highly significant.

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

The scenario for the lower value is based on: (i) late infection of the crop (with respect to plant phenology), (ii) low population abundance due to the impact of unfavourable climatic conditions, low availability of alternative hosts (e.g. *Solanum dulcamara*) and scattered spatial occurrence, (iii) low susceptible varieties, (iv) high recovery capacity of the plant, (v) relationship between population abundance on the plant and symptoms expression (e.g. including foliar damage, earlier sprouts, misshaped tubers) is not much significant.

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

The median value is expected to be in the lower side of the spectrum due to the likelihood of overestimation provided from literature, as some of the observed damages are probably coming from transmitted diseases.

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

The precision reflects the fact that the group is expecting that lower values are more likely.

3.1.2.2. Estimation of the uncertainty distribution for yield loss on potato

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 the yield loss (%) on potato.

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	1%					5%		8%		13%					25%
Fitted distribution	0.9%	1.4%	2.0%	2.9%	3.8%	4.9%	6.0%	8.2%	10.9%	12.7%	15.0%	17.9%	21.5%	25.1%	29.6%

Fitted distribution: Gamma (2.3243,0.040916), @RISK7.5

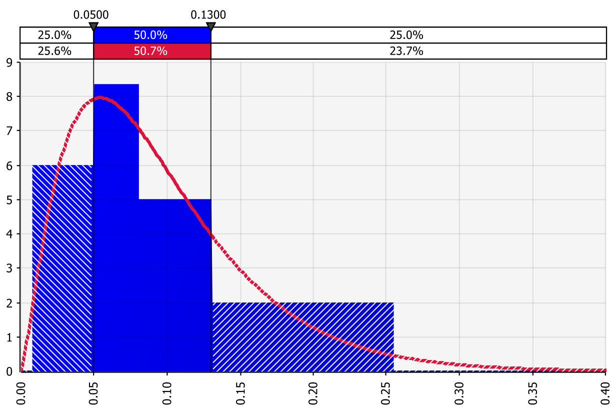

Figure 3 Comparison of judged values (histogram in blue) and fitted distribution (red line) for yield loss on potato.

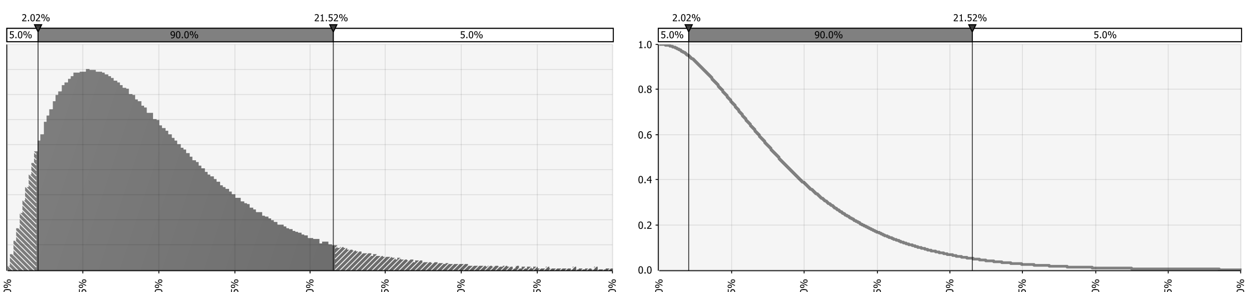

Figure 4 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for yield loss on potato.

3.1.3. Elicited values for yield loss on tomato

What is the percentage yield loss in tomato production under the scenario assumptions in the area of the EU under assessment for *Bactericera cockerelli*, as defined in the Pest Report?

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

Table 5: Summary of the 5 elicited values on yield loss (%) on tomato

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	1%	5%	8%	13%	20%

3.1.3.1. Justification for the elicited values for yield loss on tomato

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

The same reasoning presented for the potato losses can apply to tomato, noting the following additional points:

- Chemical treatments are more frequent in tomato than in potato
- The effect of temperatures in Southern EU is expected to limit the population and therefore the damage
- 60% of open field tomatoes is for processing tomato. They will go during the summer, with high temperatures and most of these varieties could be more resistant to pest infestations

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

The same reasoning presented for the potato losses can apply to tomato, noting the following additional points:

- Bigger impact in the field crop of tomato than on potato due to climatic conditions that could be more limiting in Mediterranean zones
- Adults are less attracted by tomato. The crop won't receive many insecticides as big proportion will go for processing. Smaller tomatoes and lower taste could not necessarily represent a full loss

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

The same reasoning presented for the potato losses can apply to tomato, noting the following additional points:

- Insecticides resistance observed on insecticides used in tomato
- Contradictory reports, some indicating very dramatic (but localised) impacts. On the other hand, tomato is a managed crop (in terms of amount of scrutiny and possibility of chemical control) therefore there are possibilities to limit the impact and in addition there is a high temperature effect
- This info indicates that a level of impact similar to what expected on potato is likely.

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

The precision reflects the higher confidence on lower values.

3.1.3.2. Estimation of the uncertainty distribution for yield loss on tomato

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 the yield loss (%) on tomato.

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	1%					5%		8%		13%					20%
Fitted distribution	0.7%	1.2%	1.8%	2.8%	3.8%	4.9%	6.0%	8.3%	10.8%	12.4%	14.4%	16.6%	19.4%	21.9%	24.9%

Fitted distribution: Weibull (1.7156,0.10225), @RISK7.5

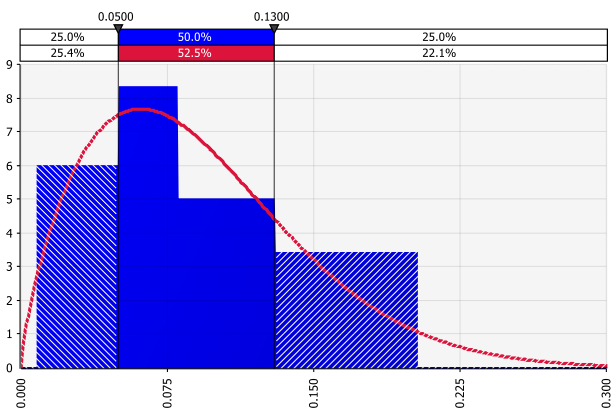

Figure 5 Comparison of judged values (histogram in blue) and fitted distribution (red line) for yield loss on tomato.

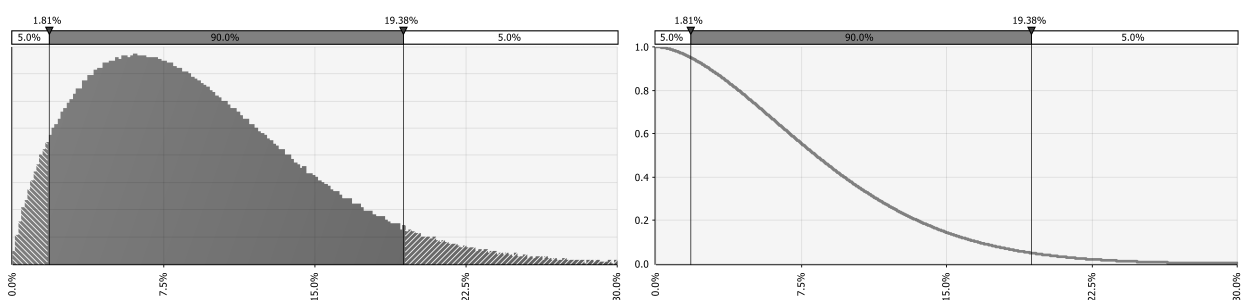

Figure 6 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for yield loss on tomato.

3.1.4. Elicited values for yield loss on pepper and eggplant

What is the percentage yield loss in eggplant and pepper production under the scenario assumptions in the area of the EU under assessment for *Bactericera cockerelli*, as defined in the Pest Report?

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

Table 7: Summary of the 5 elicited values on yield loss (%) on pepper and eggplant

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	0.5%	2.5%	4%	6%	10%

3.1.4.1. Justification for the elicited values for yield loss on pepper and eggplant

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

Little evidence is available; therefore, the tendency is to enlarge the range. However, the fact also to have contradicting evidence (authors denying impact on pepper and other speaking about strong losses) could indicate a relatively low impact, as an average.

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

The value is lower than for the two previous hosts, in order to enlarge the curve and reflect the higher uncertainty compared to the two previous EKE.

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

The median value is based on the fact that the impact expected to be lower than for the other two crops.

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

The precision reflects the fact that the impact is expected to be closer to lower values but with more uncertainty in the lower part of the curve.

3.1.4.2. Estimation of the uncertainty distribution for yield loss on pepper and eggplant

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 the yield loss (%) on pepper and eggplant.

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	0.5%					2.5%		4.0%		6.0%					10.0%
Fitted distribution	0.4%	0.7%	1.0%	1.4%	2.0%	2.5%	3.0%	4.0%	5.2%	5.9%	6.8%	7.8%	9.0%	10.1%	11.4%

Fitted distribution: Weibull (1.8337,0.049352), @RISK7.5

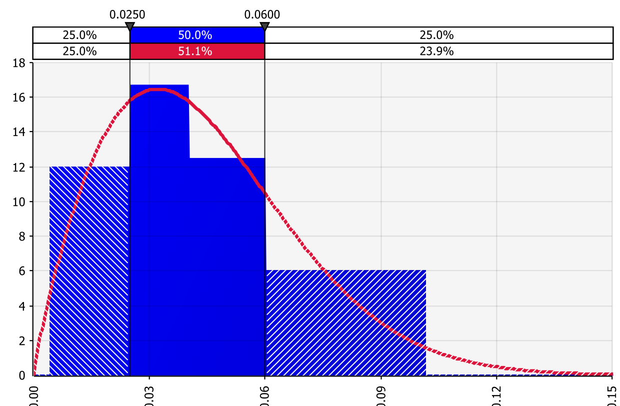

Figure 7 Comparison of judged values (histogram in blue) and fitted distribution (red line) for yield loss on pepper and eggplant.

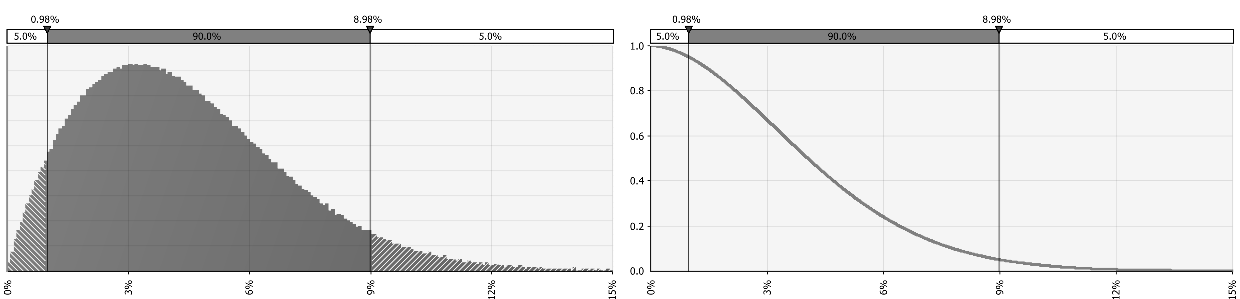

Figure 8 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for yield loss on pepper and eggplant.

3.1.5. Conclusions on yield and quality losses

Based on the general and specific scenarios considered in this assessment, the proportion (in %) of yield losses is estimated to be:

- 8.2% (with a 95% uncertainty range of 1.4 - 25.1%) for potato
- 8.3% (with a 95% uncertainty range of 1.2 - 21.9%) for tomato
- 4% (with a 95% uncertainty range of 0.7 - 10.1%) for pepper and eggplant

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, 2019).

3.2.1.2. Specific scenario assumptions

- Effect of winds is taken into account
- The spread is due to the following components:
  - Short distance dispersal in the order of metres from one field to another, mainly based on natural movement
  - Long distance dispersal in the order of kilometres, mainly based on wind assisted dispersal
  - Migration: a specific behavior of trade in which the pest can reach the distance of hundreds/thousands of kilometres supported by favorable winds and based on stepping stone process

3.2.1.3. Selection of the parameter(s) estimated

The spread rate has been assessed as the number of kilometres per year and takes into account the assessment area where establishment is possible.

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: km/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. The following points were noted:

- Differences in overwintering populations in the Pacific Northwestern US: coexistence of stable and migrating populations (Nelson et al., 2014). In New Zealand it spread to the two islands in four years
- Psyllids are caught at high altitudes and from which they can be dispersed by the wind

- Teulon et al. (2009): New Zealand spread distances

3.2.1.6. Uncertainties identified

- Expression of migratory behaviour
- Genetic composition of the population in the EU

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: km/year)

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

Table 9: Summary of the 5 elicited values on spread rate (km/y)

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	6	180	350	450	1000

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)

The upper value is based on the evidence coming from the US observations on migratory behaviour > 2000 km and takes into account: (i) a late establishment in the season, (ii) high frequency of populations expressing migratory behaviour, (iii) presence of prevailing and strong wind, (iv) low capacity to overwinter in cold climate, (v) Low frequency of populations adapted to high temperatures, (v) Relative high proportion of the migrating genotypes (vs overwintering).

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

The lower value scenario takes into account: (i) an early establishment in the season, (ii) low frequency of populations expressing migratory behaviour, (iii) no strong prevailing wind, (iv) high capacity to overwinter in cold climate, (v) high frequency of populations adapted to high temperatures, (v) Relative low proportion of the migrating genotypes (vs overwintering).

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

The median value takes into account: (i) an initial population in the south, 50% population will migrate, and 50% will stay in the 10km, higher population abundance due to favourable conditions, (ii) most of the population will behave as north west and New Zealand population, (iii) the population in the south, due to climatic conditions supporting migrating behaviour is mediated by the behaviour expected in the North. In New Zealand it is difficult to distinguish the human assisted component; however it is expected to start spreading quite fast.

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

The precision interval reflects the higher confidence on lower values, and on the median.

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 10: 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	6					180		350		450					1000
Fitted distributio n	28	48	71	108	149	193	236	321	419	479	556	643	748	844	959

Fitted distribution: Weibull (1.7321, 397.02), @RISK7.5

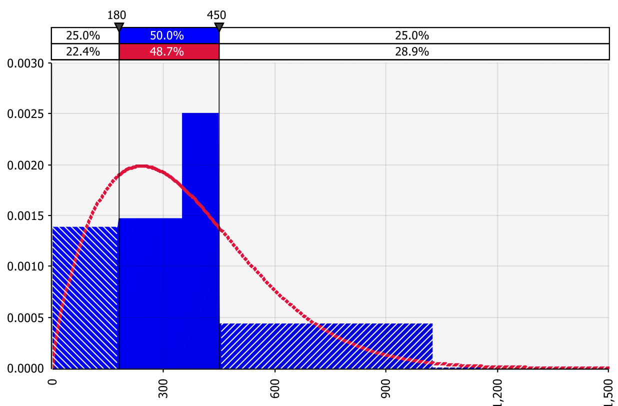

Figure 9 Comparison of judged values (histogram in blue) and fitted distribution (red line) for spread rate.

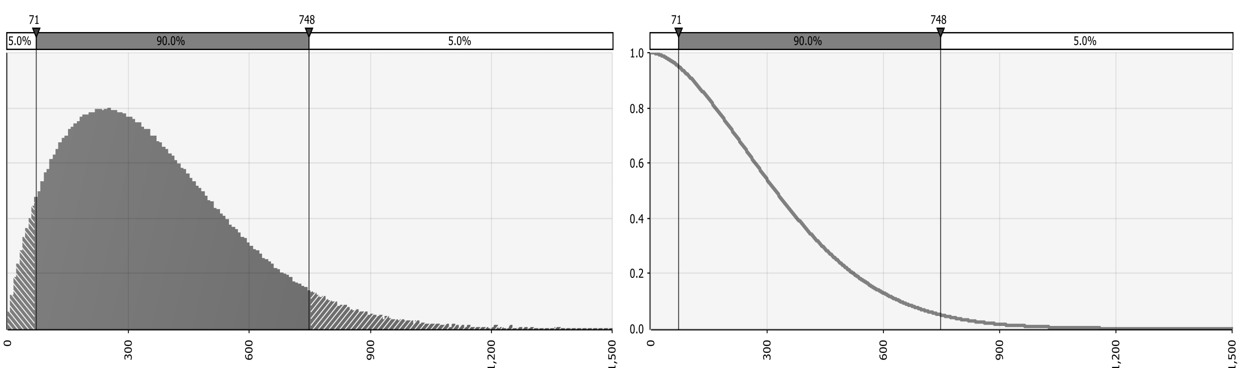

Figure 10 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for spread rate.

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 *B. cockerelli* is 321 km (with a 95% uncertainty range of 48 - 844 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, 2019).

3.3.1.2. Specific scenario assumptions

No specific assumptions are introduced for the assessment of the 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.3 in Appendix B) selecting the data and references used as the key evidence for the EKE on time to detection. The following was noted:

- Symptoms can be easily confused with virus infections, physiological disorders
- EU psyllids do not go on Solanaceae
- Main surveillance activity on Solanaceae is focused on aphids and just collaterally it could find psyllid presence
- There is surveillance of psyllids in carrot fields due to *Candidatus* Liberibacter
- Presence of honeydew is a quite specific sign in potatoes
- Private non-commercial production is not expected to spot psyllid presence very quickly

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 values on the time to detection which the group agreed are reported in the table below.

Table 11: Summary of the 5 elicited values on time to detection (months)

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	6	22	30	37	48

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

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

- Low population density
- It takes into account 1 growing season
- The symptoms can be easily confused
- The outbreak could be sustained by wild Solanaceae in not managed environments

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

- High population density
- Outbreak in a cultivated area intensively managed (e.g. pepper in greenhouse)

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

The median value takes into account the productive season and its variation in the EU.

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

The precision is mainly driven by the uncertainty on the upper side of the curve, but it expresses the likelihood for higher values.

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 12: 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	6					22		30		37					48
Fitted distributio n	8.0	10.6	13.2	16.5	19.6	22.6	25.1	29.7	34.2	36.8	39.8	43.0	46.7	49.8	53.4

Fitted distribution: Weibull (3.222,33.224), @RISK7.5

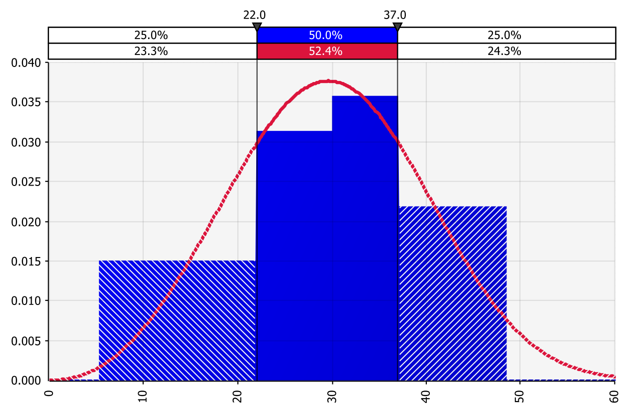

Figure 11 Comparison of judged values (histogram in blue) and fitted distribution (red line) for time to detection.

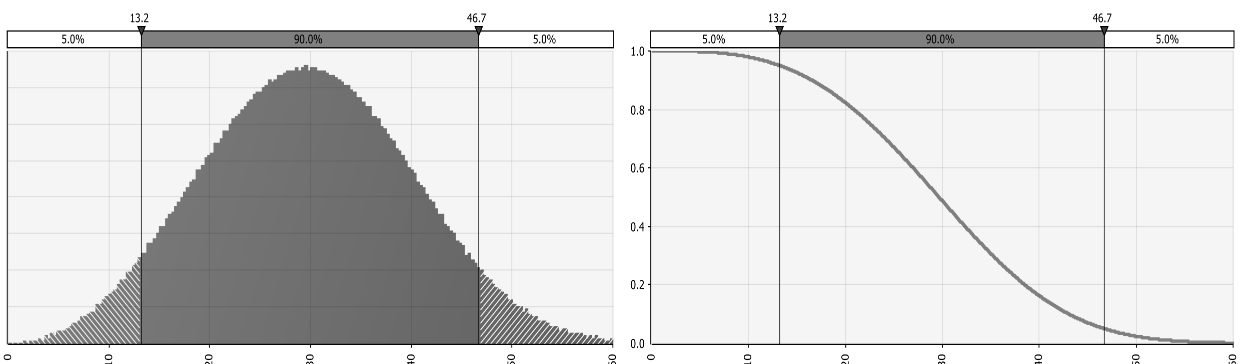

Figure 12 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for time to detection.

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 2.5 years (with a 95% uncertainty range from less than 1 to 4 years).

4. Conclusions

Hosts selection

The hosts on which the impact is assessed are potato, tomato, pepper and eggplant. Pepper and eggplant were grouped together in the assessments of impact. For each host, the losses are considered together under open-air and greenhouse conditions.

Area of potential distribution

The area of potential distribution has been defined on the basis of the results of a climatic suitability analysis for *B. cockerelli* (performed using CLIMEX). The model proposed in EPPO has been re-run considering the JRC dataset of climatic data for period 1998-2017. It shows that *B. cockerelli* would be able to establish and overwinter outdoors in the Southern and Central European part of the assessment area, as well as in areas with mild winters in the Northern part of the assessment area. The mean abundance of the pest, the main driver of the pest impact, is considered to be the same throughout the whole area of potential distribution.

Increased number of treatments

Due to the fact that PPPs applied against other pests in the risk assessment area are also potentially effective against *B. cockerelli* but only if the amount/number of treatments is increased, the most suitable PPP indicator is Case "C" and the category is "1".

Yield loss

Based on the general and specific scenarios considered in this assessment, the proportion (in %) of yield losses is estimated to be:

- 8.2% (with a 95% uncertainty range of 1.4 - 25.1%) for potato
- 8.3% (with a 95% uncertainty range of 1.2 - 21.9%) for tomato
- 4% (with a 95% uncertainty range of 0.7 - 10.1%) for pepper and eggplant

Spread rate

Based on the general and specific scenarios considered in this assessment, the maximum distance expected to be covered in one year by *B. cockerelli* is 321 km (with a 95% uncertainty range of 48 - 844 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 2.5 years (with a 95% uncertainty range from less than 1 to 4 years).

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Appendix A – CABI/EPPO host list

The following list, defined in the Methodology Report (EFSA, 2019) 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**
Capsicum	*annuum*
Convolvulus	*arvensis*
Ipomoea	*batatas*
Lycium	
Medicago	*sativa*
Mentha	
Micromeria	*douglasii*
Nepeta	
Nicandra	*physalodes*
Nicotiana	*tabacum*
Physalis	
Purshia	
Solanum	
Solanum	*capsicastrum*
Solanum	*dulcamara*
Solanum	*lycopersicum*
Solanum	*melongena*
Solanum	*tuberosum*
Thuja	*occidentalis*

Appendix B – Evidence tables

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

Susceptibility	Infection	Symptoms	Impact	Additional information	Reference	Limitation/uncertainties
	Incidence	***Severity***	***Losses***			
Tomato			Losses reaching 80%	In tomatoes, foliar symptoms are similar to those of potatoes and fruit set, size, texture and yield can be significantly decreased due to psyllid yellows (Cranshaw, 1994), with losses reaching 80% (Liu and Trumble, 2007).	Butler and Trumble, 2012a	
				It is not easy to determine which part of the damage by the complex *B. cockerelli* /Ca. L. *solanacearum* is due to *B. cockerelli* alone. However, impact has been reported from regions where the bacterium is not present.	EPPO, 2012ab	
				If only non-infective psyllids are introduced impact may be moderate.	EPPO, 2012a	
Tomato		Few or no marketable fruits from infected tomatos		Infected tomato plants produce few or no marketable fruits (List, 1939; Daniels, 1954).	EPPO, 2012a	Very old papers: if retrieved, might contain numbers
Tomato				Since 2001 a series of outbreaks occurred every year in some USA states and Mexico, in particular in controlled environment facilities for fresh market tomato production in Arizona, California and Mexico (California – over 80% losses in tomato production).	EPPO, 2012a	
Potato				In potatoes, psyllid yellows result in yellowing or purpling of foliage, early death of plants, and low yields of marketable tubers (Eyer, 1937; Pletsch, 1947; Daniels, 1954; Wallis, 1955).	EPPO, 2012a	Very old papers: if retrieved, might contain numbers
Potato	Often 100% of plants in affected fields		Yield losses exceeding 50% in some areas	In areas of outbreaks of psyllid yellows, the disorder was often present in 100% of plants in affected fields, with yield losses exceeding 50% in some areas (Pletsch, 1947).	EPPO, 2012a	Very old papers

Potato				In Imperial high populations of non-infective psyllids resulted in reduced yield and undesirable color of potatoes.	Goolsby et al., 2010	
Potato			55.2 to 93% yield loss	In experiments, 55.2 to 93% yield loss is observed in potato plants exposed to psyllids (Munyaneza et al., 2008).	EPPO, 2012a	Probably includes those infected with ZC. Check Munyaneza et al., 2008
Potato			Average yield was reduced by 49.4% in 2004 and 70.0% in 2005. In both years tuber number was also reduced, 19.2% in 2004 and 70.0% in 2005.	The yield was reduced even for populations that did not show zebra chip symptoms, suggesting that the psyllid might cause economic losses on its own	Diaz-Valasis et al., 2008	
Tomato		See Table 1 in the paper		Quantifying leaf symptoms and plant height for five psyllid densities on four tomato cultivars	Liu and Trumble, 2006	
				The authors describe the phenotypic and etiological differences between psyllid yellows and zebra chip diseases of potato. They showed that plants exposed to liberibacter-free psyllid continuously for 70 days died. However, it cannot be excluded that another yet-unknown pathogen may be associated with the psyllid.	Sengoda et al., 2010	
Chili pepper			At the beginning of the disease the affected plants showed an evident yellow colour frequently occupying > 50% of the foliar surface.	Durango estate, Mexico.	Velásquez-Valle et al., 2015	
Chili pepper				Infested chili pepper, with evident yellowing, deformation of leaves (Figure 1 in paper).	Velásquez-Valle et al., 2015	
Chili pepper				Fruit deformation and reduced size on chili pepper (Figure 4 in paper).	VelásquezValle et al., 2015	

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

Spread	Additional information	Reference
	Long distance transport of different life stages of this insect pest is possible, particularly by commercial trade of plants in the family Solanaceae, which constitute major hosts for *B. cockerelli*.	EPPO, 2013
>250 km/year	The experience with *B. cockerelli* in New Zealand has shown that the bacterium may be spread over distances of more than 1000 km within a period of 4 years after the vector's introduction. Uncertainty: combination of both natural and human-mediated dispersal.	Teulon et al., 2009; EPPO, 2012a
Several hundred km/year	The probability of spread is high (e.g. several hundred kilometres a year). The pest is a good flyer and is also known to be transported by wind over long-distances during its migrations in North America.	EPPO, 2012a

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

Reference	Case	Aspect	Results / evidence
Detection methods			
EPPO, 2012b	Main symptoms: visual	Effects on detectability	Visual inspection might allow detecting *B. cockerelli*. Eggs are difficult to detect: they are laid on the foliage, attached by short stalks (less than 0.2 mm), but detection requires use of a dissecting microscope. Nymphal stages and adults might be observed. Faeces resulting from feeding on the phloem, as white granular substance are visible (Teulon et al., 2009).
EPPO, 2017	Main symptoms: visual	Effects on detectability	Adult *B. cockerelli* may be sampled using preferably yellow sticky traps or yellow water traps. Sweep nets, vacuum trapping and sampling leaves are less efficient.
Munyaneza, 2012	Main symptoms: visual	Effects on detectability	Adults: sweep nets or vacuum devices, yellow water-pan traps. Eggs and nymphs: visual examination of foliage, which may necessitate the use of a field hand lens.
Sengoda et al., 2010	Main symptoms: visual	Effects on identification	Unlike in ZC-infected plants, tubers affected by psyllid yellows do not develop any necrotic symptoms, whether raw or processed into fried chips or fries.
Butler and Trumble, 2012b	Sampling technique	Effects on detectability	The authors propose a sampling plan for the potato psyllid.

Biology of the pest			
Butler and Trumble, 2012a			Plant symptoms of psyllid yellows include a reduction in growth, erectness of new foliage, chlorosis or reddening/purpling of leaves, basal cupping of leaves, shortened and thickened internodes, enlarged nodes, aerial tubers, premature senescence and plant death. The marginal yellowing and upward rolling or cupping of younger leaves is a diagnostic character of psyllid yellows.
Cranshaw, 1994			Tubers from potato plants infected with psyllid yellows are tiny, misshapen, flabby, and have a rough skin. These tubers often have associated with them various defects such as early sprouting, weak sprouts, and significantly smaller plants.
CABI, 2018 Yang and Liu, 2009 Yang et al., 2010	Life cycle	Effects on detectability	Longevity: 20-60 days, with females having 2-3 times longer life than males.
EPPO, 2012a	Reproduction	Effects on detectability	eggs/female: • 500 (Wallis, 1955) • 184-258 in greenhouse tomatoes (Abdullah, 2008) • 36-720 on potato, tomato or chilli pepper (Yang and Liu, 2009) • 29 on eggplant and 39 on bell pepper (Yang and Liu, 2009)
Workneh et al., 2012; Butler and Trumble, 2012b	Behaviour	Effects on detectability	Typically, psyllid populations are highest at field edges initially, but, if not controlled, the insects will eventually spread throughout the crop
Martini et al., 2012	Behaviour	Effects on detectability	Potato psyllid nymphs were most predominant in the middle portion of the potato canopy.
Richards, 1931	Life cycle	Effects on incidence	In potatoes fewer than 15 nymphs do not induce uniform disease symptoms, but with higher infestations, symptoms appear in 4-6 days.
Liu and Trumble, 2006; Butler and Trumble, 2012a	Life cycle	Effects on incidence	In tomatoes, symptoms of psyllid yellows will appear when at least 8 nymphs feed on 2 weeks old tomato plants
Abdullah, 2008; EPPO, 2012a	Life cycle	Effects on incidence	Time periods for development in controlled environment: - pre-mating period: 3.8-5 days - pre-oviposition period: 5.9-8 days - egg incubation period: 5.7-8.2 days - nymphal period: 19.1-23.8 days