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Candidatus Liberibacter 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, 2019).

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, 2019). 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 *Candidatus* Liberibacter, the following documents were used as key references: Bové, 2006; Gottwald, 2010; Grafton-Cardwell et al., 2013; Wang et al., 2017.

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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

This report focuses on *Candidatus* Liberibacter spp. associated with citrus greening (from now on CL). These are nonculturable, gram-negative, phloem-limited bacteria belonging to the Rhizobiaceae family mostly vectored by psyllid insects. Yellow shoots, leaf blotchy mottle, and lopsided fruits with colour inversion and aborted seeds are quite specific symptoms, but they do not necessarily appear together, or can be masked by other factors and be confused with mineral deficiencies or other diseases (Bové, 2006; EPPO, 2014). The symptomatology is however similar to that caused by other phloem-limited pathogens, such as *Spiroplasma citri* or *Candidatus* Phytoplasma probably due to the common consequences given by the disruption of phloem function (Wang et al., 2017). The direction of the systemic infection follows the direction of phloem sap: from sources (leaves) to sinks (roots, tubers, flushes, fruit) with a speed of approximately 2-3 cm/day (Wang et al., 2017).

Infections ultimately lead to dieback, stunted growth and plant death (Bové, 2006; Gottwald et al., 2007; Berk, 2016). When the tree is still alive, the infected fruit are of reduced quality due to the production of secondary metabolites associated with bitter and astringent tastes in orange juice (Dala Paula et al., 2017). The consequences on fruit quality are also dependent on citrus species and cultivar (e.g. experiment by Bassanezi et al. (2009): less pronounced on early and mid-season sweet orange cultivars – cv. Hamlin, Valencia Americana and Westin and cv. Pera respectively – than on late season cv. Valencia). The assessment therefore does not include quality losses, and under yield losses considers together tree decline, reduced number of fruits, reduced fruit size, change of taste.

Latent infections can take years before appearing and the distribution of the bacteria in the plant is uneven (EPPO, 2014). However, Coletta-Filho et al. (2010) observed a direct relationship between the concentration of pathogen and the expression of symptoms.

The location in the vascular tissue makes these pathogens inaccessible by chemical treatments and their spread requires the presence of vectors. This pathogen will survive as long as the infected host or vector survives.

This assessment includes the three following *Candidatus* Liberibacter species, the agents of citrus greening (or Huanglongbing; from now on HLB):

Candidatus Liberibacter africanus	primarily transmitted by *Trioza erytreae* (Bové, 2006)	in Africa and the Mascarene islands
Candidatus Liberibacter americanus	transmitted by *Diaphorina citri* (Teixeira et al., 2005)	up to now only found in Brazil
Candidatus Liberibacter asiaticus	transmitted by *Diaphorina citri* (Saponari et al., 2010)	mainly in Asia, America and more recently in Ethiopia

Diaphorina citri and *Trioza erytreae* have shown experimentally the capacity to transmit both CL africanus and CL *asiaticus* (Massonie et al., 1976; Aubert, 1987). Also a small proportion of fourth and fifth instar nymphs are reportedly able to transmit the pathogen (van den Berg et al., 1991–1992), but they are vulnerable to desiccation (Aubert, 1987), therefore with a limited capacity to spread the disease.

Two more psyllid species have been found positive to CL spp: *Diaphorina communis* in Bhutan (Donovan et al., 2012) and *Cacopsylla citrisuga* in China (Cen et al., 2012) but their transmission capacity has not yet been confirmed (Haapalainen, 2014).

CL could be considered in origin an insect endophyte that has adapted to the plant: the vector is the main source of inoculum, making its control essential for the disease management (Gottwald, 2010).

The direct impact of *D. citri* and *T. erytreae*, e.g. the excreted honeydew that coats the outside of fruits and leaves and promotes the growth of sooty mould fungus that inhibits photosynthesis, weakens the plant, and makes fruit unattractive (Martin et al., 2012ab).

No control measures are available against the bacterium and therefore successful eradication programs for CL spp have not yet been found (Polek et al., 2007). However, systemic insecticides can be applied against the vectors (Plant Biosecurity, 2010), but, according to the experience in Florida, a successful eradication of the disease is unlikely to occur where the incidence of HLB is between 50 and 100% (USDA, 2016). Moreover, systemic insecticides may control the vector but be inefficient to avoid CL transmission.

2.2. Host plants

2.2.1. List of hosts

Rutaceae are the natural hosts of CL spp. and all commercial citrus species are susceptible to HLB. All citrus species, including ornamentals, have been shown to harbour the pathogen, e.g. orange jasmine (*Murraya paniculata*) (Deng et al., 2007), *Calodendrum capensis* (Nelson et al., 2015), *Toddalia lanceolata* (Garnier and Bové, 1996). HLB has been experimentally transmitted to several hosts outside the Rutaceae family, including dodder (*Cuscuta* spp.), *Catharanthus roseus* and *Nicotiana xanthi* (Garnier and Bové, 1993), and this would suggest, according to Halbert and Manjunath (2004), a wide physiological host range for the pathogens.

Rootstock selection doesn't influence the disease incidence but can increase the scion tolerance to HLB (Albrecht et al., 2012).

Appendix A provides the full list of hosts.

2.2.2. Selection of hosts for the evaluation

All commercial citrus species are considered equally prone to develop the disease in the EU growing conditions.

2.2.3. Conclusions on the hosts selected for the evaluation

The impacts on all commercial citrus species and varieties were assessed together since they are assumed to have similar susceptibilities to *Candidatus* Liberibacter species.

2.3. Area of potential distribution

2.3.1. Area of current distribution

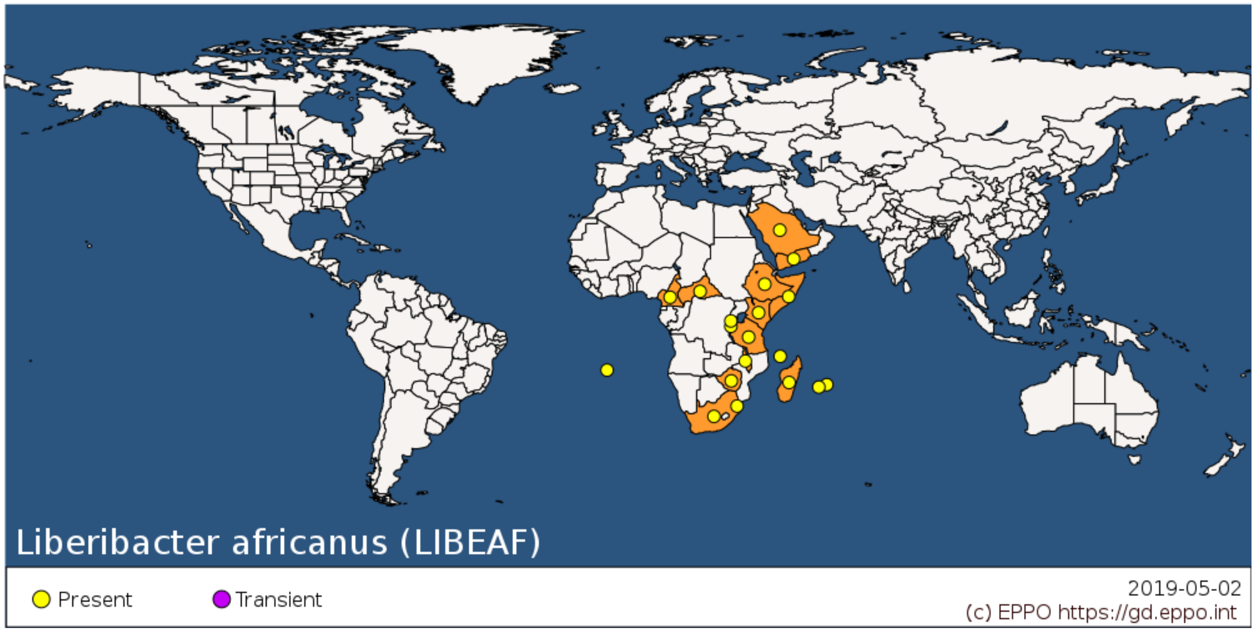

Figure 1 Distribution map of *Candidatus* Liberibacter africanus from the EPPO Global Database accessed 02/05/2019.

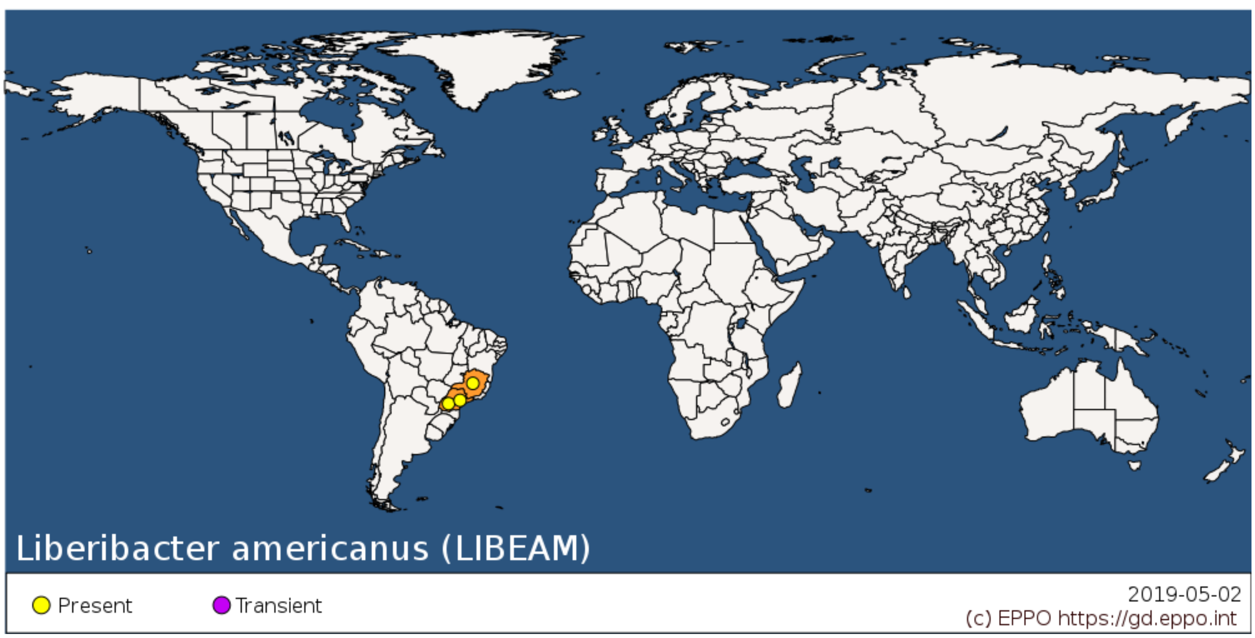

Figure 2 Distribution map of *Candidatus* Liberibacter americanus from the EPPO Global Database accessed 02/05/2019.

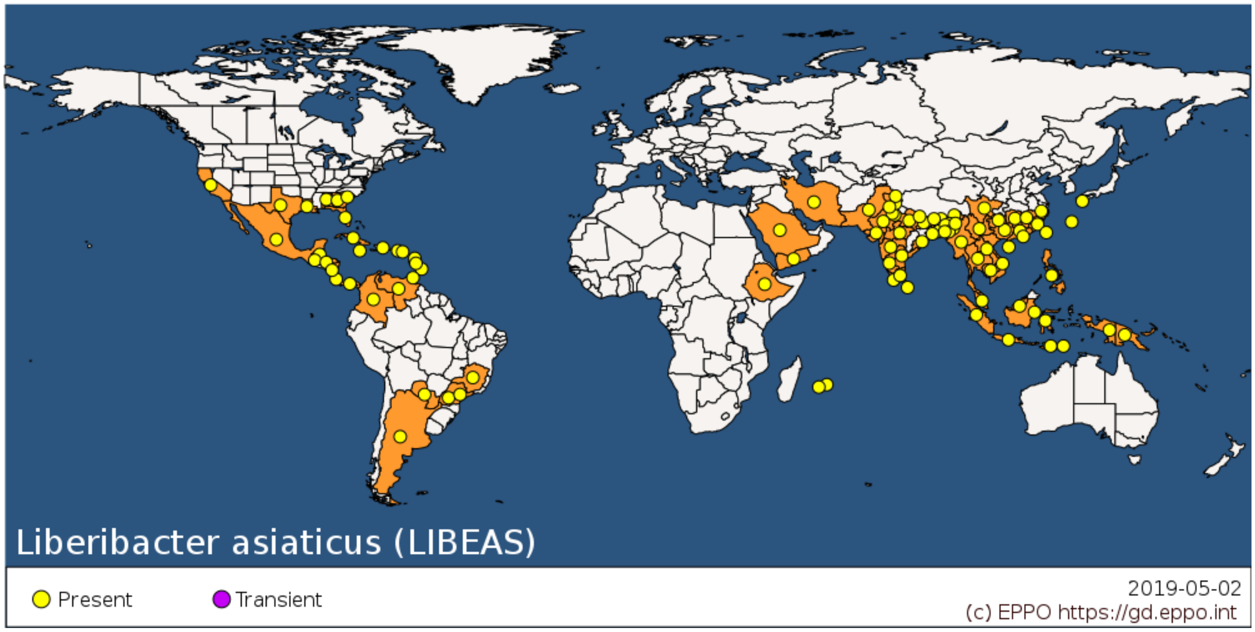

Figure 3 Distribution map of *Candidatus* Liberibacter asiaticus from the EPPO Global Database accessed 02/05/2019.

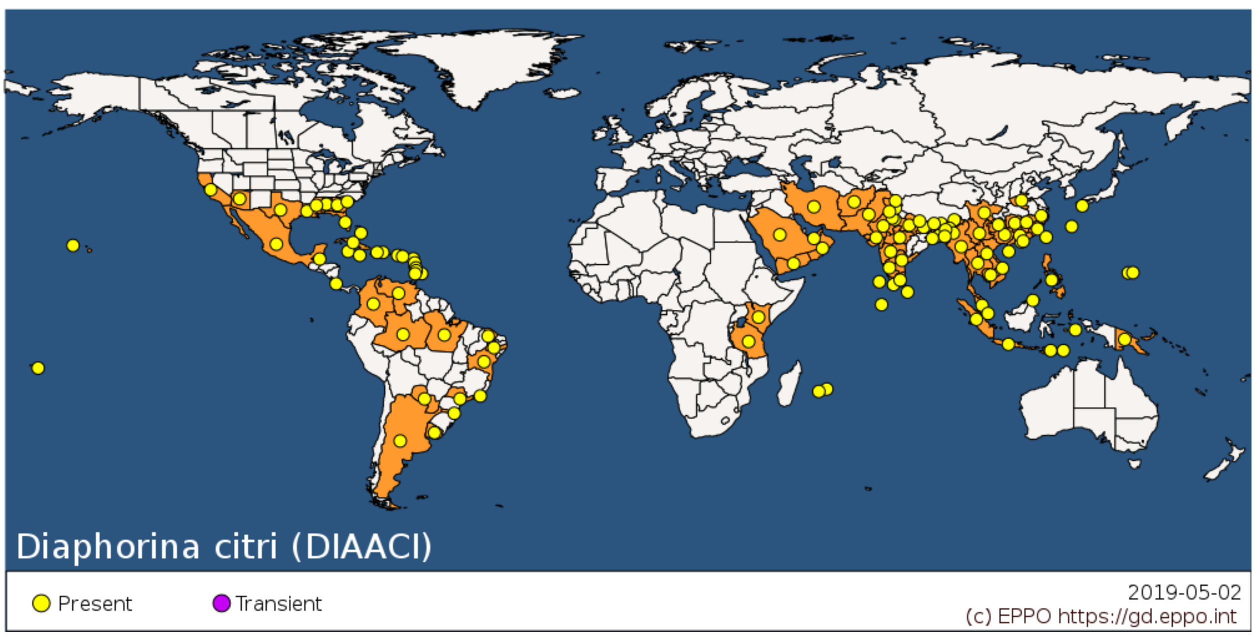

Figure 4 Distribution map of *Diaphorina citri* from the EPPO Global Database accessed 02/05/2019.

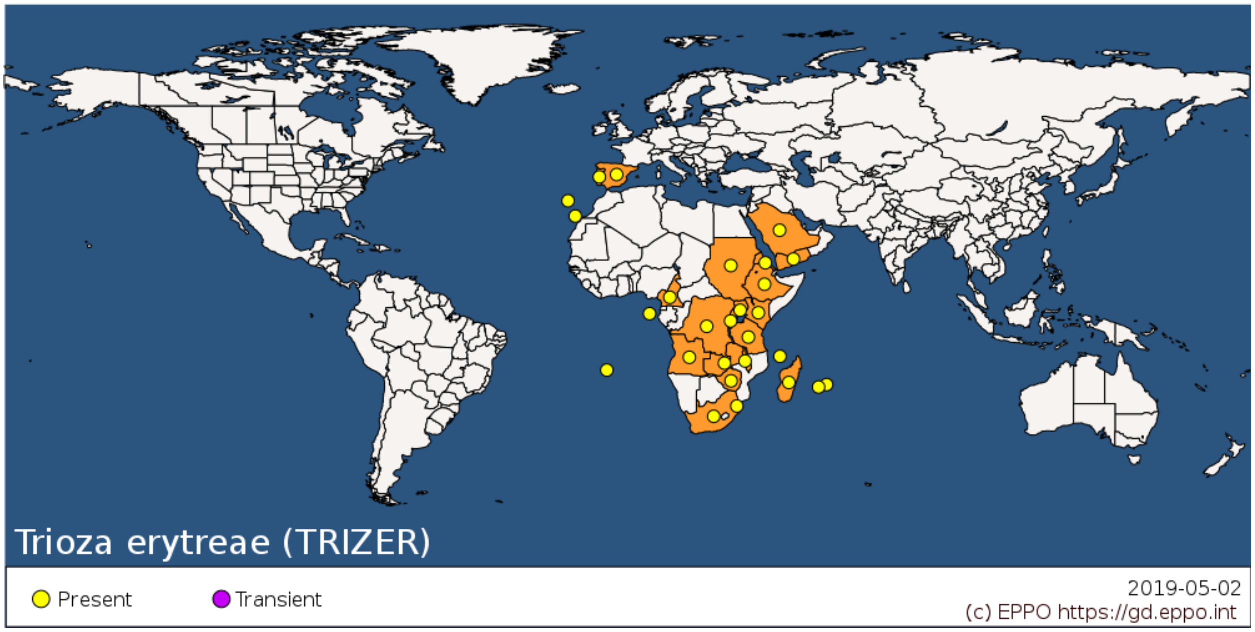

Figure 5 Distribution map of *Trioza erytreae* from the EPPO Global Database accessed 02/05/2019.

2.3.2. Area of potential establishment

The area of potential distribution takes into account the potential maximum distribution of the three CL species and of the two vectors (*D. citri* and *T. erytreae*).

CL africanus (discovered in Yemen) is heat-sensitive: Bové (2006) indicates that disease symptoms are expressed at 22–24 °C but not above 32°C.

According to many authors, CL americanus has temperature sensitivities similar to CL africanus, but Teixeira et al. (2005) observed severe symptoms at both cool (22-24 °C) and warm (27-32 °C) conditions, suggesting that CL americanus is a heat-tolerant form (Bové, 2006).

CL asiaticus was discovered in Saudi Arabia but the earliest description of HLB-like symptoms came from central India in the 1700's (Gottwald, 2010). It is heat-tolerant, causing symptoms at both cool and warm (even above 30 °C) temperatures and at low humidity (Bové, 2006; Li et al., 2008). It causes heavy damagealso to the formerly resistant pomelo and kumquat (Tsai et al., 2008).

T. erytreae is heat sensitive and its vectoring capacity is limited to areas with temperatures lower than 32 °C combined with 30% relative humidity (Aubert, 1987). Adults spend 2–3 months on host plants in cooler environments (van den Berg, 1990) and nymphs require a temperature threshold of 10–11 °C to develop (Liu and Tsai, 2000).

T. erytreae was found in Madeira in 1994 and in the Canary Islands in 2002, then in continental Europe, more precisely in Galicia (August 2014) and later (January 2015) in northern Portugal (Siverio et al., 2017).

Green and Catling (1971) showed the combined effects of temperature and humidity (measured as the saturation deficient index) and have mapped the distribution and prevalence of *T. erytreae* in South Africa through time. Only regions or seasons with high humidity and moderate temperatures resulted in high populations of *T. erytreae*. This explains why in South Africa the damage caused by CL africanus infections is particularly severe in cool areas above 600 m, with relative humidity above 25% (Bové et al., 2008).

The effect of climate on the spread of *T. erytreae* is best illustrated in Réunion Island in the Indian Ocean. The climate of Réunion is tropical, with temperatures affected by elevation. The average coastal temperature is between 18–31 °C, with temperatures dropping in the interior; humidity is high. Here, *T. erytreae* co-exists with *D. citri* (da Graça, 1991). *Trioza erytreae* is restricted to altitudes above 500-700 m where the climate is cooler while *D. citri* occurs below this altitude where the climate is warmer (da Graça, 1991; Bové, 2006).

Diaphorina citri thrives in warm environments and is tolerant of high temperatures (Bové, 2006). Depending on the duration of freeze events, a large majority of *D. citri* adults would survive freezing temperatures of 0 to -4 °C and might survive even to < -6.5° C. However, a freeze event severe enough to kill flush leaves (on which oviposition and nymph development occur) would cause mass mortality of immatures, except perhaps of older nymphs that might complete development on stems or mature leaves (Hall et al., 2011). The developmental period under experimental conditions is: 14-15 days at 28 °C and 43.5 days at 18 °C (Liu and Tsai, 2000; Nava et al., 2007), with the optimal temperatures reported at 24–28 °C.

Observations on spatiotemporal dynamics of *D. citri* invasion support the hypothesis that its spread is attributable to habitat suitability more than to wind direction (Bayles et al., 2017). Temperature, photoperiod and rainfall have been proved to produce morphometric variations on *D. citri*, with potential consequences on its spread capacity, as already observed in several insects' taxa (Paris et al., 2017). Also host species plays a role on the psyllid size and shape (Paris et al., 2016). Temperature resulted to be the most relevant factor: adult *D. citri* reared at 20°C were larger than those reared at 30°C and would have developed at approximately half the rate, based on prior studies (Paris et al., 2017).

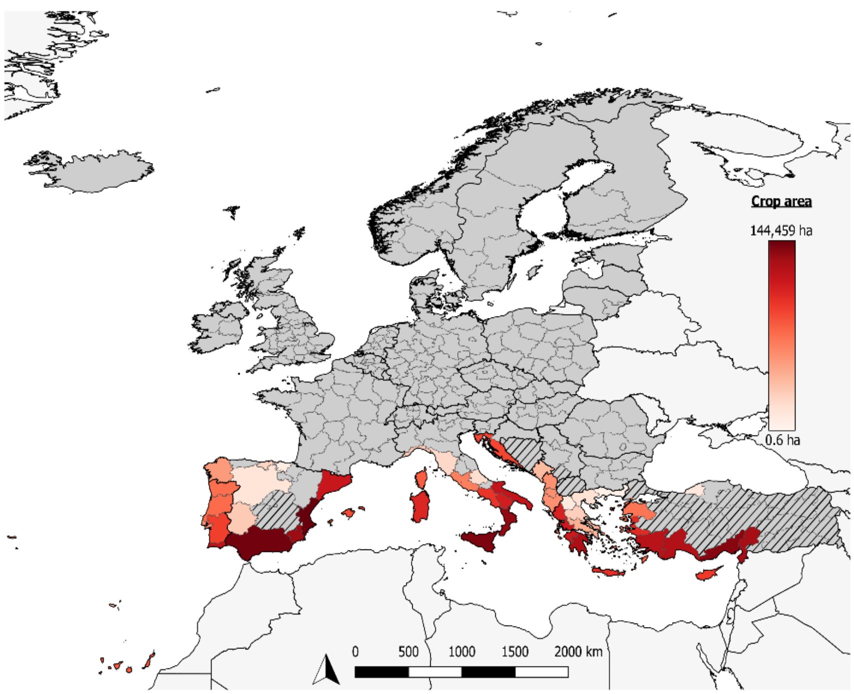

Figure 6 *Citrus* spp. growing areas. Statistic data of crop area at NUTS 2 level. Areas with lines indicate areas with no data (figure from EFSA PLH Panel, 2019).

In this assessment the area of potential distribution for *Candidatus* Liberibacter species is represented by the sum of the areas of potential establishment for all the CL species and their vectors (Figures 1-5). Since the CL species and their vectors are found in areas comparable to the climates at the limits of citrus production in the EU, the area of potential distribution for is considered to be equivalent to the area of *Citrus* production in the EU (Figure 6).

2.3.3. Transient populations

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

2.3.4. Conclusions on the area of potential distribution

The area of potential distribution for *Candidatus* Liberibacter species is equivalent to the area of *Citrus* production in the EU (Figure 7).

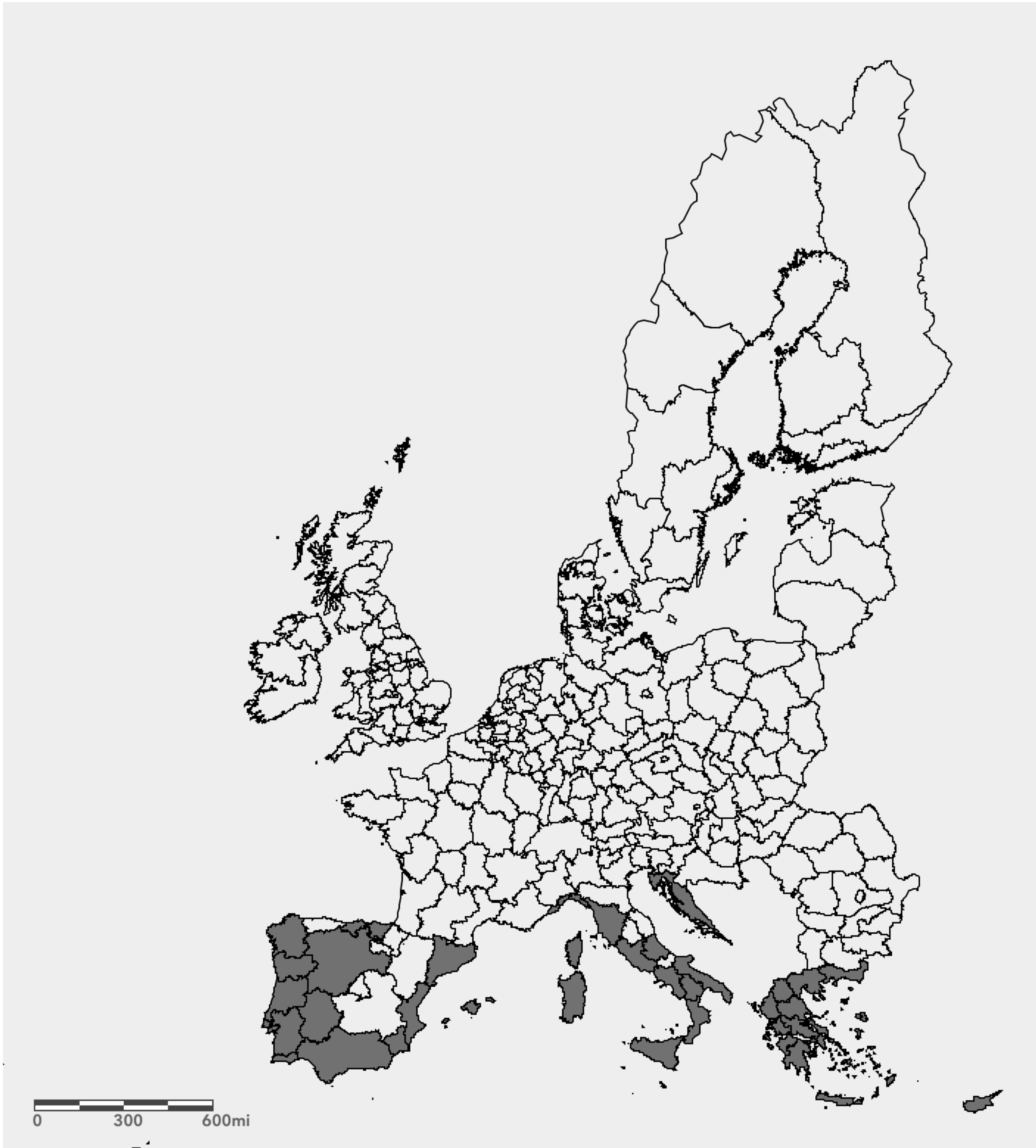

Figure 7 The potential distribution of the pest in the EU NUTS2 regions based on the scenarios established for assessing the impacts of the pest by the EFSA Working Group on EU Priority Pests (EFSA, 2019). This link provides an online interactive version of the map that can be used to explore the data further: https://arcg.is/1Lv5vr

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2.4. Expected change in the use of plant protection products

No curative methods to control CL are available and so control is by preventing trees from becoming infected (Bové, 2006). Once the pathogen reaches a new area of invasion, the only possible action is to limit the number of infected trees by eliminating the inoculum (tree removal) and reducing the vector population (Bové, 2006). Aubert (2008) indicates that chemical protection alone against extremely fertile species such as psyllid vectors may end in a vicious cycle with rising levels of resistance and damage to the environment. In addition, many insecticides presently used to control psyllids are systemic, requiring immigrating psyllids to feed to acquire lethal levels of insecticide and therefore ending up with CL transmission prior to death of vectors (Gottwald, 2010). The use of biocontrol agents has been effective in specific circumstances (e.g. in Reunion Island) (Gottwald, 2010).

Gottwald (2010) summarises the control strategy as follows:

- control of vectors in commercial plantings to reduce transmission;
- removal of infected trees in commercial plantings to reduce inoculum sources;
- geographical isolation and disease certification programs for budwood sources;
- geographical isolation of nursery production;
- all citrus nursery production conducted in secure insect proof screen houses.

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 effective in controlling *C.* Liberibacter and integrated strategies will need to be applied.

Table 1: Expected changes in the use of Plant Protection Products (PPPs) following *Candidatus* Liberibacter 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, 2019).

3.1.1.2. *Specific scenario assumptions*

- Vectors do not represent a limitation to the epidemiology of the disease since they are assumed to be present throughout the area of potential establishment of the pathogen
- The impact of the vectors on the host plants is not assessed
- The impact assessment is based on the production cycle of an orchard. Any replacement of infected trees with healthy plants is not taken into account in the assessment of impact
- All commercial citrus species and varieties are assumed to have similar susceptibilities to *Candidatus* Liberibacter species. The impact assessment therefore takes into account the average losses in the whole EU citrus crop, including most sensitive and the most tolerant hosts
- The incubation period (from infection to symptoms expression) is a maximum of 5 years

3.1.1.3. *Selection of the parameter(s) estimated*

CL infections ultimately lead to dieback, stunted growth and plant death. This is why only yield losses are assessed.

3.1.1.4. *Defined question(s)*

What is the percentage yield loss in citrus production under the scenario assumptions in the area of the EU under assessment for *Candidatus* Liberibacter, 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 main general point was made on the fact that disease severity is influenced by the climatic conditions.

3.1.1.6. *Uncertainties identified*

- Most of the available information refers to the incidence
- Most of the available information refers to CL asiaticus, but not much data is available on the other species CL africanus and CL americanus
- Most of the information available refers to *D. citri* but not to *T. erytreae*
- HLB and *D. citri* are present in California, but the disease is under eradication and quantitative information on yield losses is lacking

- No indications are available to establish a clear relationship between climatic conditions and level of impact
- Difficult to distinguish between environment and susceptibility effects
- Duration of the incubation and latency periods are not certain, particularly under Mediterranean conditions

3.1.2. Elicited values for yield losses on citrus

What is the percentage yield loss in citrus production under the scenario assumptions in the area of the EU under assessment for *Candidatus* Liberibacter, as defined in the Pest Report?

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

Table 2: The 5 elicited values on yield loss (%) on citrus

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	20%	50%	70%	80%	95%

3.1.2.1. *Justification for the elicited values for yield loss on citrus*

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

The upper value of 95% of yield loss was agreed based on the assumption that there is a latency period of 6 months. In the worst-case scenario, only one out of 20 orchards would still be productive after infection.

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

The lower value of 20 % was agreed considering that, even in the best case scenario, there is a latency period of around 1.5 year which still brings considerable losses.

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

The median value is quite high (80 %) because it considers the cumulative effect of the latency period and the fact that no replacement is usually made, therefore on a part of infected orchards, below a certain amount of infected plants, there is no removal of them.

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

The precision reflects the fact that there is more certainty around the higher values than to the lower estimates.

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 3: Fitted values of the uncertainty distribution on citrus

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	20%					50%		70%		80%					95%
Fitted distribution	17.7%	23.8%	29.9%	37.7%	45.0%	52.0%	57.8%	67.8%	76.7%	81.1%	85.7%	89.8%	93.5%	95.7%	97.6%

Fitted distribution: BetaGeneral (3.2128,1.6915,0,1), @RISK7.5

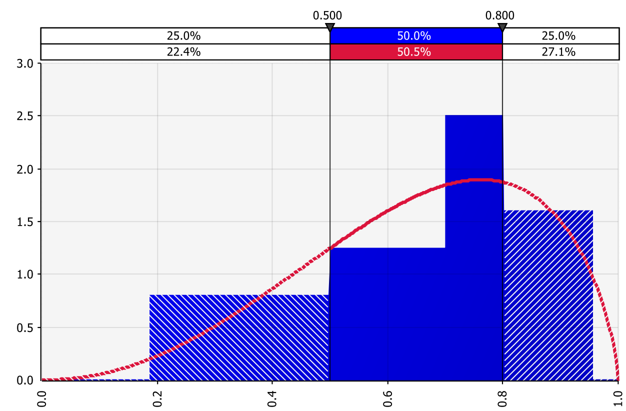

Figure 8 Comparison of judged values (histogram in blue) and fitted distribution (red line) for yield loss on citrus.

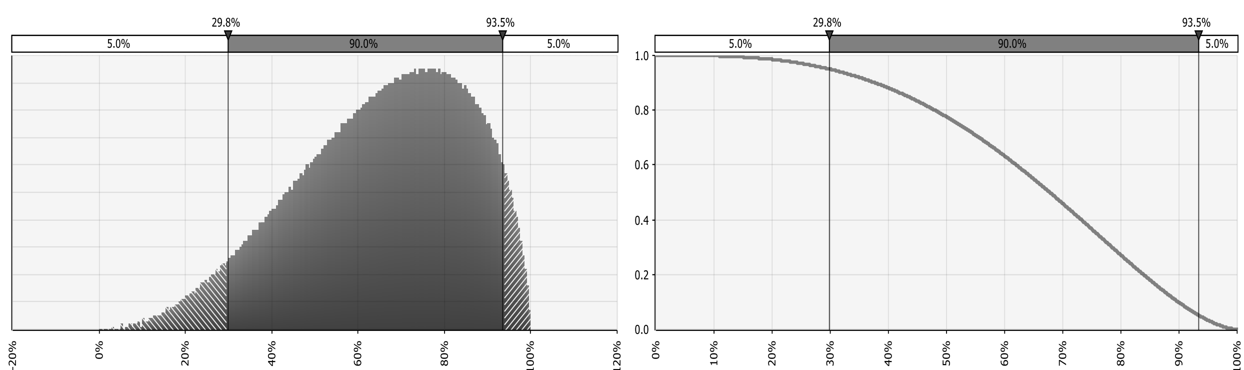

Figure 9 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for yield loss on citrus.

3.1.3. Conclusions on yield and quality losses

Based on the general and specific scenario considered in this assessment, the proportion (in %) of yield losses on citrus is estimated to be 67.8% (with a 95% uncertainty range of 23.8-95.7%).

Quality losses have not been included in the assessment because 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, 2019).

3.2.1.2. *Specific scenario assumptions*

- Vectors are present in the EU area of citrus production and their abundance and distribution do not represent a limiting factor to the pathogen spread
- The spread rate is assessed considering the disease transmission by the most efficient vector and its dispersal behavior

3.2.1.3. *Selection of the parameter(s) estimated*

The spread rate has been assessed as the number of kilometres 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: 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. A main general reference was identified in the data provided by Gottwald et al. (2007).

3.2.1.6. *Uncertainties identified*

- Extrapolation of behavior of *D. citri* under Mediterranean conditions. Limited information is provided, mainly from California, during the eradication campaign (with effects on spread of the disease)
- Disease spread not accurately assessed by visual inspection of symptoms, due to the long incubation period
- Accuracy of current detection methods when used for cryptic infections

- Climatic conditions, under which observations were collected, are not always comparable with 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 elicited values on spread rate on which the group agreed are reported in the table below.

Table 4: Summary of the 5 elicited values on spread rate (km/y)

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	1.0	12.0	20.0	30.0	40.0

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)

Gottwald et al. (2007) was mostly considered for this estimate. The paper indicates 20 Km/year as a spread rate based on the dispersal from the wind. However, a point was made that such paper only considers symptomatic plants, therefore the maximum dispersal rate should be increased for the consideration of non-symptomatic plants and also considering the human-mediated spread. A final value of 40 Km (40.000 m) was agreed.

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

A value of 1 Km (1.000 m) was agreed to be the minimum dispersal rate considering the vector spread (flies) occurring only once a year.

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

The median value of 20 Km was agreed based on the evidence provided by Gottwald et al. (2007) and the consideration that, while climatic conditions in Europe might be less favourable to dispersal, there is a need to consider the non-symptomatic plants. Therefore, the average obtained in Brazil can be considered valid for Europe as well.

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

The precision is based on the fact that there is no much uncertainty around the median. Therefore, 12 Km was indicated as 25th percentile and 30 Km for the 75th percentile.

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 5: Fitted values of the uncertainty distribution on the spread rate (km/y)

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	1.0					12.0		20.0		30.0					40.0
Fitted distribution	0.9	1.9	3.2	5.5	8.3	11.6	14.7	20.6	26.5	29.6	32.8	35.6	37.9	39.2	40.1

Fitted distribution: BetaGeneral (1.2811,1.2703,0,41), @RISK7.5

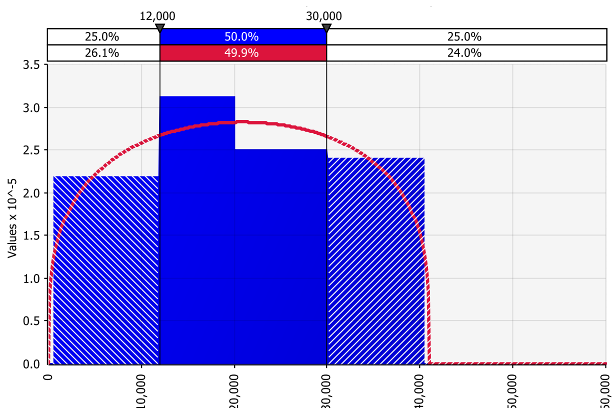

Figure 10 Comparison of judged values (histogram in blue) and fitted distribution (red line) for spread rate.

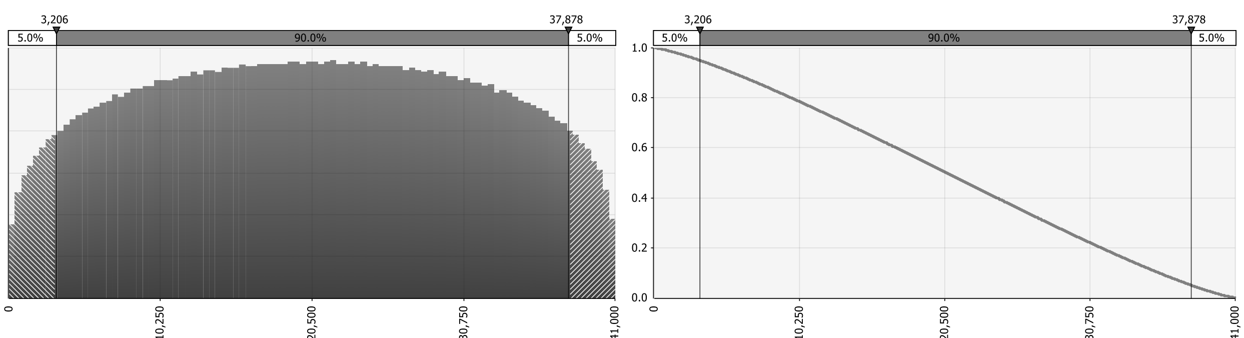

Figure 11 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for spread rate.

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 *C.* Liberibacter is 20 km (with a 95% uncertainty range of 2-39 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.2 in Appendix B) selecting the data and references used as the key evidence for the EKE on time to detection.

3.3.1.6. *Uncertainties identified*

- Duration of the incubation and latency periods, particularly under Mediterranean conditions
- Accuracy of current methods for pathogen detection uneven distribution of the bacteria in the plant, particularly in mature trees recently infected and asymptomatic
- Disease symptoms are unspecific and can be confused with other systemic diseases or nutrient deficiencies
- Initial outbreaks in California in residential areas with backyard trees, might be not subjected to formal surveys by trained inspectors
- Although the scenario indicates the vectors as present, there is the possible effect of an increase of awareness (with effect on detection probability) considering the risk of presence of HLB in the assessment area

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

Table 6: Summary of the 5 elicited values on time to detection (months)

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	9	18	24	36	72

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)

The upper value of 72 months was agreed by the elicitation experts based on the consideration that time to detection varies quite much in the various assessed literature findings, in overall ranging from 7 months to 13 years. A paper reporting a study carried out in California, reports 7 years to be the maximum time to detection. However, for this study plants imported from Asia were used and therefore it does not represent a natural condition. The experts agreed to decrease this maximum value to 6 years (72 months) to represent the natural conditions in Europe.

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

The lower value of 9 months needed for the first detection is based on the assumption that there is a good surveillance of the plants and, if the orchard is in a good condition, it is possible to observe the symptoms at an early stage. Three months would be enough for symptoms expression; however, the experts agreed that, also in the best-case scenario, it is not easy to observe the symptoms. They agreed a minimum of 9 months is needed in average for the shortest time to detection.

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

The median value of 24 months was agreed representing the sum of the incubation period (18 months) which are needed for a clear symptom expression plus 6 months needed to detect.

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

The precision reflects the fact that the time for lab confirmation is not included in the median period necessary for detection (24 months), so there is a need for 1 more year in order to confirm its presence, thus 36 months is the 75th percentile. More uncertainty exists toward the lower limit (18 months for the 25th percentile).

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 7: 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	9					18		24		36					72
Fitted distribution	7.6	9.2	10.8	13.0	15.2	17.6	19.9	24.8	30.9	34.9	40.5	47.5	57.1	67.0	80.7

Fitted distribution: Lognorm (28.211,15.269), @RISK7.5

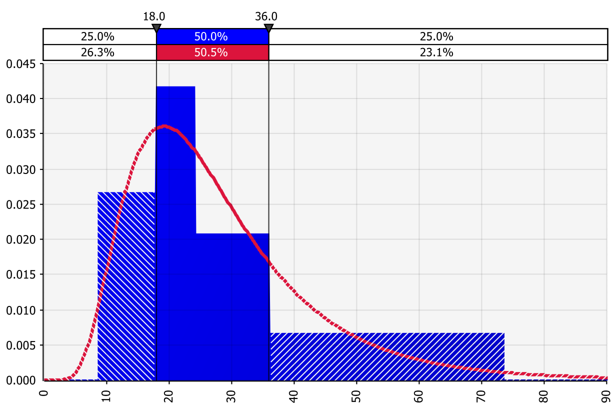

Figure 12 Comparison of judged values (histogram in blue) and fitted distribution (red line) for time to detection.

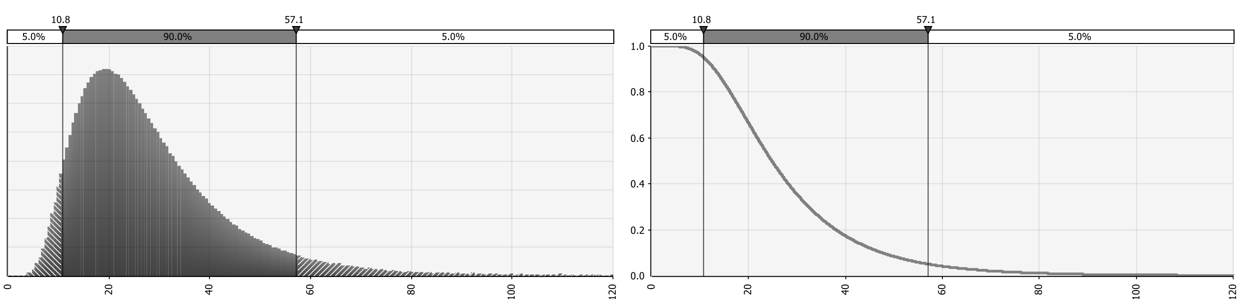

Figure 13 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for time to detection.

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 around 2 years (with a 95% uncertainty range of 9 months to 5.5 years).

4. Conclusions

Hosts selection

The impacts on all commercial citrus species and varieties were assessed together since they are assumed to have similar susceptibilities to *Candidatus* Liberibacter species.

Area of potential distribution

The area of potential distribution for *Candidatus* Liberibacter species is equivalent to the area of *Citrus* production in the EU.

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 effective in controlling *C.* Liberibacter and integrated strategies will need to be applied.

Yield and quality losses

Based on the general and specific scenario considered in this assessment, the proportion (in %) of yield losses on citrus is estimated to be 67.8% (with a 95% uncertainty range of 23.8-95.7%).

Quality losses have not been included in the assessment because 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 *C.* Liberibacter is 20 km (with a 95% uncertainty range of 2-39 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 around 2 years (with a 95% uncertainty range of 9 months to 5.5 years).

5. References

Albrecht U, McCollum G and Bowman KD, 2012. Influence of rootstock variety on Huanglongbing disease development in field-grown sweet orange (*Citrus sinensis* [L.] Osbeck) trees. Scientia Horticulturae, 138, 210-220. doi: 10.1016/j.scienta.2012.02.027

Albrecht U, Hall DG and Bowman KD, 2014. Transmission efficiency of *Candidatus* Liberibacter asiaticus and progression of Huanglongbing disease in Graftand psyllid-inoculated Citrus. HortScience, 49, 367–377.

Altamirano DM, Gonzales CI and Vifias RC, 1976. Analysis of the devastation of leaf-mottling (greening) disease of citrus and its control program in the Philippines. Conference Proceedings of the 7th International Organization of Citrus Virologists, California, p. 22 26.

Ammar ED, Ramos JE, Hall DG, Dawson WO, Shatters RG, 2016. Acquisition, replication and inoculation of *Candidatus* Liberibacter asiaticus following various acquisition periods on Huanglongbing- infected citrus by nymphs and adults of the Asian citrus psyllid. PLoS ONE, 11, e0159594. doi: 10.1371/journal.pone.0159594

Arakawa K and Miyamoto K, 2007. Flight ability of Asiatic citrus psyllid, *Diaphorina citri* Kuwayama (Homoptera; Psyllidae), measured by a flight mill. Research Bulletin of the Plant Protection Service of Japan, 43, 23–26.

Arredondo Valdés R, Delgado Ortiz JC, Beltrán Beache M, Anguiano Cabello J, Cerna Chávez E, Rodríguez Pagaza Y and Ochoa Fuentes YM, 2016. A review of techniques for detecting Huanglongbing (greening) in citrus. Canadian Journal of Microbiology, 62,, 803-811. doi: 10.1139/cjm-2016-0022

Aubert B, 1987. *Trioza erytreae* Del Guercio and *Diaphorina citri* Kuwayana (Homoptera: Psylloidea), the two vectors of Citrus greening disease: Biological aspects and possible control strategies. Fruits, 42, 149-162.

Aubert B, 2008. Historical perspectives of HLB in Asia. Proceedings of the International Research Conference on Huanglongbing, Orlando, Florida, p.14-22.

Aubert B and Xia YH, 1990. Monitoring flight activity of *Diaphorina citri* on citrus and Murraya canopies. In: Aubert B, Tontyaporn S and Buangsuwon D (eds.). Proceedings of the Fourth International Asia Pacific Conference on Citrus Rehabilitation, Chiang Mai, Thailandp. 181-187.

Aurambout JP, Finlay KJ, Luck J and Beattie GAC, 2009. A concept model to estimate the potential distribution of the Asiatic citrus psyllid (*Diaphorina citri* Kuwayama) in Australia under climate change—A means for assessing biosecurity risk. Ecological Modelling, 220, 2512-2524. doi: 10.1016/j.ecolmodel.2009.05.010

Bayles BR, Thomas SM, Simmons GS, Grafton-Cardwell EE and Daugherty MP, 2017. Spatiotemporal dynamics of the Southern California Asian citrus psyllid (*Diaphorina citri*) invasion. PLoS ONE, 12, e0173226. doi: 10.1371/journal.pone.0173226

Bassanezi RB, Montesino LH and Stuchi ES, 2009. Effects of huanglongbing on fruit quality of sweet orange cultivars in Brazil. European Journal of Plant Pathology, 125, 565-572. doi: 10.1007/s10658-009-9506-3

Bassanezi, R. B., Montesino, L. H., Gasparoto, M. C. G., Filho, A. B., and Amorim, L. 2011. Yield loss caused by huanglongbing in different sweet orange cultivars in São Paulo, Brazil. European Journal of Plant Pathology, 130, 577-586. doi: 10.1007/s10658-011-9779-1

Belasque J, Arruda JH, Chinelato GA and Pazolini K, 2017. Temporal and spatial HLB progress in citrus areas maintained under strict management are highly influenced by neighboring non-commercial citrus plants. Abstracts from the 5th International Research Conference on Huanglongbing. Journal of Citrus Pathology, 4, p. 4.

Berk Z, 2016. Diseases and pests. In: Citrus Fruit Processing. Ed. Academic Press, 83-93.

Bové JM, 2006. Huanglongbing: a destructive, newly-emerging, century-old disease of citrus. Journal of Plant Pathology, 88, 7–37.

Bové JM, Teixeira DC, Wulff NA, Eveillard S, Sailard C, Bassanezi RB, Lopes S, Yammamoto PT and Ayers AJ, 2008. Several Liberibacter and phytoplasma species are individually associated with HLB. In: Gottwald RT and Graham HJ (eds.). International Research Conference on Huanglongbing, Proceedings of the Meeting, Orlando, Florida, 152–155.

Buitendag CH and von Broembsen LA, 1993. Living with citrus greening in South Africa. Proceedings of the Twelfth Conference of the International Organization of Citrus Virologists (1957-2010), p. 269-273.

CABI (Centre for Agriculture and Bioscience International), 2019. Datasheet report for citrus huanglongbing (greening) disease (citrus greening). Crop Protection Compendium. Last modified 02 May 2019.

Canale MC, Tomaseto AF, Haddad ML, Della Coletta-Filho H and Spotti Lopes JR. 2017. Latency and Persistence of '*Candidatus* Liberibacter asiaticus' in Its Psyllid Vector, *Diaphorina citri* (Hemiptera: Liviidae). Phytopathology, 107, 264-272. doi: 10.1094/PHYTO-02-16-0088-R

Capoor SP, Rao DG and Viswanath SM, 1974. Greening disease of citrus in the Deccan Trap Country and its relationship with the vector, *Diaphorina citri* Kuwayama. Proceedings of the 6th Conference of the International Organization of Citrus Virologists, Berkeley, California, p. 43-49.

Catling HD, 1973. Notes on the biology of the South African citrus psylla *Trioza erytreae* (Del Guercio) (Homoptera: Psyllidae). Journal of the Entomological Society of South Africa, 36, 299–306.

Cen Y, Zhang L, Xia Y, Guo J, Deng X, Zhou W, Sequeira ., Gao J, Wang Z, Yue J and Gao Y, 2012. Detection of ’Candidatus Liberibacter asiaticus’ in *Cacopsylla* (*Psylla*) *citrisuga* (Hemiptera: Psyllidae). Florida Entomologist, 95, 304–311. doi: 10.1653/024.095.0210

Coletta-Filho HD, Carlos EF, Alves KCS, Pereira MAR, Boscariol-Camargo RL, de Souza AA, and Machado MA, 2010. In planta multiplication and graft transmission of '*Candidatus* Liberibacter asiaticus' revealed by Real-Time PCR. European Journal of Plant Pathology,126, 53-60. doi: 10.1007/s10658-009-9523-2

Da Graça JV, 1991. Citrus greening disease. Annual Review of Phytopathology, 29, 109–136.

Dala Paula B, Raithore S, Manthey J, Plotto A, Bai J, Gloria MB and Baldwin E, 2017. A deeper look into the causes of off-flavor in orange juice affected by huanglongbing (HLB). Abstracts from the 5th International Research Conference on Huanglongbing. Journal of Citrus Pathology, 4, 8-9.

Deng X, Zhou G, Li H and Civerolo EL, 2007. Nested PCR detection and sequence confirmation of *Candidatus* Liberibacter asiaticus from *Murraya paniculata* in Guangdong, China. Plant Disease, 91, 1051. doi: 10.1094/PDIS-91-8-1051C

Ding F, Paul C, Branskly R, Hartung JS, 2017. Immune tissue print and immune capture-PCR for diagnosis and detection of *Candidatus* Liberibacter asiaticus. Scientific Reports, 7, 46467. doi: 10.1038/srep46467

Donovan NJ, Beattie GAC, Chambers GA, Holford P, Englezou A, Hardy S, Dorjee, Wangdi P., Thinlay and Om N., 2012. First report of '*Candidatus* Liberibacter asiaticus' in *Diaphorina communis*. Australasian Plant Disease Notes, 7, 1–4. doi: 10.1007/s13314-011-0031-9

EFSA (European Food Safety Authority), Baker R, Gilioli G, Behring C, Candiani D, Gogin A, Kaluski T, Kinkar M, Mosbach-Schulz O, Neri FM, Siligato R, Stancanelli G and Tramontini S, 2019. Scientific report on the methodology applied by EFSA to provide a quantitative assessment of pest-related criteria required to rank candidate priority pests as defined by Regulation (EU) 2016/2031. EFSA Journal 2019;17(5):5731, 64 pp. https://doi.org/10.2903/j.efsa.2019.5731

EFSA PLH Panel (EFSA Panel on Plant Health), Bragard C, Dehnen-Schmutz K, Di Serio F, Gonthier P, Jacques M-A, Jaques Miret J A, Fejer Justesen A, MacLeod Alan, Magnusson Christer Sven, Milonas P, Navas-Cortes J A, Potting R, Reignault P L, Thulke H-H, Van der Werf W, Vicent Civera A, Yuen J, Zappalà L, Boscia D, Chapman D, Gilioli G, Krugner R, Mastin A, Simonetto A, Spotti Lopes J R, White S, Abrahantes J C, Delbianco A, Maiorano A, Mosbach-Schulz O, Stancanelli G, Guzzo M, and Parnell S, 2019b. Update of the Scientific Opinion on the risks to plant health posed by *Xylella fastidiosa* in the EU territory. EFSA Journal 2019;17(4):5665, 221 pp. doi: 10.2903/j.efsa.2019.5665

EPPO (European and Mediterranean Plant Protection Organization), 2014. Diagnostics - PM 7/121 (1) '*Candidatus* Liberibacter africanus', '*Candidatus* Liberibacter americanus' and '*Candidatus* Liberibacter asiaticus'. EPPO Bulletin, 44, 376-389. doi: 10.1111/epp.12161

EPPO (European and Mediterranean Plant Protection Organization), online. EPPO Global Database. Available online: https://www.eppo.int/ [Accessed: 20 May 2019]

Garnier M and Bové JM, 1993. Citrus greening disease. Proceeding of the 12th Conference of the International Organization of Citrus Virologists (IOCV). Riverside, California, p. 212-219

Garnier M and Bové JM, 1996. Distribution of the huanglongbing (greening) Liberobacter species in fifteen African and Asian countries. International Organization of Citrus Virologists Conference Proceedings, (1957-2010)Riverside, California, p. 388-391

Gonzalez Hernandez A, 2003. *Trioza erytreae* (Del Guercio 1918): nueva plaga de los citricos en Canarias. Phytoma, 153, 112-118.

Gottwald TR, 2010. Current epidemiological understanding of citrus huanglongbing. Annual Review of Phytopathology, 48, 119–139. doi: 10.1146/annurev-phyto-073009–114418

Gottwald TR, Aubert B and Xue-Yuan Z, 1989. Preliminary analysis of citrus greening (Huanglongbin) epidemics in the People's Republic of China and French Réunion Island. Phytopathology, 79, 687–693.

Gottwald TR, Aubert B and Long HK, 1991. Spatial pattern analysis of citrus greening in Shantou, China. International Organization of Citrus Virologists Conference Proceedings (1957-2010), Riverside, California, p. 421–427.

Gottwald TR, da Graça JV and Bassanezi RB, 2007. Citrus Huanglongbing: the pathogen and its impact. Plant Health Progress, 1-36. doi: 10.1094/PHP-2007-0906-01-RV.

Grafton-Cardwell EE, Stelinski LL and Stansly PA, 2013. Biology and management of Asian citrus psyllid, vector of the huanglongbing pathogens. Annual Review of Entomology, 58, 413-32. doi: 10.1146/annurev-ento-120811-153542

Green GC and Catling HD, 1971. Weather-induced mortality of the citrus psylla, *Trioza erytreae* (Del Guárico) (Homoptera: Psyllidae), a vector of greening virus, in some citrus producing areas of Southern Africa. Agricultural Meteorology, 8, 305–317.

Haapalainen M, 2014. Biology and epidemics of *Candidatus* Liberibacter species, psyllid-transmitted plant-pathogenic bacteria. Annals of Applied Biology, 165, 172–198. doi: 10.1111/aab.12149

Halbert SE and Manjunath KL, 2004. Asian citrus psyllids (Sternorrhyncha: Psyllidae) and greening disease of citrus: a literature review and assessment of risk in Florida. Florida Entomologist, 87, 330–353.

Hall DG and Hentz MG, 2011. Seasonal flight activity by the Asian citrus psyllid in east central Florida Entomologia Experimentalis et Applicata, 139, 75–85.

Hall DG, Hentz MG and Adair RC, 2008 Population ecology and phenology of *Diaphorina citri* in two Florida citrus groves. Environmental Entomology, 37, 914–924.

Hall DG, Wenninger EJ and Hentz MG, 2011. Temperature studies with the Asian citrus psyllid, *Diaphorina citri*: cold hardiness and temperature thresholds for oviposition. Journal of Insect Science, 11, 1-15.

Hall DG, Richardson ML, Ammar E and Halbert SE, 2012. Asian citrus psyllid, *Diaphorina citri*, vector of citrus huanglongbing disease. Entomologia Experimentalis et Applicata, 146, 207–223. doi: 10.1111/eea.12025

Hung TH, Hung SC, Chen CN, Hsu MH, and Su HJ, 2004. Detection by PCR of '*Candidatus* Liberibacter asiaticus', the bacterium causing citrus huanglongbing in vector psyllids: Application to the study of vector–pathogen relationships. Plant Pathology, 53, 96-102. doi: 10.1046/j.1365-3059.2003.00948.x

Hung TH, Wu ML, Su HJ, 2001. Identification of the Chinese box orange (*Severinia buxifolia*) as an alternative host of the bacterium causing citrus Huanglongbing. European Journal of Plant Pathology, 107, 183–9.

Jacobsen K, Stupiansky J and Pilyugin SS, 2013. Mathematical modeling of citrus groves infected by huanglongbing. Mathematical Biosciences and Engineering, 10, 705-728.

Keremane M, Ramadugu C, Rodriguez E, Kubota R, Shibata S, Hall D, Roose M, Jenkins D and Lee R, 2015. A rapid field detection system for citrus huanglongbing associated '*Candidatus* Liberibacter asiaticus' from the psyllid vector, *Diaphorina citri* Kuwayama and its implications in disease management. Crop Protection, 68, 41-48. doi: 10.1016/j.cropro.2014.10.026

Knapp JL, Halbert S, Lee R, Hoy M, Clark R and Kesinger M, 2006. The Asian citrus psyllid and citrus greening disease. Florida IPM (Integrated Pest Management). Available online: http://ipm.ifas.ufl.edu/Agricultural_IPM/asian.shtml [Accessed: 21 May 2019]

Lee JA, Halbert SE, Dawson WO, Robertson CJ, Keesling JE and Singer BH, 2015. Asymptomatic spread of huanglongbing and implications for disease control. Proceedings of the National Academy of Sciences of the United States of America, 112, 7605-7610. doi: 7610.1073/pnas.1508253112

Levesque C, Davis C, Fink R, Godfrey K, Jin H, Keremane M, Kunta MB, Leveau J, Ma W, McCollum G, McRoberts N, Morse J and Slupsky C, 2017. Comparative study of early detection techniques: TX2. Abstracts from the 5th International Research Conference on Huanglongbing. Journal of Citrus Pathology, 4, p 24.

Lewis-Rosenblum H, Martini X, Tiwari S and Stelinski LL, 2015. Seasonal movement patterns and long-range dispersal of Asian citrus psyllid in Florida citrus. Journal of Economic Entomology, 108, 3-10. doi: 10.1093/jee/tou008

Li W, Li D, Twieg E, Hartung JS and Levy L, 2008. Optimized quantification of unculturable *Candidatus* Liberibacter species in host plants using real-time PCR. Plant Disease, 92, 854–861. doi: 10.1094/PDIS-92-6-0854

Li W, Levy L and Hartung JS, 2009. Quantitative Distribution of '*Candidatus* Liberibacter asiaticus' in Citrus Plants with Citrus Huanglongbing. Phytopathology, 99, 139-144. doi: 10.1094/PHYTO-99-2-0139

Liu YH and Tsai JH, 2000. Effects of temperature and biology on life table parameters of the Asian citrus Psyllid, *Diaphorina citri* Kuwayama (Homoptera: Psyllidae). Annals of Applied Biology, 137, 201–206.

Lopes SA, Bertolini E, Frare GF, Martins EC, Wulff NA, Teixeira DC, Fernandes NG and Cambra M, 2009a. Graft transmission efficiencies and multiplication of '*Candidatus* Liberibacter americanus' and '*Candidatus* Liberibacter asiaticus' in citrus plant. Pytopathology, 99, 301–306.

Lopes SA, Frare GF, Bertolini E, Cambra M, Fernandes NG, Ayres AJ, Marin DR and Bové JM, 2009b. Liberibacters associated citrus Huanglongbing in Brazil: '*Candidatus* Liberibacter asiaticus' is heat tolerant, '*Candidatus* Liberibacter americanus' is heat sensitive. Plant Disease, 93, 257–262.

Martin KW, Hodges AC and Leppla NC, 2012a. Asian citrus psyllid. Citrus Pests. Available online: http://idtools.org/id/citrus/pests/factsheet.php?name=Asian+citrus+psyllid [Accessed 21 May 2019]

Martin KW, Hodges AC and Leppla NC, 2012b. African citrus psyllid. Citrus Pests. Available online: http://idtools.org/id/citrus/pests/factsheet.php?name=Asian+citrus+psyllid [Accessed 21 May 2019]

Massonie G, Garnier M and Bové JM, 1976. Transmission of Indian citrus greening by *Trioza erytreae* (Del Guercio), the vector of South African greening. Proceeding of the 7th Conference on International Organization of Citrus Virologists, p. 18-20.

McCollum TG, Hilf ME, Irey M, Weiqu L and Gottwald TR, 2016. Susceptibility of sixteen citrus genotypes to *Candidatus* Liberibacter asiaticus. Plant Disease, 100, 1080-1086. doi: 10.1094/PDIS-08-15-0940-RE

McFarland CD and Hoy MA, 2001. Survival of *Diaphorina citri* (Homoptera: Psyllidae), and its two parasitoids, *Tamarixia radiata* (Hymenoptera: Eulophidae) and *Diaphorencyrtus aligarhensis* (Hymenoptera: Encyrtidae), under different relative humidities and temperature regimes. Florida Entomologist, 84, 227-233.

Nava DE, Torres MLG, Rodrigues MDL, Bento JMS and Parra JRP, 2007. Biology of *Diaphorina citri* (Hem. Psyllidae) on different hosts and at different temperatures. Journal of Applied Entomology, 131, 709–715.

Nelson WR, Eveillard S, Dubrana MP and Bové JM, 2015. Cryptic haplotypes of "*Candidatus* Liberibacter africanus". Journal of Plant Pathology, 97, 291-295.

Paris TM, Allan SA, Hall DG, Hentz MG, Hetesy G and Stansly PA, 2016. Host plant affects morphometric variation of *Diaphorina citri* (Hemiptera: Liviidae). PeerJ, 4, e2663. doi: 10.7717/peerj.2663

Paris TM, Allan S, Hall D, Hentz M, Croxton S, Ainpudi N and Stansly P, 2017. Effects of temperature, photoperiod, and rainfall on morphometric variation of *Diaphorina citri* (Hemiptera: Liviidae). Environmental Entomology, 46,143–158.

Parry M, Gibson GJ, Parnell S, Gottwald TR, Irey MS, Gast TC and Gilligan CA, 2014. Bayesian inference for an emerging arboreal epidemic in the presence of control. Proceedings of the National Academy of Sciences of the United States of America, 111, 6258–6262. doi: 10.1073/pnas.1310997111

Pietersen G, Arrebola E, Breytenbach JHJ, Korsten L, le Roux HF, la Grange H, Lopes SA, Meyer JB, Pretorius MC, Schwerdtfeger M, van Vuuren SP and Yamamoto P, 2010. A survey for '*Candidatus* Liberibacter' species in South Africa confirms the presence of only 'Ca. L. africanus' in commercial citrus. Plant Disease, 94, 244–249.

Plant Biosecurity, 2010. Draft pest risk analysis report for '*Candidatus* Liberibacter species' and their vectors associated with Rutaceous hosts. Australian Government, Biosecurity Australia, Canberra, 228 pp.

Polek M, Vidalakis G and Godfrey K, 2007. Citrus Bacterial Canker Disease and Huanglongbing (Citrus Greening). University of California, Division of Agriculture and Natural Resources, Exotic and Invasive Pests and Diseases Research Program, 8218, 1-11

Pretorius MC and van Vuuren SP, 2006. Managing Huanglongbing (citrus greening disease) in the Western Cape. South African Fruit Journal, 5, 59 - 62.

Saponari M, De Bac G, Breithaupt J, Loconsole G, Yokomi RK and Catalano L, 2010. First report of '*Candidatus* Liberibacter asiaticus' associated with huanglongbing in sweet orange in Ethiopia. Plant Disease, 94, 482.

Schwarz RE and Green GC, 1972. Heat requirements for symptom suppression and inactivation of the greening pathogen. International Organization of Citrus Virologists Conference Proceedings (1957-2010), Riverside, California, p. 43-51.

Siverio F, Marco-Noales E, Bertolini E, Teresani GR, Peñalver J, Mansilla P, Aguín O, Pérez-Otero R, Abelleira A, Guerra-García JA, Hernández E, Cambra M and Milagros López M, 2017. Survey of huanglongbing associated with '*Candidatus* Liberibacter' species in Spain: analyses of citrus plants and Trioza erytreae. Phytopathologia Mediterranea, 56 98−110. doi: 10.14601/Phytopathol_Mediterr-18679

Teixeira DdC, Saillard C, Eveillard S, Danet JL, Ayres AJ and Bové JM, 2005. "*Candidatus* Liberibacter americanus", associated with citrus huanglongbing (greening disease) in São Paulo State, Brazil. International Journal of Systematic Evolution Microbiology, 55, 1857-1862. doi: 10.1099/ijs.0.63677-0

Tsai CH, Hung TH and Su HJ, 2008. Strain identification and distribution of citrus Huanglongbing bacteria in Taiwan. Botanical Studies, 49, 49–56.

USDA (United States Department of Agriculture), 2012. New Pest Response Guidelines – Citrus Greening Disease. USDA, 148 pp.

USDA (United States Department of Agriculture), 2016. Fact sheet – Huanglongbing (HLB). USDA. 2pp. Available online: https://nifa.usda.gov/resource/citrus-greening-huanglongbing-hlb

van den Berg MA, 1990. The citrus psylla, *Trioza erytreae* (Del Guárico) (Hemiptera: Triozidae): a review. Agriculture, Ecosystems and the Environment, 30, 171–194.

van den Berg MA and Deacon VE, 1988. Dispersal of the citrus psylla, *Trioza erytreae*, in the absence of its host plants. Phytophylactica, 20, 361-368.

van den Berg MA, van Vuuren SP and Deacon VE, 1991-1992. Studies on greening disease transmission by the citrus psylla, *Trioza erytreae* (Hemiptera: Triozidae). Israel Journal of Entomology, 25 - 26: 51 - 56.

van Vuuren SP, Moll JN and Wagner MJ, 1986. The dynamics of greening transmission. Proceedings of the Citrus and Subtropical Fruit Research Institute Symposium (CSFRI), Nelspruit, South Africa, p. 48

van Vuuren SP and Van der Merwe MJ, 1992. Efficacy of citrus psylla, *Trioza erytreae*, as a vector of citrus greening disease. Phytophylactica, 24, 285–288.

Wang N, Pierson E, Setubal JC, Xu J, Levy J, Zhang Y, Li J, Rangel LT and Martins Jr. J, 2017. The *Candidatus* Liberibacter – Host interface: insights into pathogenesis mechanisms and disease control. Annual Review of Phytopathology, 55, 451-482. doi: 10.1146/annurev-phyto-080516-035513

Yang Y, Huang M, Beattie A, Xia Y, Ouyang G and Xiong J, 2006. Distribution, biology, ecology and control of the psyllid *Diaphorina citri* Kuwayama, a major pest of citrus: a status report for China. International Journal of Pest Management, 52, 343-352. doi: 10.1080/09670870600872994

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
Atalantia	*buxifolia*
Catharanthus	*roseus*
Citrofortunella	*microcarpa*
Citroncirus	
Citrus	
Citrus	*aurantiifolia*
Citrus	*aurantium*
Citrus	*jambhiri*
Citrus	*latifolia*
Citrus	*limettioides*
Citrus	*limon*
Citrus	*limonia*
Citrus	*macroptera*
Citrus	*maxima*
Citrus	*medica*
Citrus	*nobilis*
Citrus	*paradisi*
Citrus	*reticulata*
Citrus	*sinensis*
Citrus	*tangelo*
Clausena	*indica*
Clausena	*lansium*
Cleome	*rutidosperma*
Fortunella	
Limonia	*acidissima*
Murraya	*paniculata*
Pisonia	*aculeata*
Poncirus	*trifoliata*
Rutaceae	
Trichostigma	*octandrum*
Triphasia	*trifolia*

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
	Incidence	***Severity***	***Losses***		
Mandarin			Area 1961: 19,330 ha 1965: 12,010 ha (-38%) 1970: 7,080 ha (-63%) 1974: 4,840 ha (-75%)	Entire Philippines production. According to authors the main cause was CL	Altamirano et al., 1976
Sweet orange			1962: 5,750 ha 1965: 5,330 ha (-7%) 1970: 4,600 ha (-20%) 1974: 3,470 ha (-40%)	Entire Philippines production. According to authors the main cause was CL	Altamirano et al., 1976
Pummelo			1962: 6,910 ha 1965: 5,720 ha (-17%) 1970: 5,220 ha (-24%) 1974: 4,200 ha (-39%)	Entire Philippines production. According to authors the main cause was CL	Altamirano et al., 1976
Citrus			CL spp. destroy citrus orchards within 5–8 years where they occur		Gottwald et al., 1989
Citrus	Estimated 4/11 million trees infected		production was virtually eliminated in three major citrus areas	South Africa, mid 1970s	Buitendag and von Broembsen, 1993
Citrus	6/22 adult psyllids sampled from a tree were infected (max psyllid infection rate of 27%)			Brazil, CL americanus However, samples were lots of 10 psyllids and thus the actual infection rate is	Teixeira et al., 2005

				probably lower than 27%	
Citrus			Crop losses of 30–100% have been reported	some production regions of South Africa, between 1932 to 1960	Pretorius and Van Vuuren, 2006
Citrus	Disease incidence: 2 years after plantation (yap): 0.4-20% 3 yap: 26-40% 4 yap: 24% 5 yap: 70% A similar block had an increase from 6% to 27.4% in 9–10 months			São Paulo Brazil orchard surrounded by heavily infected adult trees	Gottwald et al., 2007
Citrus	From 0.2% to 39% incidence in 10 months			Commercial planting in South Florida	Gottwald et al., 2007
Citrus	incidence > 95% in 3–13 years after the first symptoms occur			Fast disease progression	Gottwald et al., 2007
Citrus		Symptoms are more pronounced in somewhat moist, cool conditions and at high elevations.		CL africanus	Schwarz and Green, 1972; Polek et al., 2007
Citrus	the increasing incidence of CL asiaticus suggests the CL americanus is not a good competitor			CL americanus and CL asiaticus at the same location in two orchards of São Paulo State, Brazil	Lopes et al., 2009a and b
8 months-old Valencia sweet orange (*C. sinensis*)	Bacterial population 10^3 CN at 30 dpi 10^8 CN at 240 dpi (10,000 times)	10^5 CN g^{-1} → yellowed leaves or shoots 10^7 CN g^{-1} after 180 dpi → blotchy mottle		Brazil, plants grafted on Rangpur lime (*C. limonia*) rootstock	Coletta-Filho et al., 2010

Citrus	Disease can reach more than 50% incidence in 3-5 years, whereas in older groves the disease will not reach such high incidence. 3 years after planting, incidence was - 0.96 without any insecticide - 0.74 with conventional insecticides - 0.24 with monthly trunk applications of systemic insecticide	Severe symptoms in trees have been observed 1-5 years after onset of the first symptoms, depending on the age of the tree at the time of infection, but also on the number of infections per tree, which are often multiple.	Younger orchards will express symptoms within 6-12 months after planting, indicating that young, rapidly growing trees, much smaller in canopy volume, have a shorter incubation period. Observations of trees over 10 years of age indicate even slower symptom development.	Excellent paper with relevant information to consider in risk assessment (see table 1 with indicated terminal incidence in different regions according to planting years.	Gottwald, 2010
Citrus		Relationship of the relative yield with HLB severity described by a negative exponential model		Brazil Disease severity and yield were assessed on 949 trees distributed in 11 different blocks from sweet orange cultivars Hamlin, Westin, Pera and Valencia	Bassanezi et al., 2011
Citrus		100%	Up to 19%		Bassanezi et al., 2011
16 citrus scion types	70% after 45 days			Plants in greenhouse exposed to *D. citri*	McCollum et al., 2016
Citrus			Before 2004: 80 million trees on 748,555 acres (302,929 ha) 2013: 60 million trees on 524,640 acres (212,314 ha) = 30% losses	Florida	USDA, 2016
Grapefruit			From 14 to 5 million trees	Florida	USDA, 2016

Sweet orange	<4.0-80% cumulative disease incidence 7.1-25.9% incidence/farm, in spite of similar disease management with high spatial heterogeneity and high concentration of affected trees in some plots located in the borders. In the majority of plots, especially those presenting higher disease incidences, >95% of HLB-trees occurred up to 200 metres from their borders		~260 plots from 5 farms (2. 5 million trees), under strict management (≥4 HLB-tree removal/year and ≥12 insecticide sprays/year)	São Paulo state, Brazil	Belasque et al., 2017

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

Spread	Additional information	Reference
Fly distances of at least 1.5 km	*T. erytreae*	Van den Berg and Deacon, 1988
3-5 m	Adult *D. citri* fly from one tree to the other	Aubert and Xia, 1990
Vertical flight at 7 m followed by wind assisted dispersal of 0.5–1 km	*D. citri*	Aubert and Xia, 1990
25–30 m	Adults of *D. citri* when disturbed	Gottwald et al., 1991
> 10 km on seasonal trade winds or hurricanes	It is believed that *T. erytreae* was introduced from Madeira into the Canary island by the dominant North-South trade winds	Bové, 2006 citing Gonzales Hernandez, 2003
12 miles (19.3 km) per year	*D. citri* Estimation from the presumed point of introduction to the advancing edge of the epidemic. The most frequent spatial relationship of 1.58 km may well indicate a common or average distance for psyllid dispersal of HLB regionally	Gottwald et al., 2007
There is some evidence for occasional adult mass migrations	*D. citri*	Hall et al., 2008
	dynamic point model, spatialised over the Australian landscape, for understanding the interactions between *D. citri* and its Valencia orange host and their responses to increasing temperatures	Aurambout et al., 2009
Fly distances of 8–60 m	*D. citri*	Hall and Hentz, 2011
The longest continuous flight distance: 978 m for females and 1241 m for males	*D. citri* using a flight mill	Arakawa and Miyamoto, 2007
	Model analysing how the numbers in each class (i susceptible; ii, infected but not symptomatic; iii infected and symptomatic; iv dead) change over time due to bacterial transmission between trees and psyllids	Jacobsen et al., 2013

	Spatially explicit disease model determining the transmission process among trees (which are either Susceptible, Exposed, Infectious, Detected or Removed) considering the effect of psyllid management, host age. Integration of the model with biological data	Parry et al., 2014
	Model describing how the pattern of HLB spread in a grove depends upon the location within the grove that psyllids initially invade. Integration of the model with biological data	Lee et al., 2015
> 2 km/12 days.	*D. citri* Japan in the absence of severe weather events, wind direction was not correlated with the number of marked psyllids captured	Lewis-Rosenblum, 2015
	From 2009 (first detection in Tenerife) to 2015, *Trioza erythreae* colonized all the 7 islands of archipelago	Siverio et al., 2017
Systemic infection: 2-3 cm/day	The direction is that of phloem sap: from sources (leaves) to sinks (roots, tubers, flushes, fruit)	Wang et al., 2017

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

Category of factors	**Case**	**Effect**	**Additional information**	**Reference**
Detection methods		Bacterium detected in the fruits even if the population levels were 1000-fold higher in the midribs, leaf blades, bark and roots.	CL asiaticus	Li et al., 2009
		-Incomplete distribution of the bacterium in the tree, could produce false negative -Visual detection inadequate due to long incubation period		Gottwald, 2010
		CL africanus and CL americanus are more similar for symptoms severity and temperature tolerance therefore the two species can be easily confused if identification is only visual		Pietersen et al., 2010
		Generally, the bacterium is detected only in symptomatic fruits.		Plant Biosecurity, 2010
		Difficult to consistently detect the pest through the use of biological assays, the presence of fluorescent substances, light or electron microscopy, or ELISA, presumably because of the low concentration and uneven distribution of the pathogen in hosts and vectors		USDA, 2012
		LAMP is 100 times more sensitive than traditional real time PCR	30 min for 6 samples	Keremane et al., 2015
		Detection techniques comparison		Arredondo Valdés et al., 2016

		Adults of *D. citri* poorly detected by shoot evaluation conducted 2 to 5 times/month in 1% of trees in each plot. Higher frequency in the most HLB-affected plots where yellow stick cards were used	Sweet orange	Belasque et al., 2017
		When asymptomatic citrus tissues were tested, the tissue printing method gave a higher rate of detection (83%) than the qPCR method (64%)		Ding et al., 2017
		Leaf microbiome profiling and metabolomics are superior to qPCR both for tree diagnoses and individual samples		Levesque et al., 2017
Biology of pest and vectors	Vectors life cycle	The duration of the psyllid lifecycle from egg to adult is 15-47 days depending upon food supply and ambient temperature	*D. citri*	Knapp et al., 2006
		Adults are known to survive 8–9 months over winter on suitable hosts	*D. citri*	Yang et al., 2006
	Vectors reproduction	217-1305 eggs by a mated female under insectary conditions	*T. erytreae*	Catling, 1973
		748 eggs laid at 28°C	*D citri*	Liu and Tsai, 2000
		Extremely fertile vectors: each female lays 1000-2000 eggs in matter of three weeks		Aubert, 2008
	Vectors behaviour	Adults of *D. citri* survive up to 52.5 (at 30 °C) – 94.5 (at 25 °C) h without feeding if suitable foliage is not available	*D. citri*	McFarland and Hoy, 2001
		T. erytreae nymphs are embedded in pits or nests on the underside of the leaves which look like bumps on the upper side. The bump remains after the adult emergence, therefore the presence of even one single bump on one single leaf is proof of *T. erytreae* occurrence. Such bumps are not produced by *D. citri*		Bové, 2006
		Spatial and temporal distribution of *D. citri* in Southern California is non-random: statistically significant hotspots of *D. citri* occurrence identified		Bayles et al., 2017
	Transmission capacity	Adults can acquire the pathogen within 24 h of feeding and after a latent period of an additional 24 h can transmit the disease	*T. erytreae*	van Vuuren et al., 1986
		Latent period of 3–4 days if acquisition feeding for 1-4 h no latent period if acquisition feeding for 8-24 hours high transmission rates (23%: the best transmission efficiency observed in literature according to Haapalainen, 2014) within 7 days after a one-day acquisition feeding	*T. erytreae* adults	van Vuuren and van der Merwe 1992
		30 min feeding for acquisition, 1-21 days of latent period	*D. citri*	Halbert and Manjunath, 2004
		Psyllids can carry CL asiaticus in either adult or nymphal stages, except in the first instar. The pathogen persists in the adult's body but CL is not transovarially transmitted to the offspring.	*D. citri*	Hung et al., 2004
		In the absence of control measures, known vectors have been recorded to spread the pathogen to 100% of trees in five years		Bové, 2006
		CL africanus can multiply and survive in the salivary glands of its psyllid vectors for as long as the vector is alive		Gottwald et al., 2007

		Higher titres increase the chances for pathogen acquisition and transmission by the insect vector		Lopes et al., 2009b
		Transmission frequency to sweet orange: - < 38% 6 to 12 months by controlled psyllid inoculation - 50% in 1 year and 100% in min 3 years by natural inoculation in field conditions	*D. citri*	Albrecht et al., 2014
		CL acquisition by *D. citri* was positively associated with plant infection level and time since inoculation. Psyllids can acquire CL during the asymptomatic phase	*D. citri* on sweet orange plants graft inoculated with CL asiaticus	Coletta-Filho et al., 2014
		CL is a circulative and persistent pathogen In the specific population studied by the authors nymphs resulted much more efficient vectors than adults	*D. citri*	Ammar et al., 2016
		-Young flush become infectious within 15 days after receiving an inoculum of CL asiaticus - Psyllid introduction scenarios to show that entire groves can become infected with up to 12,000 psyllids per tree in less than 1 y, before most of the trees show any symptoms		Lee et al., 2015
		Psyllids transmitted for up to 5 weeks, when submitted to sequential 1-week inoculation access periods IAPs after a 14-day acquisition access period AAP as nymphs. A median latent period (LP50, i.e., acquisition time after which 50% of the individuals can inoculate) of 16.8 and 17.8 days for psyllids that acquired Las as nymphs and adults		Canale et al., 2017
	Symptoms expression	Disease progression can be quite fast: after the first symptoms occur, incidence can reach more than 95% in 3–13 years		Gottwald et al., 2007
		Symptom development may be delayed for several months, or as long as 2–3 years after initial infection		Gottwald et al., 2007
		Symptomless leaves are either healthy, and will never give positive PCR reactions, or they are already infected, but the CL titer is still too low to be detected by the PCR methods available. Therefore, CL cannot be detected in symptomless leaves, even though its detection in mottled leaves is straightforward		Bové, 2006
		budwood sourced from asymptomatic trees could present low concentrations of the bacterium		Li et al., 2009
		Plant infection levels increased rapidly over time, saturating at uniformly high levels near 200 days after inoculation	*D. citri* on sweet orange plants graft inoculated with CL asiaticus	Coletta-Filho et al., 2014
		A newly infected flush can become infectious within 15 days, after transmission. Transmission does not require symptoms expression: infected adult psyllids can transmit the pathogen to the next generation via nymphs feeding on infectious flush	CL asiaticus and *D. citri*	Lee et al., 2015

	Differences among subspecies	CL americanus is unable to multiply efficiently in citrus plants		Lopes and Frare, 2008
		CL americanus titres in hosts are much lower than CL asiaticus titres. This may result in lower vector acquisition and transmission rates		Lopes and et al., 2009a
		'CL americanus' is less heat tolerant than 'CL asiaticus		Lopes et al., 2009b
Hosts		non-commercial trees are very effective sources of HLB, even when represented by a few plants.		Belasque et al., 2017