Grapevine Flavescence dorée Pest Report to support ranking of EU candidate priority pests

EFSA (European Food Safety Authority),

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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, 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 Flavescence dorée phytoplasma, the following documents were used as key references: Chuche and Thiéry (2014), EFSA risk assessment (2016), EPPO diagnostic protocol (2016).

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

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

2. The biology, ecology and distribution of the pest

2.1. Summary of the biology and taxonomy

The Flavescence dorée phytoplasma (FDp) belongs to the genus '*Candidatus* Phytoplasma', comprising pleiomorphic non-culturable bacteria with no cell walls. The species name is not yet defined according to requirements proposed by the subcommittee for the taxonomy of Mollicutes (Malembic-Maher et al., 2011), nevertheless, FDp can be considered a sufficiently clearly defined organism (EFSA PLH Panel, 2014).

FDp is the causal agent of grapevine yellows diseases, affecting from few to all branches and inducing: stunting or lack of bud break, yellowish/reddish colouring and downwards curling of leaves, drying and death of inflorescences and berries, lack of lignification, presence of black spots on the new canes and premature leaf fall. Consequences range from total yield loss to a decrease in grape quality; infected plants remain less productive even if they recover (EFSA PLH Panel, 2014).

FDp is a phloem obligate parasite that is vector-transmitted, surviving during winter in roots and canes and moving to the upper part of the plant during spring (EPPO, 1996). *Scaphoideus titanus* Ball (Cicadellidae, Deltocephalinae) is an ampelophagous (mainly feeding on *V. vinifera* in Europe) monovoltine leafhopper and the only FDp vector observed in natural conditions.

The vector remains infectious for life (including moulting) therefore being able to infect a plant whenever feeding or probing from early June to late September (EFSA PLH Panel, 2014). The earlier the nymph acquires FDp, the longer the time frame the vector has for spreading the pathogen. The males are more efficient than females in transmitting the disease (Chuche and Thiéry, 2014). There is only a little evidence of FDp adult-to-egg transmission, but the evidence is conflicting and considered to be an exception. For example, Bressan et al. (2005) demonstrated no adult-to-egg transmission in 72 leafhoppers individually tested by PCR for the presence of FDp.

Chilling enhances the precocity and synchrony of hatchings, usually occurring from May onward; adults appear during the first half of July until the beginning of September. Females lay eggs from August through September inside the excoriated bark of woody vines where they overwinter. It is important to mention that the minimal age of host plants is 2 years before the bark may be considered a suitable recipient for the eggs (Bagnoli and Gargani, 2011).

Other leafhoppers and planthoppers have been shown to be capable of harbouring or transmitting FDp, but for various reasons they are not considered to pose a threat (EFSA PLH Panel, 2014). Transmission is also possible through grafting.

2.2. Host plants

2.2.1. List of hosts

According to EFSA PLH Panel (2016), suitable uncultivated perennial plant hosts, such as wild *Vitis* spp., *Alnus* spp., *Ailanthus altissima* and *Clematis vitalba*, are widespread in the EU. *Alnus* spp. and *Ailanthus* are all largely symptomless carriers of FDp, whereas the infected Clematises express symptoms more often.

V. vinifera cultivars are the main FDp hosts, in addition to other *Vitis* species such as *V. riparia*, *V. labrusca*, *V. longii*, *V. simpsonii*, *V. doaniana*, *V. champinii*, *V. armurensis*, *V. rubra*, *V. rupestris*, *V. pentagona*, *V. sylvestris* and interspecific hybrids used as rootstocks (EFSA PLH Panel, 2014; EPPO, 1996).

Eveillard et al. (2016) observed differences in the level of susceptibility among 28 different *V. vinifera* cultivars, and classified them in three groups: (1) accessions with high FDp titers and a high proportion of infected plants, (2) accessions with intermediate FDp titers and a high proportion of infected plants, and (3) accessions with intermediate to low FDp titers and a low proportion of infected plants. Interestingly, 12 wild *Vitis* species were distributed among the three categories, demonstrating that even wild rootstocks may be highly influenced by FDp in their natural environment. The efficiency of transmission and FDp titers may not to be linked but dependent on different plant traits; alternatively, FDp titers are closely linked with symptom severity (Eveillard et al., 2016).

Grapevine is deciduous in temperate climates whereas it bears leaves all year round in tropical environments. An average spring temperature of 10 °C marks the beginning of the vegetative period that ends when leaves fall in autumn. Grapevines may survive in arid environments (<200 mm rainfall/year) and low winter temperatures (<-20 °C). Optimal growing temperature is 25 °C, the minimum thermal requirement being 18 °C. Mediterranean countries are therefore the most suitable regions where grapevines may develop (CABI, 2018). Harvest begins at the end of August until the end of October in the Northern hemisphere, depending on the cultivar and the local climate.

Appendix A provides the full list of hosts.

2.2.2. Selection of hosts for the evaluation

EU produced 23.7 million tonnes of grapes in 2016, the leading countries being Italy (30.4%), France (26.1%) and Spain (24.5%), followed by Germany (5.2 %), Portugal (3.3 %), Romania (2.9 %), Greece (2.3 %), Hungary (1.8 %), and Austria (1.1 %). Bulgaria, Croatia and Slovenia are also grape producers.

2.2.3. Conclusions on the hosts selected for the evaluation

Only the impacts on *Vitis vinifera* were assessed since this is the commercial crop. Despite some differences in susceptibility, wine and table grape cultivars were evaluated together.

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. FDp occurs only in Europe. It is unevenly distributed in eight of the main grape-growing EU countries (Austria, Croatia, France, Hungary, Italy, Portugal, Slovenia and Spain) as well as in Switzerland and in Serbia.
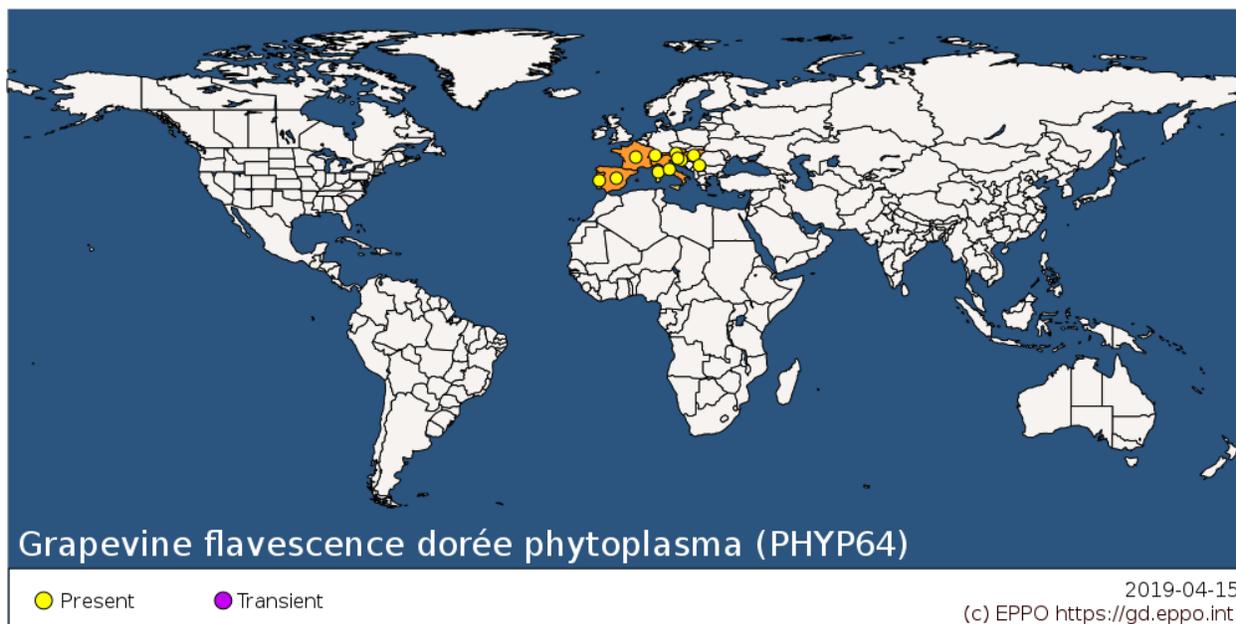
Figure 1 Distribution map of Flavescence dorée phytoplasma from the EPPO Global Database accessed 15/04/2019.

Figure 2 provides an overview of the current area of distribution of the vector, the Northern American leafhopper *S. titanus*. This leafhopper was first observed in France in 1958 and it is strictly associated with *Vitis* spp. (*V. vinifera*, *V. labrusca* and *V. riparia*), requiring grapevine for oviposition and completion of the life cycle.

The vector has so far spread to 12 EU Member States (Austria, Bulgaria, Croatia, Czech Republic, France, Hungary, Italy, Portugal, Spain, Romania, Slovenia and Slovakia) in addition to Bosnia Herzegovina, Moldova, Montenegro, Switzerland, Serbia and Ukraine. Therefore, the distribution area of the vector is larger than that recorded for the pest (EFSA PLH Panel, 2016).
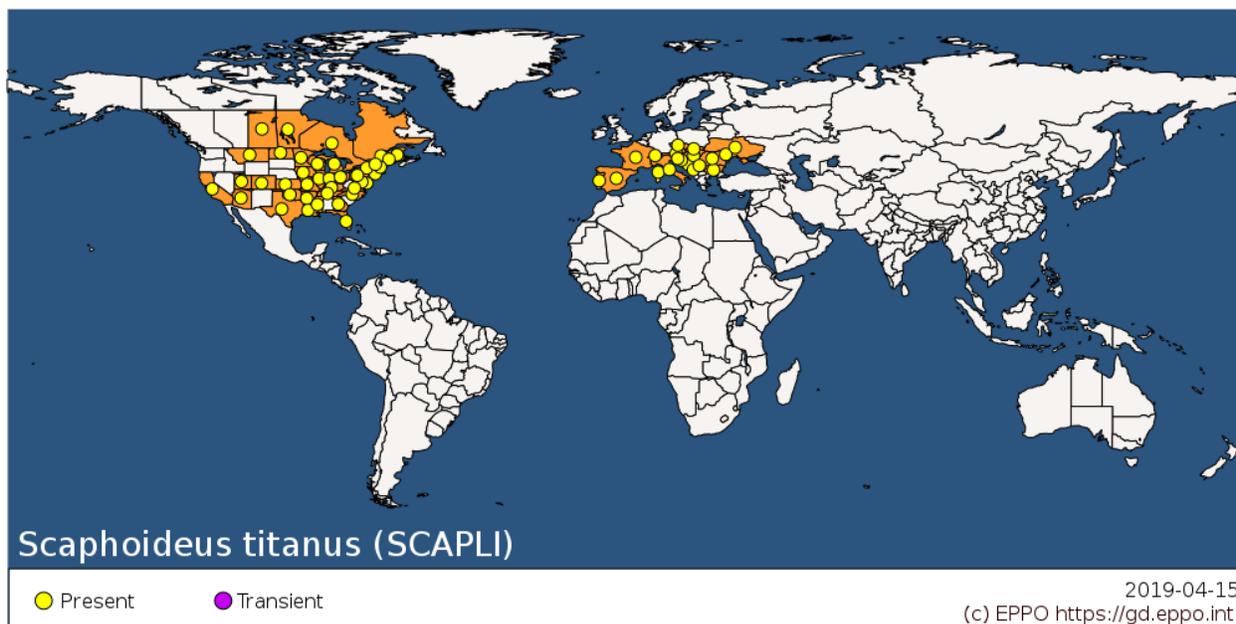
Figure 2 Distribution map of *Scaphoideus titanus* from the EPPO Global Database accessed 15/04/2019.

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2.3.2. Area of potential establishment

Figures 3-6 were used to determine the area of potential establishment. Figure 3 provides the distribution of grapevine cultivation, Figure 4 combines this with the distribution of FDp infection and the vector and Figure 5 shows the distribution of protected zones. The CLIMEX model (ACRP, 2013; EFSA PLH Panel, 2016) (Fig. 6) shows that the establishment potential of *S. titanus* is wider than the current growing area of grapevines in Europe. Its potential distribution in northern Europe is therefore limited by the absence of the host itself, rather than the climate. In southern areas dry weather conditions limit vector spread, but prolonged warmer summers generally favour vector establishment. It is expected that climate change will promote the spread and establishment of the vector in the northern hemisphere. FDp grows faster at 25-26 °C rather than 20-22 °C (EFSA PLH Panel, 2014), but the pathogen is expected to infect grapevines wherever they grow. The latency period between phytoplasma acquisition by *S. titanus* and transmission on new host plants is also temperature dependent.

In conclusion, the major factor limiting the distribution of the vector *S. titanus* is the distribution of the host plant *V. vinifera*.
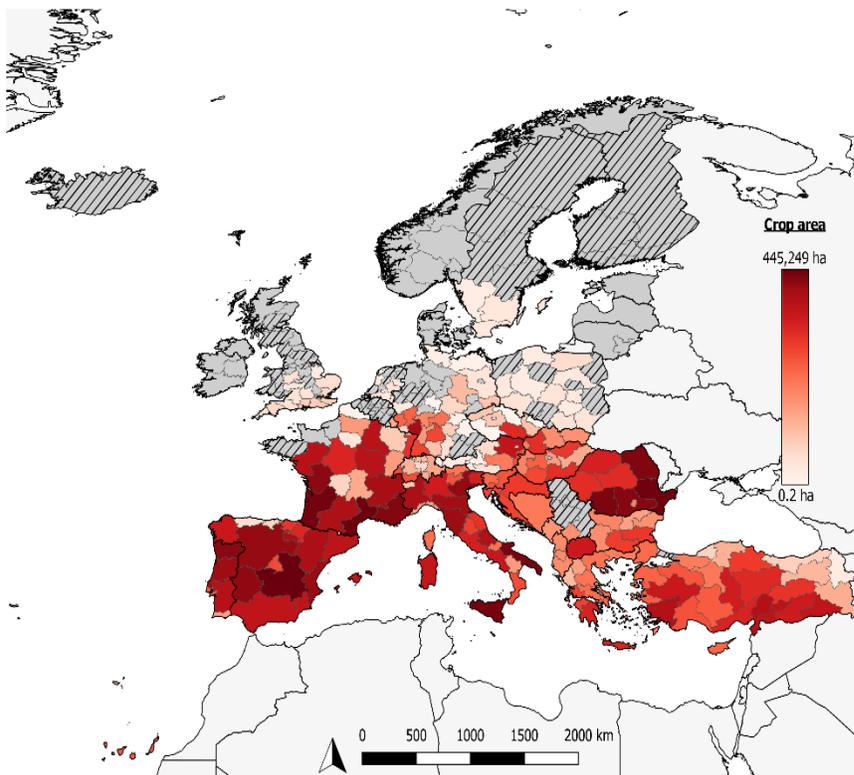
Figure 3 Grapevine growing areas in ha per NUTS 2 regions. Areas with diagonal lines indicate zero values or absence of data (figure copied from EFSA PLH Panel, 2019).
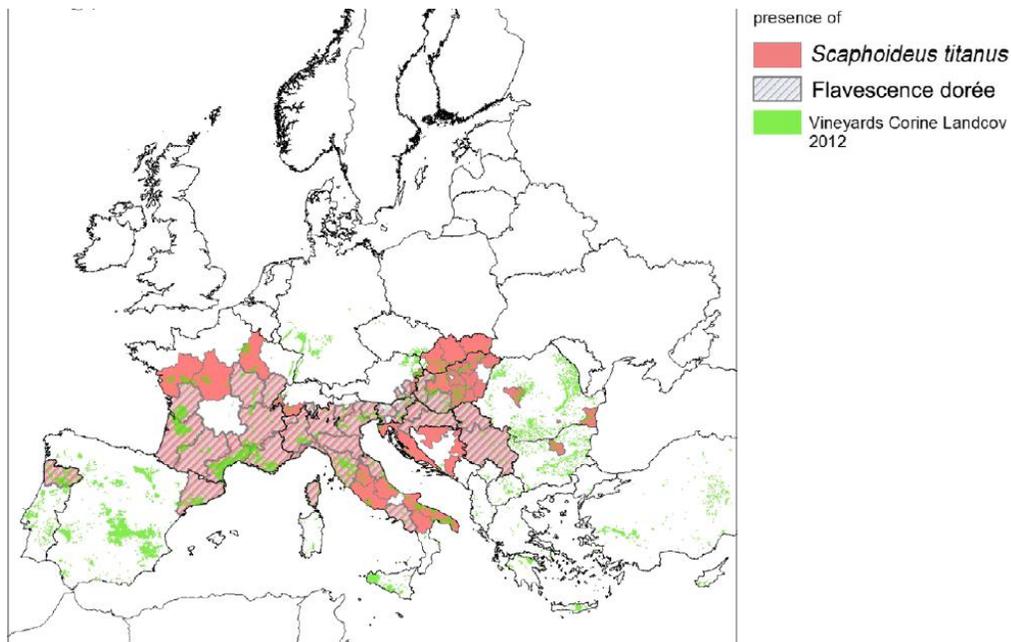
Figure 4 Observed distributions of grapevine cultivation (CLC, 2012), of FDp infection in grapevine (at NUTS2 level), and of *Scaphoideus titanus* in Europe (at NUTS2 level) in 2014 (figure copied from EFSA PLH Panel, 2016).
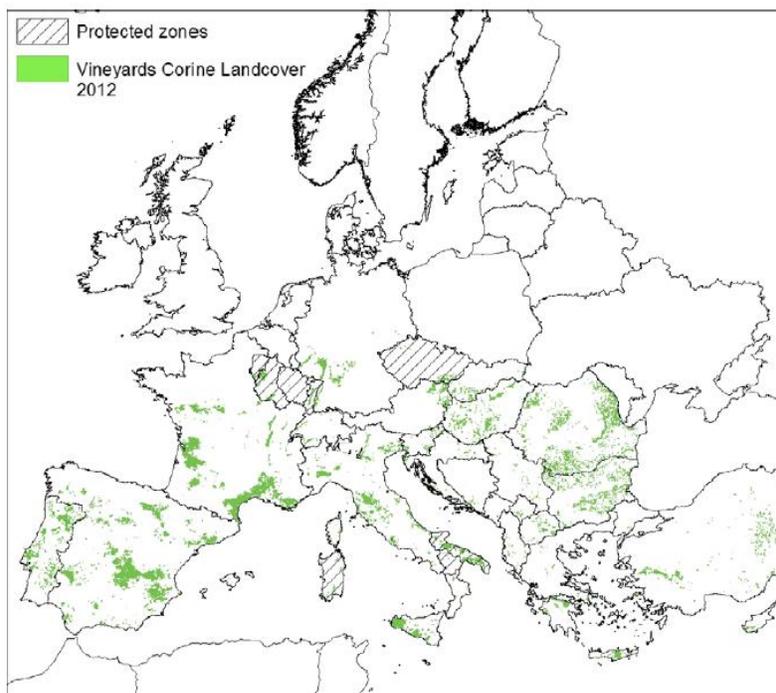
Figure 5 FDp protected zones (PZs): the Czech Republic, France (Alsace, Champagne-Ardenne, Picardie (Departement de l'Aisne), and Lorraine) and Italy (Apulia, Basilicata and Sardinia). In addition, the communes of Citry, Nanteuil-sur-Marne and Saâcy-sur-Marne of Ile de France have the status of PZs (not shown on the map because of scale constraints) (figure copied from EFSA PLH Panel, 2016).
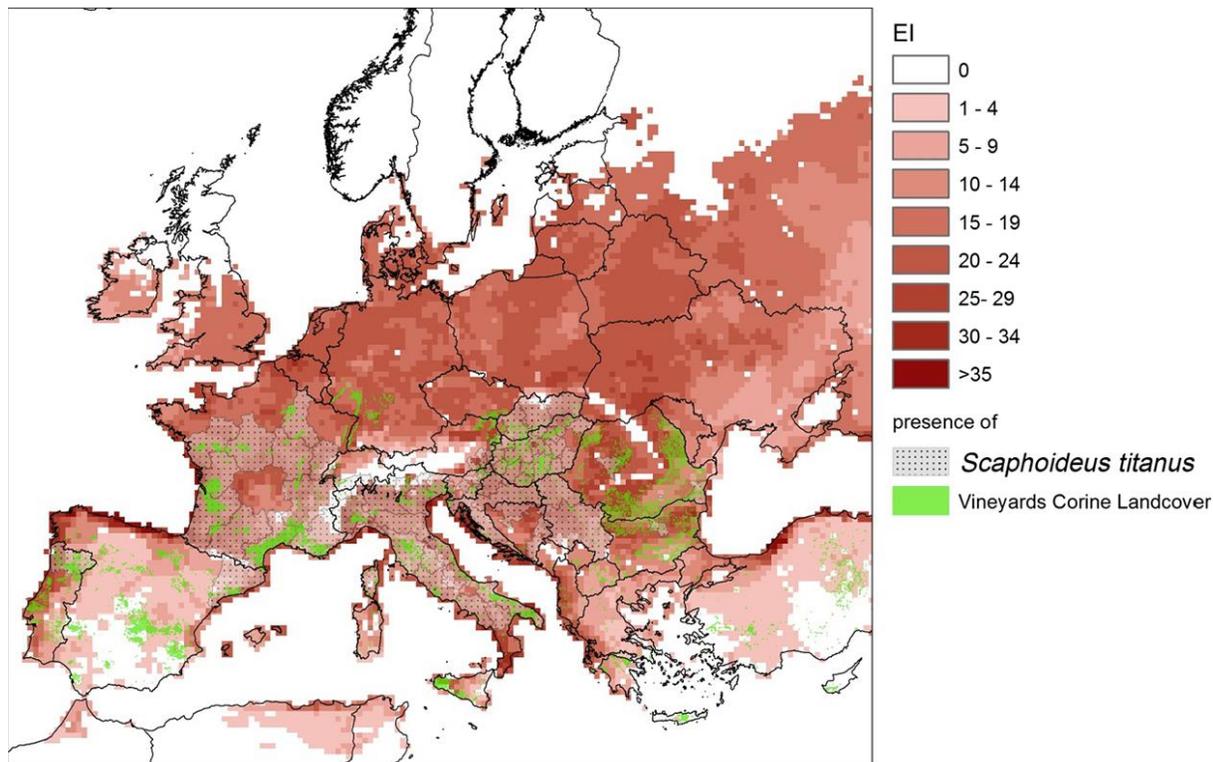
Figure 6 Predicted suitability for establishment of *Scaphoideus titanus* in Europe based on climate data 1999– 2010 (JRC) modelled with the CLIMEX model (ACRP, 2013) combined with the vine-growing areas in Europe (based on the map in EFSA PLH Panel, 2016).

2.3.3. Transient populations

FDp 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 is based on the area of *Vitis* production (wine and table grapes) in the EU, because the bacterium can survive wherever the crop is grown and, based on climate modelling, the vector, *S. titanus*, can establish in all NUTS2 zones of the EU where *Vitis* is grown, even in southern Spain where some locations may be too hot and dry for survival in summer months without irrigation. For the assessment of the impact on yield the mean abundance of the pest, the main driver of pest impact, is considered to be the same throughout the area of potential distribution.

2.4. Expected change in the use of plant protection products

Several control methods against FDp are applied in the EU, however it is practically impossible to cure a plant once infected. The only chemicals allowed to control FDp are those targeting *S. titanus* (nymphs and adults), for example: alpha-cypermethrin, azadirachtin, beta-cyfluthrin, bifenthrin, buprofezin, deltamethrin, esfenvalerate, etofenprox, lambda-cyhalothrin. Insecticide applications have low effectiveness against infected adults migrating into vineyards.

In addition to the plant protection products targeted to the vector, the control of the disease includes production of disease-free material for planting and destruction of infected plants.

Among the consulted references, the following have been considered for the different control options:

- Hot water treatment: Linder et al., 2010; EPPO, 2012; EFSA PLH Panel, 2016;
- Removal of infected plants: EFSA PLH Panel, 2016
- Plant protection products: EPPO, 2002; Pavan et al., 2004; Žežlina et al., 2013; Chuche and Thiéry, 2014; EFSA PLH Panel, 2014; Lessio et al., 2015; Trivellone et al., 2016; Tacoli et al., 2017

Hot water treatment of the propagation material is known to be effective in killing both FDp and vector eggs and is widely applied in the EU (Caudwell et al., 1997). The vector has one generation/year and it is therefore sufficient to destroy the hatching nymphs (usually 2 treatments/year separated by no more than 4 weeks) in order to prevent the spread and infection of surrounding hosts.

The currently applied PPPs work effectively to control the vector in vineyards and there is increasing attention in order to reduce the number of treatments. In addition, the use of hot water treatment is widely applied in the EU as it works effectively on several grapevine pathogens and it can therefore be included with the standard control options applied in vine production. In conclusion, based on the table below, this pest belongs to Case "C" and category "1" because in the presence of FDp there is an increase in the use of PPPs to control *S. titanus*.

Table 1: Expected changes in the use of Plant Protection Products (PPPs) following Flavescence dorée phytoplasma 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

- The impact is assessed in all the area of potential establishment equally for protected zones and the rest of EU.
- *S. titanus* has reached its maximum potential distribution, without taking into account the effect of protected zones.
- Due to the widely applied conventional agriculture practices (including the use of pesticides) in areas affected by FDp in the EU, the scenario doesn't take into account the specific situation of yield losses in organic vineyards.
- The impact on nurseries is not assessed due to the currently applied measures, such as hot water treatment, effective against FDp and its vector.
- The estimation of the damage is considered equal for wine and table grapes.
- Replacement is considered among the agricultural practices.
- The current EU cultivars composition and proportion is not considered changing in consequence of FDp attacks therefore the varietal susceptibility and recovery rate are not considered affecting the estimation.

3.1.1.3. Selection of the parameter(s) estimated

The impact of FDp is assessed considering the long-term average proportion (in %) of yield loss in grapevine production, taking into account the current cropping practices applied in EU vineyards.

The bunches collected from infected plants could be either harvested together with the other bunches or excluded and used for alcohol production (e.g. in case of high-quality wines), therefore the quality loss is not assessed separately but interpreted in terms of yield reduction.

3.1.1.4. Defined question(s)

What is the percentage yield loss in wine/table grape production under the scenario assumptions in the area of the EU under assessment for Flavescence dorée phytoplasma, as defined in the Pest Report?

3.1.1.5. Evidence selected

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

- Typical lifespan of a vineyard is 30 years. New plants will not enter production for 2-3 years.
- Current control measures involve the full destruction of plots with more than 20% infections.
- Infected plants may survive up to 3 years or more before dying (Maggi et al., 2017).
- Different levels of host susceptibility are due to

- o Grapevine cv (e.g. Barbera more susceptible than Nebbiolo, see Roggia et al., 2014)
  - o Age of the plant
- The evaluation of the losses is based on damages observed on varieties with different levels of susceptibility (e.g. Merlot as low susceptible and Cabernet Sauvignon as high susceptible).
- *S. titanus* can spread the disease from the beginning of June to end September and the severity of the disease won't be influenced by the inoculation date. Symptoms will develop the next year (CABI, 2018a).

3.1.1.6.   Uncertainties identified

- The reason that causes a recovering plant to express symptoms again (re-infection events vs re-expression of the infection)
- Influence of current agricultural practices on the recovery
- Influence of climatic conditions
- Different susceptibility based on the grapevine varieties
- Substitution of varieties with less susceptible is not predictable
- Presence of FDp reservoir in wild and abandoned vines

3.1.2.   Elicited values for yield losses

What is the percentage yield loss in wine/table grape production under the scenario assumptions in the area of the EU under assessment for FDp, as defined in the Pest Report?

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

Table 2:   The 5 elicited values on yield loss (%) on wine/table grape

Percentile	1%	25%	50%	75%	99%
Expert elicitation	1%	3%	4%	8%	30%

3.1.2.1.   Justification for the elicited values for yield loss

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

There is presence of large vector populations due to inefficient control, favourable environmental conditions, inefficient removal of infected plants, presence of FDp reservoir in wild and abandoned vines. In addition, in presence of heavily infected vineyards, the full field could be fully replaced after reaching the threshold of 20% infected plants, causing years without any production.

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

There is low or no vector populations, scattered distribution of the vector in the assessment area due for example to the use of insecticides targeted to other pests (e.g. *Lobesia botrana*), intensive cultivation practices (including the use of insecticides).

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

The median value takes into account the current agricultural practices including the targeted use of insecticides. The assessment results reported in the EFSA PRA were considered and the estimation took into account that, differently from EFSA 2016, all wine producing NUTS2 regions suitable for the establishment by the vector and FDp are infected, in our assessment scenario. Observations from currently infected areas were also considered.

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

The precision indicates that the group is quite confident on the fact that the impact would not reach the 30% level of damage. Large uncertainty has been identified on the lower values of the distribution.

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 yield loss on wine/table grape

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	1%					3%		4%		8%					30%
Fitted distribution	0.6%	0.8%	1.1%	1.5%	1.9%	2.4%	3.0%	4.3%	6.1%	7.5%	9.6%	12.4%	16.8%	21.9%	29.6%

Fitted distribution: Lognorm(0.060478,0.060416), @RISK7.5

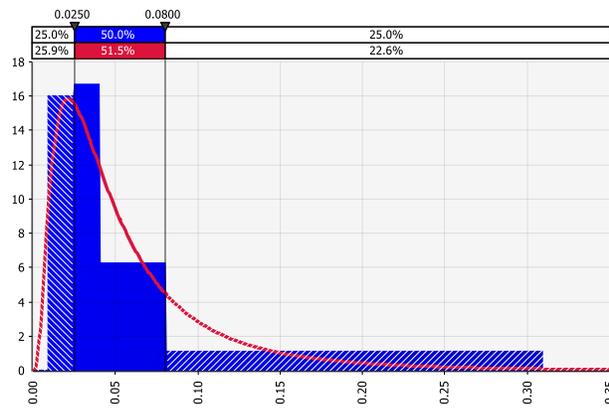**Figure 7** Comparison of judged values (histogram in blue) and fitted distribution (red line) for yield loss on wine/table grape.
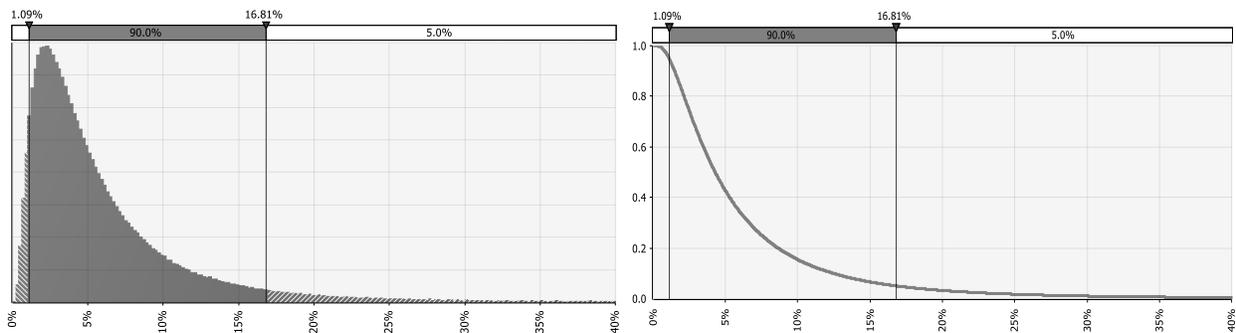

Figure 8 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for yield loss on wine/table grape.

3.1.3. Conclusions on yield and quality losses

Based on the general and specific scenarios considered in this assessment, the proportion (in %) of yield losses (here with the meaning of decline of plant, rejected and not harvested grapes) is estimated to be 4.3% (with a 95% uncertainty range of 0.8 – 21.9%).

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

- The disease spread is caused by the dispersal of the infected vectors
- The density of the vector populations is not a limiting/triggering factor (e.g. there is no competition among individuals of vectors population causing an increase of flying activity)
- In one year the disease spread is considered as a one-step event
- The vectors hitchhiking component of the spread is only considered for the short distance dispersal of the disease (e.g., movement of machineries)
- The effect of pesticides commonly applied in conventional wine production that are not directly targeting *S. titanus* are not considered as affecting the spread rate of the disease

3.2.1.3. Selection of the parameter(s) estimated

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

- The estimation of the disease dispersal requires symptoms expression: time 0 is when the tree is already infectious. From that moment the spread is quantified after 1 year.

3.2.1.4. Defined question(s)

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

3.2.1.5. Evidence selected

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

- from section 2 (paragraph 2.3.4.): *S. titanus*, can establish in all NUTS2 zones of the EU, even in southern Spain where some locations may be too hot and dry for survival in summer months without irrigation
- FDp cannot be transmitted mechanically, e.g. with pruning scissors (EFSA, 2014).

3.2.1.6. Uncertainties identified

- General biases of using mark recapture experiments to estimate dispersal capacity
- Steffek et al. (2007) and Zeisner (2008) assume relevant passive spread mechanism of *S. titanus* in case of favorable winds

3.2.2. Elicited values for the spread rate

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

The five elicited values 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 (m/y)

Percentile	1%	25%	50%	75%	99%
Expert elicitation	3	17	30	200	1,000

3.2.2.1. Justification for the elicited values of the spread rate

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

The upper value is justified by the effect of extreme events (passive dispersal due to strong winds) and by the movement of machineries from a vineyard to the next, displacing vectors via hitchhiking.

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

The lower value is based on the vector behaviour: *S. titanus* is not a strong flier, with reduced flying activity in presence of a continuous of grapevine plants; in addition, there are indications that *S. titanus* infected by FDp are less vital than non-infected *S. titanus*. Other field observations support the idea that this vector tends to aggregate, particularly to already infected plants.

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

The median value is supported by the fact that the FDp spread is mainly caused by vector dispersal compared to trade of infective material, as shown in the EFSA PRA (table B.1). The aggregative behaviour of the vectors, causing aggregation of plants expressing symptoms, justifies a low central value. The fact that *S. titanus* doesn't fly high, makes infrequent its passive dispersal by common winds, therefore there is a very little contribution of wind dispersal.

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

The precision is related to the high uncertainty concerning the lower part of the curve. The possibility of having values close to the median is considered high and the possibility that the vector moves at rates of hundreds of metres is well supported.

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 (m/y)

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	3					17		30		200					1,000
Fitted distribution	1	1	3	5	8	14	21	44	93	143	237	410	772	1,335	2,526

Fitted distribution: Lognorm(200.42,888.22), @RISK7.5
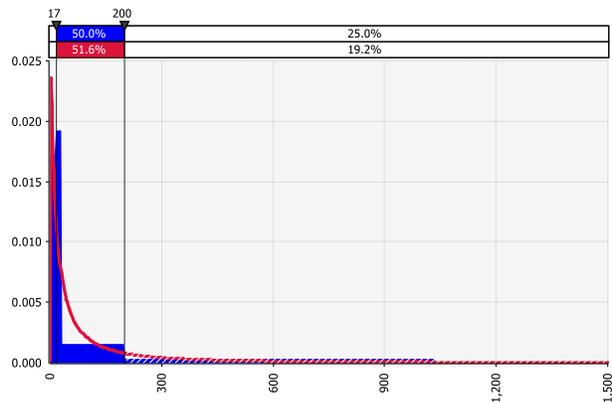

Figure 9 Comparison of judged values (histogram in blue) and fitted distribution (red line) for spread rate.
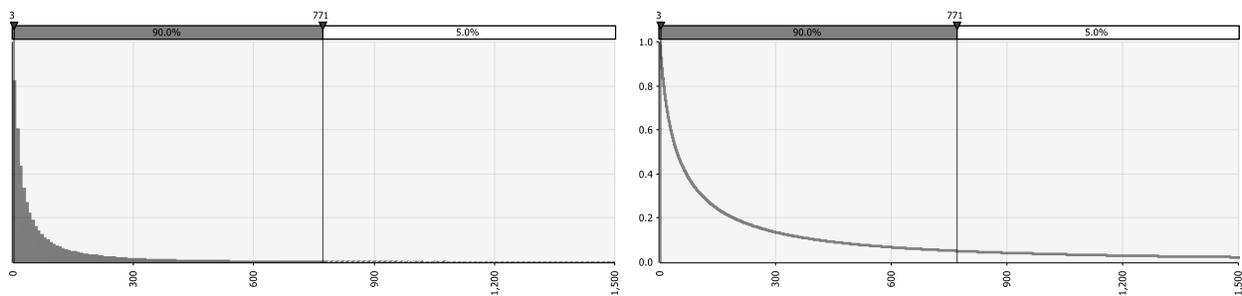

Figure 10 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for spread rate.

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 FDp is 44 m (with a 95% uncertainty range of 1-1,300 m).

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

- The estimation of the disease dispersal requires symptoms expression: time 0 is when the tree is already infectious. From that moment the time to detect the presence of the pathogen in the host is quantified.
- The scenario considers the initial phase of infestation, when the amount of inoculum (in terms of number of infected plants and bacterial load in the plant) is not particularly high.

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? (unit: months)

3.3.1.5. Evidence selected

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

- symptoms may be confused with those caused by other infectious agents (i.e. viruses)
- serological assays lack sensitivity
- only molecular detection can be considered reliable
- the official EPPO protocol for detection is available (EPPO, 2016).

3.3.1.6. Uncertainties identified

- The level of attention and frequency of surveillance is very diverse, depending from presence of the disease in the area and agricultural practices

3.3.2. Elicited values for the time to detection

What is the time between the first event of pest transfer to a suitable host and its detection (units: 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	10	40	50	66	120

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 scenario influenced by conditions like the characteristics of the newly infected area, high time for detection is considered possibly on wild *Vitis* plants or abandoned vineyards, or in area without viticultural technicians experienced in identifying the symptoms (e.g. confusion with bois noir, deficiencies). Time for detection would be higher also in areas with no regular surveillance activity and infection on less susceptible cultivars not expressing clear symptoms. In this case a large outbreak is required before awareness is raised.

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

The scenario is characterised by the presence of expert people, able to identify the disease, presence of susceptible cultivar. The time to express the symptom from the moment of inoculation is minimum: infected vector inoculating the plant at the end of the season (i.e. October), and a susceptible cultivar expressing symptoms in early summer (i.e. June).

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

The median value considers that 1 year is needed to express symptoms after inoculation. Most of the survey activity in the vineyards is done late in summer. Years are needed for the outbreak to reach a certain extent in order to be spotted out. In addition, bois noir (which shows identical symptoms) has a masking effect: in this situation sampling will most likely not select FDp infected plants.

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

The precision is linked to the fact that 10 months is a very optimistic scenario and the group is more confident in the median value.

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

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

Table 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	10					40		50		66					120
Fitted distribution	21	24	28	31	35	39	43	51	60	65	73	82	94	105	121

Fitted distribution: Lognorm(54.416,20.993), @RISK7.5
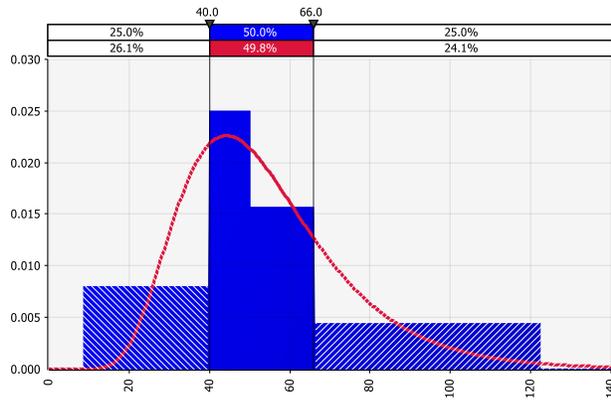

Figure 11 Comparison of judged values (histogram in blue) and fitted distribution (red line) for time to detection.
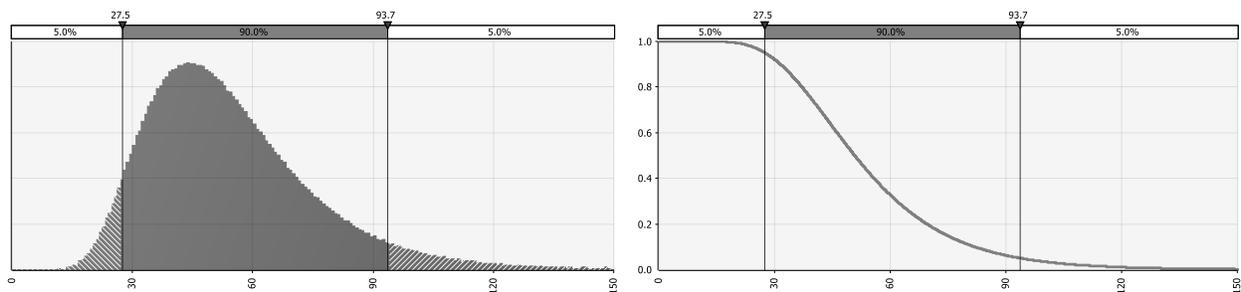

Figure 12 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for time to detection.

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 more than 4 years (with a 95% uncertainty range of 2 to almost 9 years).

4. Conclusions

Hosts selection

Only the impacts on *Vitis vinifera* were assessed since this is the commercial crop. Despite some differences in susceptibility, wine and table grape cultivars were evaluated together.

Area of potential distribution

The area of potential distribution is based on the area of *Vitis* production (wine and table grapes) in the EU, because the bacterium can survive wherever the crop is grown and, based on climate modelling, the vector, *S. titanus*, can establish in all NUTS2 zones of the EU where *Vitis* is grown, even in southern Spain where some locations may be too hot and dry for survival in summer months without irrigation. For the assessment of the impact on yield the mean abundance of the pest, the main driver of pest impact, is considered to be the same throughout the area of potential distribution.

Increased number of treatments

This pest belongs to Case "C" and category "1" because in the presence of FDp there is an increase in the use of PPPs to control *S. titanus*.

Yield and quality losses

Based on the general and specific scenarios considered in this assessment, the proportion (in %) of yield losses (here with the meaning of decline of plant, rejected and not harvested grapes) is estimated to be 4.3% (with a 95% uncertainty range of 0.8 – 21.9%).

Spread rate

Based on the general and specific scenarios considered in this assessment, the maximum distance expected to be covered in one year by FDp is 44 m (with a 95% uncertainty range of 1-1,300 m).

Time to detection

Based on the general and specific scenarios considered in this assessment, the time between the event of pest transfer to a suitable host and its detection is estimated to be more than 4 years (with a 95% uncertainty range of 2 to almost 9 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
Clematis	vitalba
Vitis	
Vitis	vinifera

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	Uncertainty
	Incidence	*Severity*	*Losses*			
Merlot Chardonnay		Merlot grapevines recovery: 80% (in 2 years) Chardonnay grapevines recovery: 40% (in 2 years)	Yield loss in symptomatic grapevines: Merlot: 40% Chardonnay (55%)	10% of recovered Merlot grapevines showed symptoms the following year	Bellomo et al., 2007	
Varieties: "Dolcetto" (3 vineyards), "Barbera" (2 vineyards), "Bonarda" (1 vineyard), "Cortese" (1 vineyard)			Yield of recovered plants was always approximately 80% more than that of the symptomatic vines. Symptomatic plants show yields on average between 30% and 50% in comparison to healthy plants.	No significant differences in the number of newly affected, healthy, or recovered plants among the vineyards within years. The 7 vineyards were therefore considered as replicates. Grapevine varieties did not affect the efficiency of recovery.	Morone et al., 2007	Results about varietal effect in conflict with what indicated in Caudwell et al. 1987
	During the period 2003-2005 the number of symptomatic plants increased: • From 45.5% to 93% (Area 1) • From 12.4% to 19.6% (Area 2) • From 5% to 90% (Cultivar Plovdina)			Serbia. Molecular analysis No insecticide treatments	Kuzmanovic et al., 2008	

Merlot Chardonnay Perera	Index of new infections: Merlot: 32% Chardonnay: 43% Perera: 50%	In 5 years: 19% death in Chardonnay 10% death in Perera	34 % yield loss for Merlot 56 % yield loss for Chardonnay 81 % yield loss for Perera Lower yield losses in symptomatic grapevines associated with greater ability to recover	The susceptibility of 'Chardonnay' was greater than 'Merlot', therefore it is not profitable to replace Merlot vineyards whereas it is profitable to remove Chardonnay and Perera cultivars (for latter only if combined with treatments against the vector). Merlot cultivar shows high recovery rates.	Pavan et al., 2012	
Cv: Barbera and Nebbiolo		significant positive correlation between FDp concentration and symptom severity		grapevine cultivars with different susceptibility to FDp support different pathogen titres	Roggia et al., 2014	
			0.5-1% impact on grapes and wine production (8000 tonnes of grapes across the whole EU)	Predicted under the current regulatory/legislative situation (defined as "scenario A0")	EFSA PLH Panel, 2016	The EFSA document mentions high uncertainties (50%), the value ranging from 1000 tonnes to 50 000 tonnes.
28 different *Vitis* species analysed, including 12 wild cultivars	Accessions with high FDp titers and high proportion of infected plants: Cabernet Sauvignon, *V. rubra*, *V. labrusca*, *V. berlandieri*, Sauvignon Accessions with intermediate FDp titers and high proportion of infected plants: *Vitis amurensis*, Riparia Gloire de Montpellier, Cabernet Franc, 3309 Courdec, *V. rupestris*, *Vitis longii*, Grenache, Chardonnay, Sélection Oppenheim 4, 41 B Millardet et de Grasset, *V. doaniana*, 110 Richter, *V. pentagona*, *V. coignetiae* Accessions with intermediate to low FDp titers and low proportion of infected				Eveillard et al., 2016	

plants: Syrah, Magdeleine Noire des Charentes, Pinot Noir, Merlot, *V. simpsonii*, Nemadex Alain Bouquet, *V.vinifera* subsp. *sylvestris*, *Vitis champinii*, Kober 5 BB	

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

Spread	Additional information	Reference	Uncertainty
FDp Expansion from 60 ha in 1991 to 20 000 ha in 1993	Pyrénées-Orientales (southwestern France)	Pueyo et al. 2008	
S. titanus No significant spread outside the vineyard within a 24-metres radius in normal wind conditions. Few specimens were caught by traps placed at a height of 2.40 metres (therefore the pest does not seem to fly above the canopy)	Northwestern Italy. Field studies. Yellow sticky traps. Natural spread.	Lessio and Alma, 2004b	
S. titanus The distance between North American vineyards and alternative North American grapevine yellows phytoplasma host plants beyond which this species are less apt to travel is at least 40 m (traps 30 m from the vineyard edge and 40 m from the forest edge rarely captured *S. titanus*)	North America. Field studies: surveys. Sticky traps; sweep sampling. Logistic regression analyses; logistic regression model predictions. Natural spread.	Beanland et al., 2006	
S. titanus 80% of *S. titanus* covered short distances of up to 30 m, the rest being able to cover up to 200 m.	Northwestern Italy. Natural low dispersal ability. Field studies (natural environment): from wild to cultivated grapevines. Mark-capture techniques (yellow sticky traps) Modeling: Data subjected to exponential regression and spatial interpolation.	Lessio et al., 2014	
S. titanus Majority of adults captured within 40-50 m; some individuals captured at 80-100 m.	North-west of Italy. Field studies: surveys. Yellow sticky traps. Natural spread. SADIE (Spatial Analysis by Distance IndicEs) red–blue Methodology to detect spatial patterns.	Mori et al., 2014	Not really demonstrated clearly, as only the 2012 map shows the result
S. titanus	Central-Eastern Italy.	Riolo et al., 2014	

Leafhopper dispersal showed a maximum 600-m radius from the nursery of scion mother plants where it was first recorded	Field studies: annual surveys coordinated by the Regional Plant protection Service. Natural spread. Yellow sticky traps. Taylor's power law and distance-weighted least-squares contour maps were used to determine the leafhopper distribution within vine fields. Distance-weighted least-squares (DWLS) non-parametric interpolation was used to visualise the insect densities in the contour maps.			
S. titanus Spread distance of at least 75 m. Adult *S. titanus* migrate into the peripheral parts of commercial vineyards at the end of the season	Austria. Modelling study; field trials. Natural spread. Trap plants and yellow sticky traps.	Strauss et al., 2014	Austria. Conflicting sentences in the paper. In the Abstract they mention "maximum spread distance of 75 m", in the Conclusion "distance of at least 75 m". Results seem to favour the second sentence.
S. titanus The vector randomly chooses a direction for short flights. 50% of travel distances were within 3 m.	Piemonte, Italy. Field studies: survey. Space-time dynamic (year-to-year) point pattern analyses. Natural spread.	Maggi 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	Uncertainty
Detection	Molecular analysis	Polymerase chain reaction (PCR)	Phytoplasma-universal primer pair P1/P7 followed by nested, 16S rDNA V group-specific primers	Lee et al., 1994	
	Molecular analysis	Restriction fragment length polymorphism analysis		Davis and Dally, 2001	
	Molecular analysis	Biplex nested PCR	Detection and determination of both FDp and Bois Noir phytoplasma	Clair et al., 2003	

	Molecular analysis	Genetic typing	By targeting non-ribosomal genes such as *sec*Y, *rps*C, *map* and *uvr*B-*deg*V	Martini et al., 2002 Botti and Bertaccini, 2007 Arnaud et al., 2007	
	Molecular analysis	Real-time PCR assays	According to EPPO (2012), these tests give the best performances	Hren et al., 2007 Pelletier et al., 2009	
	Molecular analysis	Reverse transcription PCR (RT-PCR)		Margaria et al., 2007	
	Molecular analysis	Real-time PCR assays	Multiplex assay can be applied for the simultaneous detection of grapevine viruses and FDp	Margaria et al., 2009	
	Monitoring	Counting number: 1) of nymphs on the underside of leaves 2) after beating 3) using a suction apparatus (e.g. D-vax) 4) using sticky traps		Chuche and Thiéry, 2014	
	Symptoms	Affected grapevines, starting from spring but mostly during summer, show reduced growth and sometimes absence of shooting, eventually bending to the ground		Belli et al., 1973	
	Symptoms	A minimum of 3 years is necessary for the development of large outbreaks, i.e. when more than 20% of the vineyard is affected.		EFSA PLH Panel, 2016	
	Symptoms	Infected plants may survive up to 3 years or more before dying.		Maggi et al., 2017	
	Symptoms	Symptoms normally appear the year after the infection.		CABI, 2018	

	Symptoms	During the 1st year of infection only few shoots develop visible symptoms; usually symptoms appear the year after inoculation.		CABI, 2018	
	Sampling moment	Best time for sampling and detection: early summer (highest phytoplasma titre)	FDp can still be detected as early as flowering season, on in case of susceptible cv such as Barbera even earlier	Roggia et al., 2014	
Biology	Life cycle	Duration of *S. titanus* life cycle	Mid-May (juveniles), from mid-July/end of June to mid-October (first adults)	Lessio and Alma, 2004a	In Northern Italy
	Life cycle	Latency period (FDp incubation inside *S. titanus* before being transmitted by third-instar nymphs)	Best efficiency after 35 days	Bressan et al., 2006	
	Life cycle	FDp	FDp multiplication in *S. titanus* was faster at lower T and CO2 concentration. Overall, phytoplasma multiplication was faster under cooler conditions in insects and under warmer conditions in plants.	Galetto et al., 2011	
	Life cycle	*S. titanus* lower temperature threshold for development	8 °C	ACRP, 2013	No data. Just mentioned
	Life cycle	*S. titanus* development time	Approximately 18 weeks (from egg hatching to adult leafhopper)	ACRP, 2013	No data. Just mentioned
	Life cycle	Flavescence dorée phytoplasma	FDp multiplication rate was nearly twice as fast (14 hours instead of 26 hours) in broad beans incubated at 25 °C than in broad beans incubated at 20 °C. As a consequence, plants expressed symptoms 1 week earlier. Once reached the stationary phase, FDp numbers were equal though.	Salar et al., 2013	Experiments performed in broad beans *V. faba* by using the vector *E. variegatus*
	Life cycle	S. titanus	Incubation temperatures regulate the beginning and length of the hatching dynamic	Chuche and Thiéry, 2014	
	Life cycle	*S. titanus* life cycle duration	Beginning of June (young larvae) until late September (old adults)	CABI, 2018	
	Behaviour	*S. titanus*	Flight activity peaks between late afternoon and early morning	Lessio and Alma, 2004a	Early morning activities speculated but not demonstrated

	Distribution	*S. titanus*	Aggregated	Bosco et al., 1997	
	Distribution	*S. titanus*	Aggregated. Nymphs seem not to move far away from the leaves where the settle at first. Mean number/plant= from 0.17 to 7.8	Lessio and Alma, 2006	
	Behaviour	*S. titanus*	Males are active before mating, whereas females must displace themselves to lay their eggs later in the season. As a consequence, more males are trapped in comparison to females.	Mazzoni et al., 2009	
	Behaviour	*S. titanus*	No probing difference between males and females has ever been demonstrated	Chuche and Thiéry, 2014	
	Behaviour	*S. titanus*	Flight activity increases with the daily minimum temperature	Chuche and Thiéry, 2014	
Vectors	Relation pest-vector	FDp and *S. titanus*	FDp infection caused a reduction of 50% in the number of eggs carried by females and a reduction of 66% in the number of hatched nymphs	Bressan et al., 2005	
	Relation pest-vector	FDp and *S. titanus*	The males are more efficient than females in transmitting the disease	Chuche and Thiéry, 2014	Review paper, with a reference to a very old paper
	Relation pest-vector	Latency period (FDp incubation inside *S. titanus* before being transmitted by third-instar nymphs)	Around 1 month	Chuche and Thiéry, 2014	
Host Plants	Relation vector – host plant - pest	Acquisition efficiency	Dependent on grapevine variety and FDp load in the plant. Nevertheless, even varieties supporting low FDp multiplication rates may be highly susceptible and an efficient source for vector infection. Poorly susceptible varieties can host high phytoplasma loads. 34%-48% acquisition efficiency on Arneis, Brachetto, Docletto and Freisa 22% acquisition efficiency on Timorasso 9% acquisition efficiency on Moscato	Galetto et al., 2016	