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Spodoptera frugiperda 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 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 *Spodoptera frugiperda*, the following documents were used as key references: the impact assessment by van der Gaag and van der Straten, 2017, the pest categorization and pest risk assessment by EFSA PLH Panel (2017 and 2018).

[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

Spodoptera frugiperda (Smith) has two genetically distinct (but morphologically identical) strains: the corn strain and the rice strain. Although the strains are reported to have host preferences, this could not be confirmed consistently in lab trials, while high rates of hybridization have been observed (Juárez et al., 2012). Both strains occur in Africa (Nagoshi et al., 2018) with severe impacts being reported on maize (Abrahams et al., 2017). This assessment, together with the EFSA pest categorisation of 2017, follows the taxonomy of Pogue (2002) and considers *S. frugiperda* as a single species with two strains. Feeding preferences driven by *S. frugiperda* genetic variability are not taken into account during the EKEs, which are conducted at the species level.

This very polyphagous pest attacks many important crops: its larvae, at early stages, scrape the epidermis off the underside of the leaves and, later, produce feeding holes in fruits and leaves. Symptoms are generic for most primarily foliage feeding Lepidoptera species (Smith et al., 1997), although *S. frugiperda* larvae never spin the leaves together.

Adult females are relatively short-lived (13–19 days at 26.8 °C) (Johnson, 1987) and a single female can lay 1,000 eggs (Johnson, 1987) in clusters of 100–300 which are covered with a protective layer of scales from the female abdomen (Abrahams et al., 2017). Eggs are preferably laid on the underside of leaves but, at high population densities, can be found on almost any surface.

There are five to six larval instars:

- First and second instars feed together on the host where the eggs were laid (Pannuti et al., 2015), favouring young leaves and tender growing tips
- Third instars disperse away from each other but generally do not go far. At high population densities, larvae feed gregariously and disperse in swarms, usually moving to grasses when available (Smith et al., 1997). However, the larvae of this species rarely display the typical “armyworm” behaviour of massing and “marching” across fields (FAO, 2018)

Under natural circumstances mature larvae burrow into the soil to pupate. However, pupation can take place anywhere, regardless of the presence of soil or any other hiding place (e.g. in packaging material during transport of a commodity or on rock wool in a greenhouse).

2.2. Host plants

2.2.1. List of hosts

In North and Central America, *S. frugiperda* has been observed feeding on 186 plant species belonging to 42 different families (van der Gaag and van der Straten, 2017). Favoured hosts pertain to Poaceae: maize, rice and sorghum, wild and cultivated grasses, millet and sugarcane. Other hosts of economic relevance in the EU are: *Allium* (Liliaceae), *Brassica* (Brassicaceae), *Capsicum* and other Solanaceae including aubergines, potatoes and tomatoes, *Cucumis* (Cucurbitaceae), *Gossypium* (Malvaceae), *Phaseolus* (Fabaceae) and *Ipomoea* (Convolvulaceae) as well as various ornamental plants (chrysanthemums, carnations, *Rosa* (EU interceptions) and *Pelargonium*) (Smith et al., 1997; CABI, 2019). In Brazil, the third largest maize producer after US and China, where *S. frugiperda* can continuously reproduce, it is considered the most important pest of corn (Mello Filho and Richetti , 1997). In laboratory host preference studies examining larval feeding choices, maize and wheat were preferred above soybean and cotton (da Silva et al., 2017).

Appendix A provides the full list of hosts.

2.2.2. Selection of hosts for the evaluation

Maize is one of the most important crops in Europe, covering a production area of approximately 14.6 million hectares in 2018 (EUROSTAT, online). Grain maize production dominates in central and southern Europe, while maize in northern Europe is typically grown for silage. It is either grown as continuous maize or in rotation with other crops and crop protection is mainly pesticide-based, with different levels of IPM implementation within Europe (Meissle et al., 2010).

S. frugiperda favours maize and sorghum and is less attracted to other crops; rice is also an important host. Due to availability of these main hosts in the EU and the absence of relevant information on pest/host interaction for other EU major crops (e.g. wheat, onions, potatoes, strawberries, sugar beet and citrus) (EFSA PLH Panel, 2017) the prioritisation assessment has been conducted on maize, sorghum and rice.

2.2.3. Conclusions on the hosts selected for the evaluation

The complete list of hosts is produced by merging

- the list of host plants defined by EPPO (EPPO, online)
- the list of host species reported by CABI (CABI, 2019)
- the list of species reported in van der Gaag and van der Straten (2017)

The hosts on which the impacts are assessed are:

- sweet corn
- grain maize and sorghum
- maize and sorghum used for forage and biofuel production
- rice

2.3. Area of potential distribution

2.3.1. Area of current distribution

In 2016, *S. frugiperda* was reported for the first time in Africa with outbreaks in Benin, Nigeria, Sao Tomé and Principe, and Togo (Goergen et al., 2016; IITA, 2016). News reports and media coverage indicate that *S. frugiperda* continues to spread in sub-Saharan Africa and in August 2018 the first records were published from Senegal (Brevault et al., 2018). In May 2018, it was found in India (EPPO, online). The overall distribution of *S. frugiperda* is given in Figure 1 but no attempt has been made to distinguish established from transient populations.

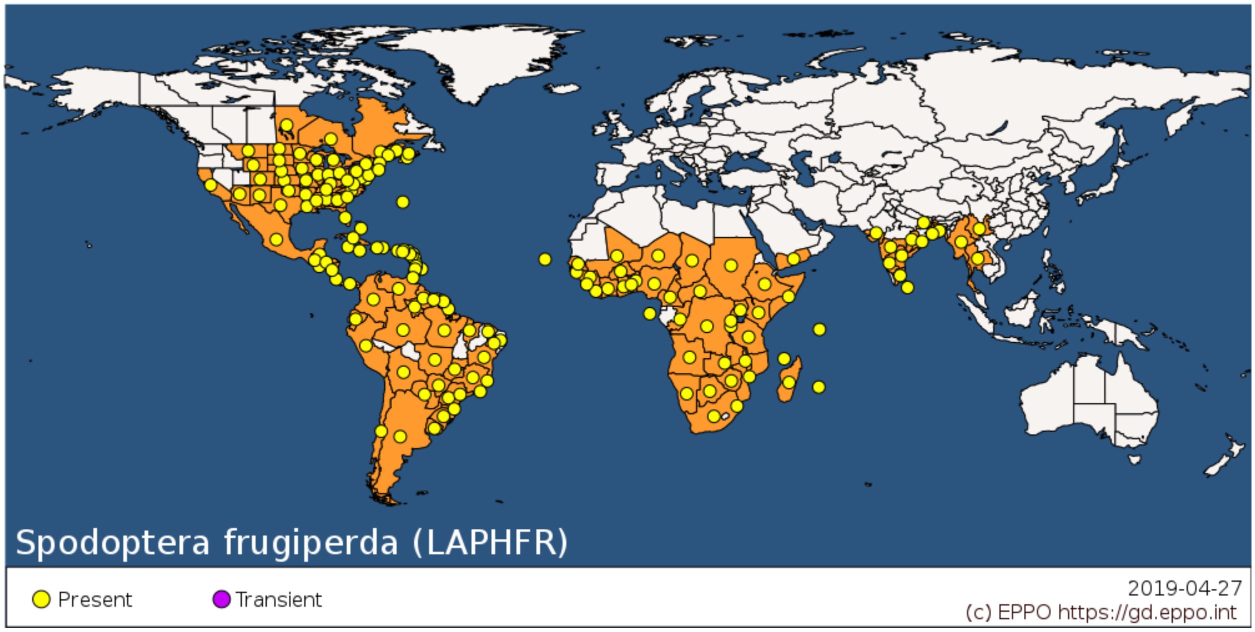

Figure 1 Distribution map of *Spodoptera frugiperda* from the EPPO Global Database accessed 27/04/2019.

2.3.2. Area of potential establishment

S. frugiperda is native to tropical and subtropical regions of the Americas, where winter temperatures rarely fall below 10°C (Sparks, 1979; Ashley et al., 1989; Nagoshi and Meagher, 2008). *S. frugiperda* can breed year-round in Central and South America (Johnson, 1987) and in southern Florida and Texas (Nagoshi and Meagher, 2008; Abrahams et al., 2017), producing 4-6 generations per year (Abrahams et al., 2017). It migrates to temperate regions in North and South America during the summer where it dies out in winter due to its inability to diapause (Westbrook et al., 2016). Pupae developing during the winter in Florida were not able to complete development during a month when the minimum soil temperature was below 10°C for two or more days (Wood et al., 1979).

- The reported minimum temperature for development varies considerably, with the following records in descending order: 16.95 °C (Barfield et al., 1978), 13.8 °C (Hogg et al., 1982), 12.57°C (Schlemmer, 2018); 12.69 °C (Ali et al., 1990), 10.9 °C (Ramirez-Garcia et al., 1987), 9.5–10.9°C (Busato et al., 2005), and 8.7°C (Valdez-Torres et al., 2012).
- At 21–27°C eggs hatch in 2–4 days (Sparks, 1979).
- At 18.3°C egg to adult development takes around 66 days and
- at 35.0°C egg to adult development takes around 18 days (Barfield et al., 1978).
- The degree days for egg-adult development also vary. A threshold temperature of 10.9°C and 559 degree-days above the threshold is required for development from egg to adult (Ramirez-Garcia et al., 1987). In South Africa, Schlemmer (2018) found the values to be 12.6°C and 391 day-degrees and also obtained values for the minimum thresholds and degree-day requirements for all life stages and larval instars.
- At 26.8°C adult females live 13–19 days (Johnson, 1987).
- All stages are usually killed by freezing temperatures (Abrahams et al., 2017).

The following models to forecast the potential establishment of *S. frugiperda* have recently been published:

- Early et al (2018) used an ensemble of eight species distribution models to map potential global establishment. This was adapted by EFSA PLH Panel (2018) to prepare two maps (Fig. 15 and 16) with different suitability thresholds. Four climatic variables were selected: one based on temperature (mean temperature of the coldest month of the year) and three based on precipitation (the total amount of precipitation in the wettest 3 months of the year, the number of months when rain is greater than average and the seasonality of precipitation (difference in rainfall between the rainy and dry seasons)). Climatic variables were based on monthly averages for 1961–1990 at a resolution of 10 minutes latitude and longitude and the maps were masked to display only agricultural grid cells from the European Space Agency's Global Land Cover map. EFSA PLH Panel (2018) concluded that: "Depending on the sensitivity threshold selected, pockets of habitat in a few NUTS 2 regions in Spain, Italy and Greece, and possibly Portugal, have climatic conditions where it is reasonable to expect *S. frugiperda* can establish year-round populations".
- Du Plessis et al (2018) used a different species distribution model, CLIMEX, with 1961-90 (mid-point 1975) climatic data to model potential global distribution at a resolution of 10 minutes latitude and longitude. Several parameters were selected including a minimum threshold of development of 12°C and a degree day sum of 600 for egg-adult development and they applied an irrigation scenario. No potential establishment was forecast in Europe but EFSA PLH Panel (2018) re-ran this model based on monthly averages for meteorological stations in Europe. Both southern Spain (Andalucía), southern Italy (including Sicily) and Greece were found to have positive ecoclimatic indices indicating potential establishment.

These models have relatively limited applicability in the assessment of potential impacts in the EU because:

- the models forecast only the areas where year-round establishment is possible and not the areas where transient damaging populations develop from migrating adults. A complete generation is not needed for considerable crop damage to occur (even the 3rd -4th larval instars can cause serious damage to rice, as indicated by Pantoja et al., 1986).
- The great variation in the input parameters creates considerable model uncertainty. As shown above there is, for example, a very wide range of published minimum temperature thresholds for development. It is likely that this is principally due to the variability of *S. frugiperda* itself.
- Both models were run with mean 1961-1990 climate and global warming has occurred since. This implies that both models provide very conservative estimates of the areas of potential establishment in Europe. Further, the 30-year monthly averages do not take into account the variation in annual weather conditions, principally, temperature and wind, that are likely to play a major role in determining the areas where overwintering is possible and transient populations can invade and develop damaging populations.

2.3.3. Transient populations

In order to explore the area of Europe affected by transient migrant populations under more recent climate conditions and show the potential number of generations, a degree-day map of Europe was produced with mean 1997-2017 climatic data based on a degree day model with a minimum temperature threshold of 10.9°C and 559 day-degrees (Ramirez-Garcia et al., 1987) for egg to adult development (Figure 2).

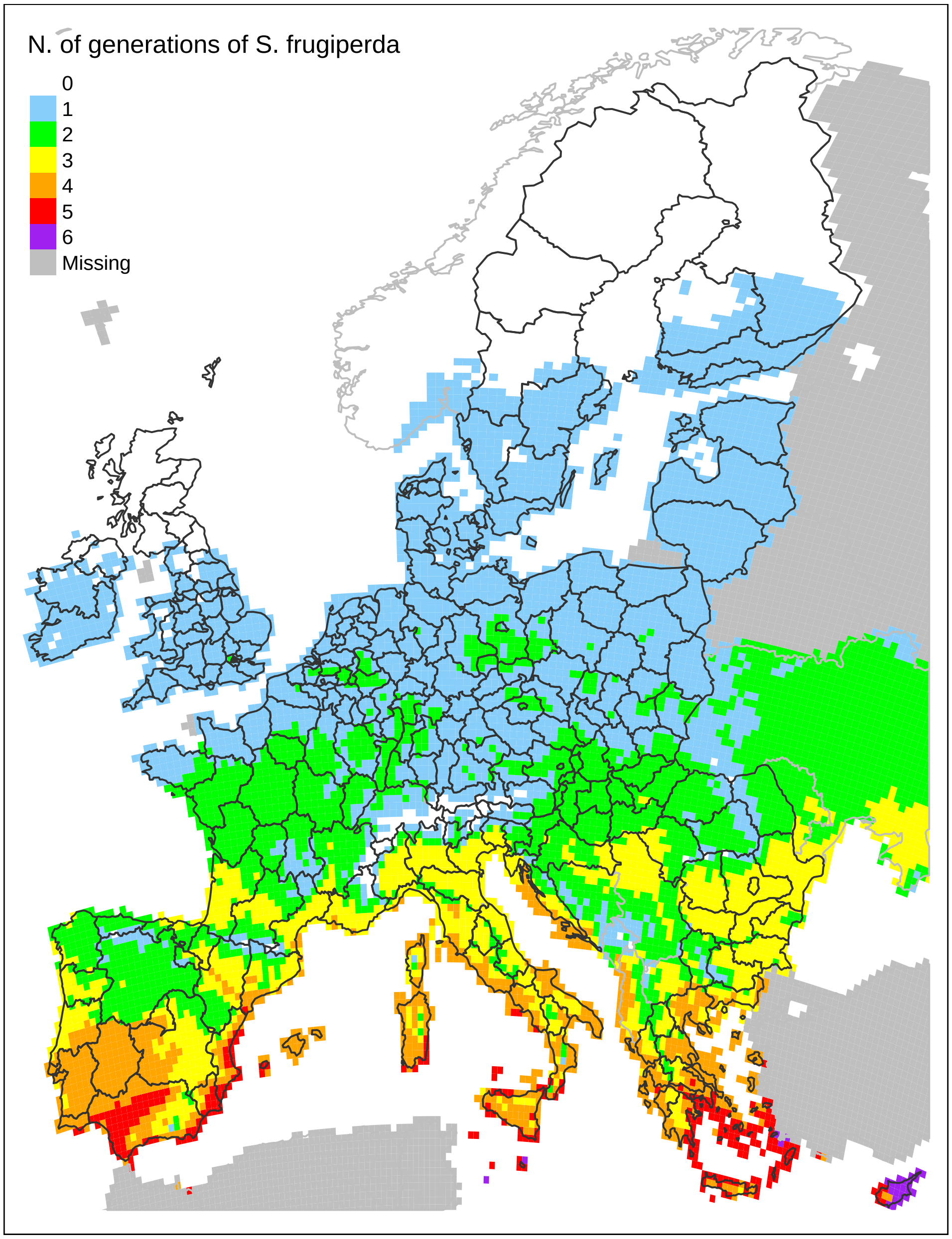

Figure 2 The number of potential generations of *Spodoptera frugiperda* in Europe based on 1997-2017 climatic data from JRC-Ispra and a degree-day model with a minimum temperature threshold of 10.9°C and 559 day-degrees required to complete development from egg to adult (Ramirez-Garcia et al., 1987).

Based on this appraisal of the evidence, the following scenario assumptions have been made:

- despite considerable annual variation, *S. frugiperda* can overwinter in southern areas of Europe with the warmest winters: Portugal, Spain, Italy, Malta, Greece and Cyprus and here permanent populations will be present.
- adults emerging in spring from these southern European populations, supplemented by invasions from North Africa including the Nile delta as shown by EFSA PLH Panel (2018), will fly northwards to invade more northerly areas of Europe.
- taking into account the long-distance migration data from North America, the widespread distribution of the principal foodplants, particularly maize and rice, in Europe, and temperatures suitable for completing its life cycle or developing populations with larval instars capable of serious impacts (instars 3-6), at maximum, transient *S. frugiperda* populations may occur wherever maize is grown in Europe.
- There will be a considerable annual variation in the area invaded each year and also a gradient with diminishing population density related to the distance from the source of the invasion in southern Europe where overwintering populations occur.

2.3.4. Conclusions on the area of potential distribution

Based of the available information on the life history strategies of the species (survival, development and reproduction) and the scenario assumptions introduced for assessing the area of potential distribution we conclude that:

- the species can have permanent populations only in southern areas of Europe with the warmest winters: Portugal, Spain, Italy, Malta, Greece and Cyprus. The area of potential establishment corresponds to the area where the species has 5 or more generations per year according to the model from Ramirez-Garcia et al. (1987) and run with JRC climatic data for the period 1997-2017.
- *S. frugiperda* can have transient populations in the EU (the species has a 99° quantile of the estimated spread rate higher than the threshold value of 100 km/year). The 99° quantile of the estimated spread rate is in the order of 1,500 km/year. The area with potential transient populations is calculated as an expansion of the area of potential establishment by a radius of 1,500 km/year from its border. The area of potential distribution corresponds to the area of potential establishment plus the area where transient populations can occur (Figure 3).

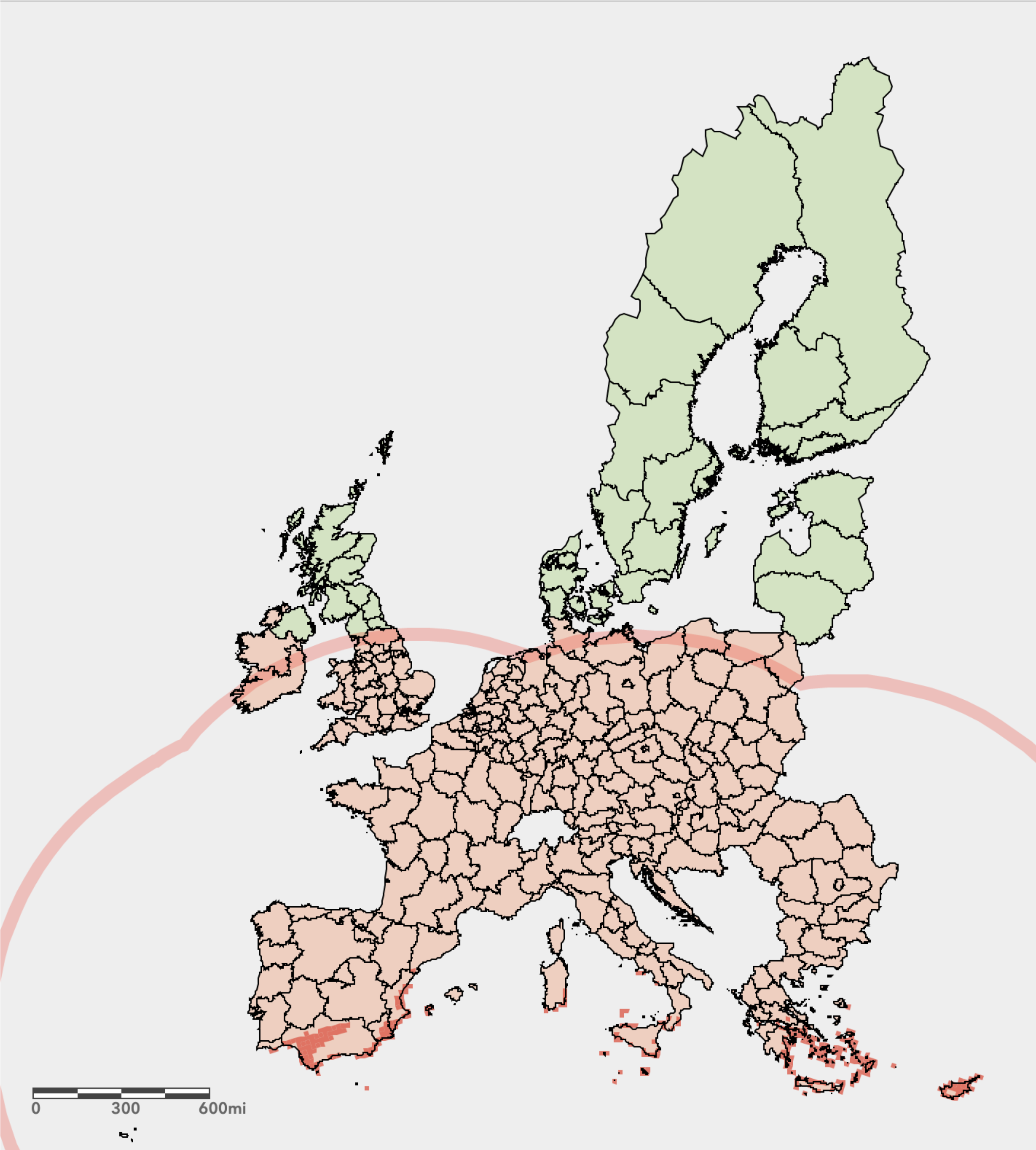

Figure 3 Area of potential distribution of *S. frugiperda* in the EU comprising the area of potential establishment (in red) and the area where transient populations can occur (in pink). This link provides an online interactive version of the map that can be used to explore the data further: https://arcg.is/0PvK0z

2.4. Expected change in the use of plant protection products

The opinion by EFSA PLH Panel (2017) provides an overview of the options, including chemical control, available to control *S frugiperda.* (Dequech et al., 2013; Abrahams et al., 2017).

Arthropod pests affecting maize production in the EU are often controlled with broad-spectrum insecticides including pyrethroids and organophosphates. Spraying is effective only when timed shortly after the eggs hatch and before the larvae bore into the maize stem. This requires frequent scouting and often several treatments. An alternative solution, with comparable efficacy under optimal conditions is the release of the biocontrol agents *Trichogramma* sp., small wasps parasitizing eggs of the European corn borer (*Ostrinia nubilalis*) and other Lepidoptera pests of maize. In Europe, about 150,000 ha per year are treated with this biocontrol agent, with the largest area being in France (Meissle et al., 2010). Appropriate scouting, forecast systems and efficient logistics are also crucial. Furthermore, the use of virus-based insecticides is advancing rapidly in the Americas and Australia and could soon become an important option in Europe.

In America it migrates every year to the north-eastern part of the USA and south-eastern part of Canada, where it regularly requires control measures on corn. These control measures, however, are also needed for other Lepidoptera pests on corn such as *O. nubilalis* (van der Gaag and van der Straten, 2017). The control practices currently applied in the EU against other Lepidoptera pests of corn, such as *O. nubilalis* and *S. nonagrioides*, could also be potentially effective against *S. frugiperda*, although there is no confirmation even with an increase in the number of applications (EFSA PLH Panel, 2017). In Pennsylvania, for example, *S. frugiperda* is a pest that regularly requires specific control measures to prevent economic damage, e.g. on sweet corn and occasionally on tomato, although insecticide sprays already applied against other Lepidopteran pest also control *S. frugiperda* (van der Gaag and van der Straten, 2017).

As a consequence of the selection pressure from the use of synthetic insecticides and *B. thuringiensis* insecticidal proteins applied on transgenic maize crops, *S. frugiperda* has developed resistance against at least 24 different active substances and tolerance to Bt proteins Cry1Ab, Cry1Ac, and Cry1F under field conditions (Figueiredo et al., 2005; Aguirre et al., 2016; Blanco et al., 2016; Abrahams et al., 2017; MSU, online). For example, in Argentina, Brazil, Puerto Rico and Uruguay, maize growers initially controlled *S. frugiperda* with Bt maize that expressed one Bt protein (Cry1Ab of Cry1F); now it is necessary to plant maize cultivars that produce two Bt proteins and/or spray synthetic insecticides on Bt maize to achieve satisfactory control, that in the case of Puerto Rico requires 25 insecticide applications in a single growing season (Belay et al., 2012).

In conclusion, based on the table below, this pest belongs to Case “C” and category “1” due to the availability of effective plant protection products currently applied on maize fields which would require an increasing number of applications or of type of products in order to be effective against *S. frugiperda*.

Table 1: Expected changes in the use of Plant Protection Products (PPPs) following *Spodoptera frugiperda* 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

This pest produces direct kernel damage during feeding often accompanied by additional kernel damage due to the fungi these insects either introduce or allow entry through wound openings (Herrington et al., 2013).

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 area of potential impact on cereals is considered to include all the area where these crops are grown in the EU in the area of potential distribution (area of establishment and area where transient populations can occur).
- Similar levels of impact are assumed to occur in the area of potential establishment and in the area affected by transient populations.
- Quality loss caused by an increasing amount of mycotoxins is not included in the assessment as it is likely to be more relevant at the beginning of an invasion and not in a stable situation.
- Quality losses due to a downgrading from human to animal consumption are not included as they are considered negligible

3.1.1.3. Selection of the parameter(s) estimated

The yield losses are mainly caused by the larval feeding which limits the plant photosynthetic capacity and, in case of later instars, produces cuts through the young stems.

In case of sweet corn and grain maize and sorghum, losses are the consequence of plant decline, rejected and unharvested cobs.

In case of forage maize and sorghum and/or biofuel production, losses are the consequence of plant decline and reduction of harvested volumes.

In case of rice production, losses are the consequence of plant decline, rejected and unharvested seed heads.

3.1.1.4. Defined question(s)

What is the percentage yield loss in sweet corn production under the scenario assumptions in the area of the EU under assessment for *Spodoptera frugiperda*, as defined in the Pest Report?

What is the percentage yield loss in grain maize and sorghum production under the scenario assumptions in the area of the EU under assessment for *Spodoptera frugiperda*, as defined in the Pest Report?

What is the percentage yield loss in forage maize and sorghum/biofuel reduction under the scenario assumptions in the area of the EU under assessment for *Spodoptera frugiperda*, as defined in the Pest Report?

What is the percentage yield loss in rice production under the scenario assumptions in the area of the EU under assessment for *Spodoptera frugiperda*, 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:

- The agricultural practice of flooding the field can have a high control effect on rice production, compared with maize production
- The first three instars cause < 2% of the total loss (in foliar area) produced by a larva during its whole development, while the 5th instar consumes 16.3% and the 6th instar 77.2% of the total loss (Sparks, 1979).
- The environmental impact that *S. frugiperda* could cause in the EU is assessed as “minimal” or “minor” by van der Gaag and van der Straten (2017).
- There is a likelihood of overestimation of the damage, particular on maize for forage use (the maize for biofuel is expected to have a same level of damage).
- In Spain, maize is treated against *Spodoptera exigua* and therefore these treatments are also expected to affect *S. frugiperda* populations, while the currently grown GMO maize in Spain would not work effectively due to resistance of *S. frugiperda* to Bt810.
- Sweetcorn is for human consumption and mainly grown in EU as an organic crop, with applications of *B. thuringiensis* to protect from Lepidoptera attacks.
- The level of impact increases if plants are stressed
- Heavy rain can remove the larvae from the plant or even kill them.
- Pers.comm R. Fleisher: *“…I work with vegetable crops in Pennsylvania, and have some knowledge of what to expect with Spodoptera frugiperda in northeastern and mid-Atlantic states. ….. We definitely have problems with S. frugiperda every year. Some years it arrives late, at a time when crops are being sprayed for other Lepidoptera such as Helicoverpa zea, and S. frugiperda may be controlled by those same sprays, so that this may mask some of the problem. But some years it arrives earlier, or in high numbers. We have a website, www.pestwatch.psu.edu where we've been trying to keep track of pheromone trap captures*….”
- In rice the infestations start at the borders. Larvae feed mainly on plantlets, before the rice field is flooded. The damages on this crop consist of severing the plant stems at the soil level, defoliation, and even attacks to flowers and inflorescences. In certain years, with high pest population levels, there can even be total loss of the crop (Busato et al., 2005). In flooded rice fields the infestations are limited to the parts of the plants above the water level (Bowling, 1978). Grützmacher et al. (1999) indicated that larvae favour water grass (*Echinochloa crus-galli*) and move to rice only after elimination of the weed. Botton et al. (1998) observed that this pest develops faster, with higher fertility and viability on water grass than on rice.

3.1.1.6. *Uncertainties identified*

- Early instars of many of the *Spodoptera* species are hard to distinguish from each other. Damage may have been attributed to the wrong *Spodoptera* species, for example to a species that was already known as a pest in the area or in the crop. In addition, damage is often reported as being caused by a *Spodoptera*-complex, consisting of more than one *Spodoptera* species. The true extent of the damage caused by the different *Spodoptera* species is therefore not always clear (van der Gaag and van der Straten, 2017).
- Gradient in damage from border to the area of establishment to area of original incursion
- Different control strategies from South to North of the EU
- Natural barriers to migration (e.g. the Alps)
- Not clear if current treatment regimes on sweet corn are effective against *S. frugiperda*
- Summary of aspects specific for sweet corn
    - In France a stable area of about 25,000 ha of sweet maize is grown, mostly in Aquitaine (Maizeurop). Hungary is the leading country in the EU with over 30,000 hectares in 2006.
    - Bt sprays are used in all sweet corn production
    - Damage is on cobs so 1% damage means 1 cob lost out of every 100
- Summary of aspects specific for rice:
    - the main evidence refers to an artificial infestation
    - cultural practices and period of production are different in the regions where this pest occurs

3.1.2. Elicited values for yield losses on sweet corn

What is the percentage yield loss for sweet corn production under the scenario assumptions in the area of the EU under assessment for *S. frugiperda*, as defined in the Pest Report?

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

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

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	1%	10%	15%	30%	50%

3.1.2.1. *Justification for the elicited values for yield loss on sweet corn*

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

- The upper limit reflects the expectation of high population densities and, due to its flight capacity and short generation time, widespread distribution in the EU sweet corn crop.

  - At high population densities the pest may also attack the cobs
  - The pest reaches all the production area by moving constantly
- If the application of Bt spray is targeted to other pests (e.g. *O. nubilalis*) it is not likely to be effective against *S. frugiperda*, e.g. due to wrong timing
- Being a high value crop, quality control is expected to be very strict and, if the infestation is high, all the crop may be abandoned
- Based on these factors, it is assumed that the high levels of yield loss could equal or exceed the high levels of impact recorded in the literature.

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

- Current control practices with Bt sprays work well, however it can easily be that a few individuals survive and cause damage, e.g. if treatment timing is not perfectly synchronised with the application of *S. frugiperda* control
- since sweet corn is a high value crop and yield losses are expected there will be careful control of the affected cobs.
- At low population abundance there is a limited chance that *S. frugiperda* attacks the cob: infestations start with the leaves and do not necessarily reach the cob.
- sweet corn production is mostly conducted without pesticides, and so the effect of natural enemies should also be taken into account.

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

Two main reasons:

- Efficacy of the current control option (Bt spray)
- Infestation is more likely to affect leaves instead of cobs

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

The precision is mainly driven by the uncertainty on the application of Bt spray (e.g. due to the timing). The uncertainty mainly concerns the right side of the curve.

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 sweet corn

Percentile	**1%**	**2.5 %**	**5%**	**10%**	**17%**	**25%**	**33%**	**50%**	**67%**	**75%**	**83%**	**90%**	**95%**	**97.5%**	**99%**
Expert elicitation	1%					10 %		15%		30%					50%
Fitted distributio n	0.8 %	1.5%	2.5 %	4.2 %	6.3 %	8.8%	11.4 %	16.9 %	23.6 %	27.9 %	33.3 %	39.5 %	46.8 %	53.2 %	60.3 %

Fitted distribution: BetaGeneral(1.4225,5.7789,0,1), @RISK7.5

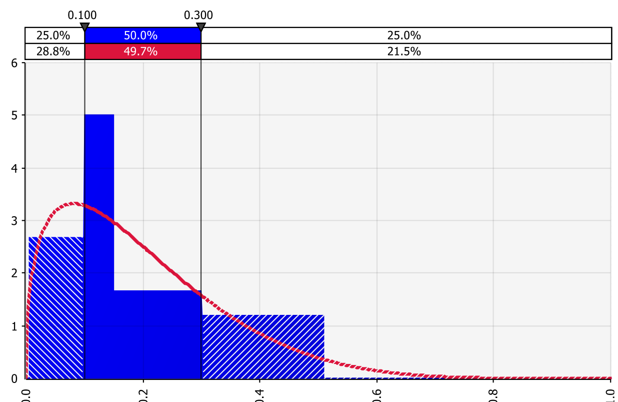

Figure 4 Comparison of judged values (histogram in blue) and fitted distribution (red line) for yield loss on sweet corn.

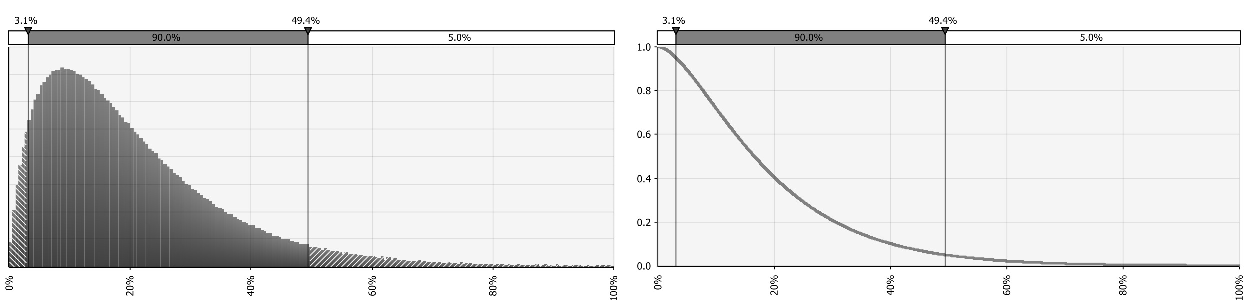

Figure 5 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for yield loss on sweet corn.

3.1.3. Elicited values for yield losses on grain maize and sorghum

What is the percentage yield loss in grain maize and sorghum production under the scenario assumptions in the area of the EU under assessment for *S. frugiperda*, as defined in the Pest Report?

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

Table 4: The 5 elicited values on yield loss (%) on sweet corn

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	1%	4%	7%	15%	30%

3.1.3.1. Justification for the elicited values for yield loss on grain maize and sorghum

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

- The pest reaches most of the area of grain maize production in the EU at the most susceptible stage
- The high population abundance affects both leaves and cobs
- Only one generation attacks each crop: the following generation of females flies to the next crop
- Treatments that are not targeted at *S. frugiperda* may not be fully effective (e.g. poor timing)

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

- Current control practices are effective against *S. frugiperda* (e.g. more effective insecticides)
- In the best case, treatments are expected to be applied at a higher frequency and with better timing
- The rejection rate is not as high as that for sweet corn
- the likelihood that *S. frugiperda* attacks the cob is not as high: infestations starting with the leaves do not necessarily reach the cob

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

- Current control practices are considered to be effective
- Infestation is more likely to affect the leaves than the cobs
- Some infestation of the cobs does not substantially affect yield (unlike with sweet corn)
- In the EU climatic conditions are less ideal than in Africa

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

There is more confidence around the median due to the following reasons:

- Irrigated crop are grown in the EU so there is no effect of drought
- Good efficacy of current control practices
- Recovery capacity.

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

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

Table 5: Fitted values of the uncertainty distribution on grain maize and sorghum

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	1%					4%		7%		15%					30%
Fitted distribution	0.3%	0.6%	1.0%	1.7%	2.7%	3.8%	5.1%	7.8%	11.4%	13.7%	16.9%	20.6%	25.4%	29.8%	35.2%

Fitted distribution: BetaGeneral(1.3057,12.028,0,1), @RISK7.5

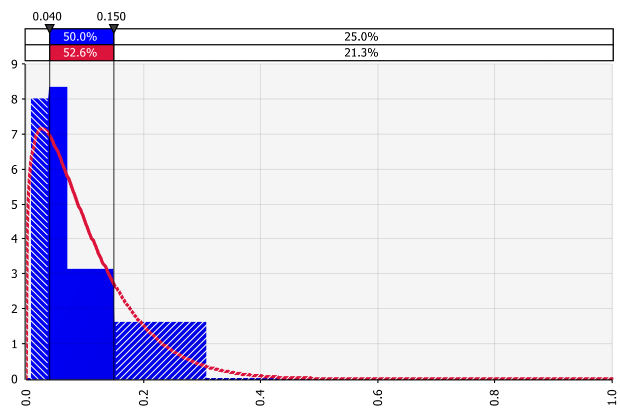

Figure 6 Comparison of judged values (histogram in blue) and fitted distribution (red line) for yield loss on grain maize and sorghum.

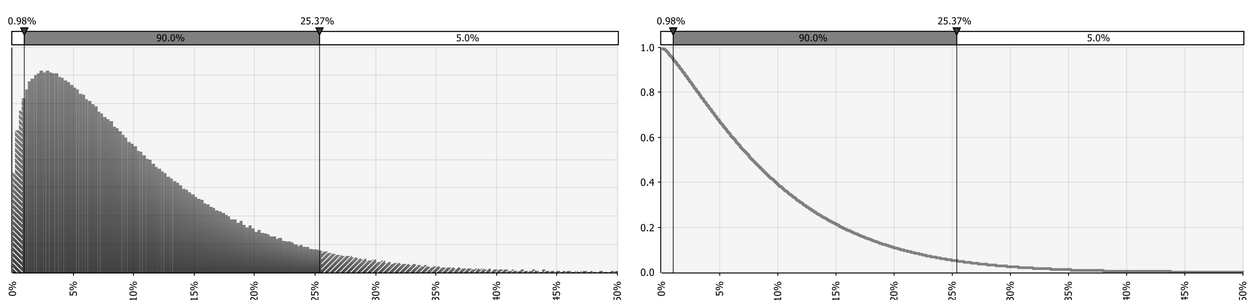

Figure 7 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for yield loss on grain maize and sorghum.

3.1.4. Elicited values for yield losses on forage maize and biofuel

What is the percentage yield loss in forage maize and sorghum/biofuel production under the scenario assumptions in the area of the EU under assessment for *S. frugiperda*, as defined in the Pest Report?

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

Table 6: The 5 elicited values on yield loss (%) on forage maize and biofuel

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	0.1%	2%	4%	6%	10%

3.1.4.1. Justification for the elicited values for yield loss on forage maize and biofuel

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

- Relative forage yield after defoliation (Lauer et al., 2004, figure 1 page. 1462) is taken into account: 50% defoliation rate would cause a yield loss not higher than 20%
- In Northern EU fewer treatments on maize are potentially effective against *S. frugiperda*
- Each crop will have one *S. frugiperda* generation associated with it: the following generation of females flies to the next crop

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

- Small population feeding on leaves
- Damage to leaves and its effect on relative forage yield (Lauer et al., 2004, figure 1 page. 1462) is compensated by other plant parts, that can still be used for forage/biofuel production
- Some impact on kernels would justify impact > 0%
- No detectable change in the yield

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

The central value is mainly due to the expected compensation for the damage on leaves.

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

The confidence around the median is mainly due to the effect of compensation that justifies the expected low yield loss.

3.1.4.2. Estimation of the uncertainty distribution for yield loss

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

Table 7: Fitted values of the uncertainty distribution on forage maize and biofuel

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	0.1%					2%		4%		6%					10%
Fitted distribution	0.3%	0.5%	0.7%	1.1%	1.6%	2.2%	2.7%	3.8%	5.1%	6.0%	7.0%	8.2%	9.8%	11.1%	12.8%

Fitted distribution: Weibull(1.5634,0.048331), @RISK7.5

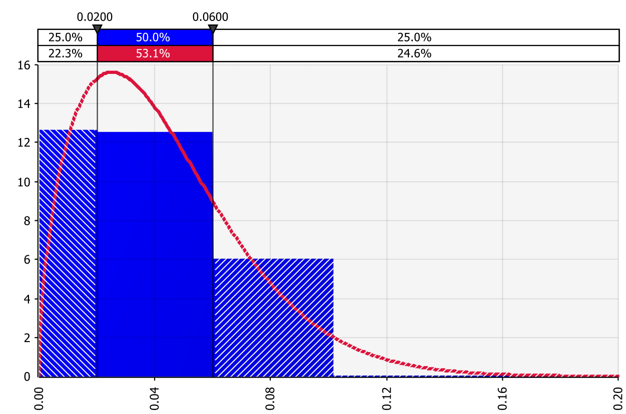

Figure 8 Comparison of judged values (histogram in blue) and fitted distribution (red line) for yield loss on forage maize and biofuel.

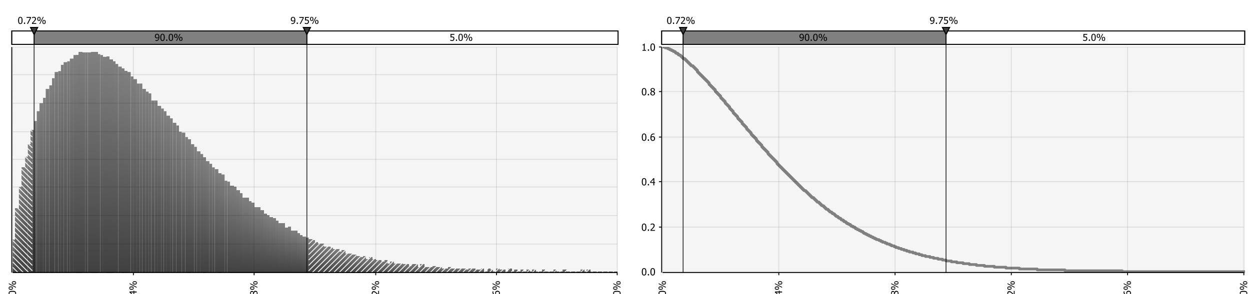

Figure 9 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for yield loss on forage maize and biofuel.

3.1.5. Elicited values for yield losses on rice

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

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

Table 8: The 5 elicited values on yield loss (%) on rice

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	1%	4%	7%	12%	20%

3.1.5.1. Justification for the elicited values for yield loss on rice

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

- where populations move particularly fast and therefore reach the rice fields at a very early growth stage
- the crop is grown as a monoculture

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

- Late arrival of the pest in the field: the vulnerable stage of the crop are not attacked

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

- Most of the rice production zones are close to maize fields where *S. frugiperda* is likely to prefer maize (e.g. Andalucia)
- EU zones of rice production are closer to the area of potential establishment of *S. frugiperda*, compared to maize

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

The maximum uncertainty is around the lower range (values below the median).

3.1.5.2. Estimation of the uncertainty distribution for yield loss

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

Table 9: Fitted values of the uncertainty distribution on rice

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	1%					4%		7%		12%					20%
Fitted distribution	0.44 %	0.82 %	1.30 %	2.09 %	3.00 %	4.04 %	5.07 %	7.22 %	9.77 %	11.39 %	13.49 %	15.91 %	18.92 %	21.70 %	25.12 %

Fitted distribution: Weibull(1.5186,0.091882), @RISK7.5

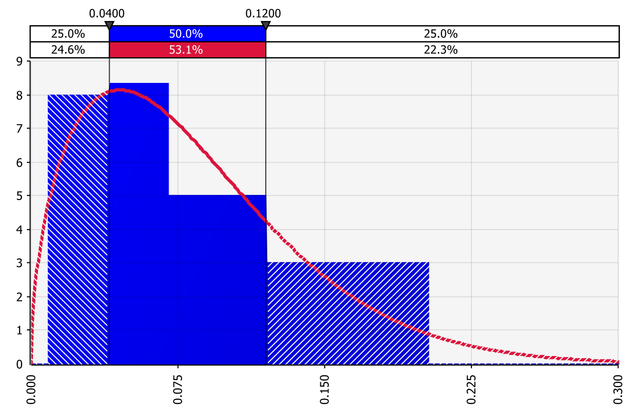

Figure 10 Comparison of judged values (histogram in blue) and fitted distribution (red line) for yield loss on rice.

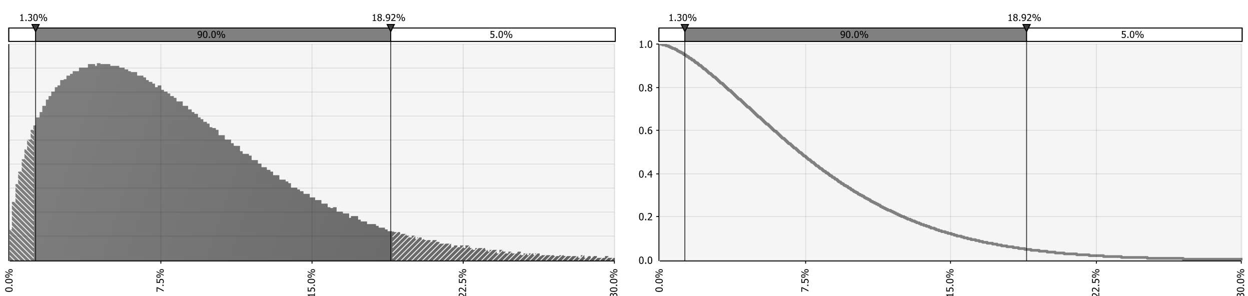

Figure 11 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for yield loss on rice.

3.1.6. Conclusions on yield losses

Based on the general and specific scenario considered in this assessment, the percentage yield losses (here with the meaning of proportion of production lost due to larval infestation at harvest) is estimated to be

- 17% (with a 95% uncertainty range of 1.5-53%) in sweet corn
- 8% (with a 95% uncertainty range of 0.6-30%) in grain maize and sorghum
- 4% (with a 95% uncertainty range of 0.5-11%) in forage maize and biofuel
- 7% (with a 95% uncertainty range of 0.8-22%) in rice

Quality losses have not been included in the assessment because they are considered as full losses and included under the assessment of 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

- The initial outbreak is in an area of potential establishment that, in the case of *S. frugiperda* could parts be southern EU, where the pest is expected to overwinter
- The timing of the outbreak influences the opportunity for migration and further spread
- Maximum spread corresponds to the average maximum distance covered in one year in the area of potential establishment
- The phenomenon of reverse migration is not considered in this assessment
- Number of generations in one year is assumed to be six (see Figure 2)?

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 few general points were made:

- information has been taken from the section on spread in EFSA PLH Panel, 2018
- The speed and direction of flights is primarily dictated by wind vectors (Srygley and Dudley, 2008)
- Summer Mediterranean winds are not favorable for flights in a northerly direction http://www.ancientportsantiques.com/ancient-port-structures/design-waves/
- Pers.comm R. Fleisher: ".. *We definitely have problems with S. frugiperda every year. Some years it arrives late, at a time when crops are being sprayed for other lepidoptera such as Helicoverpa zea, and S. frugiperda may be controlled by those same sprays, so that may mask some of the problem. But some years it arrives earlier, or in high numbers*. …"

3.2.1.6. Uncertainties identified

- Boundaries of the overwintering area

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

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	250	700	900	1,200	1,500

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 takes into account the fact that the area of potential establishment is not the whole EU but only part of it and assumes that favourable winds are present.

North America experience is 2,000 km/year, assuming an early infestation, with presence of favourable winds: the EU upper limit is expected not to reach such a high value.

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

The lower value of spread rate is based on a limited distribution of suitable areas, unfavourable winds and no flights across the Mediterranean Sea.

- only one single flight from the area of potential establishment;
- an absence of knowledge of wind patterns
- the outbreak happens late in the year
- the outbreak is isolated and long distance dispersal is not successful.

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

The median value is because the maximum distance could be higher but the maximum distance of within the area of potential establishment is more limited. Long distance dispersal is balanced by the availability of the area.

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

The precision is given by the uncertainty in the higher values. The group is more confident in the precision of the median regarding lower distances due to the migratory behaviour of this species, which favours long distance flights.

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 11: 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	250					700		900		1,200					1,500
Fitted distribution	254	313	379	475	573	675	766	932	1,094	1,179	1,271	1,357	1,437	1,489	1,533

Fitted distribution: BetaGeneral(2.1172,1.8547,150,1600), @RISK7.5

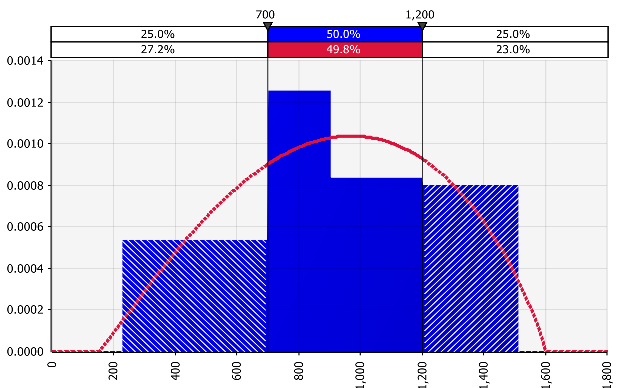

Figure 12 Comparison of judged values (histogram in blue) and fitted distribution (red line) for spread rate.

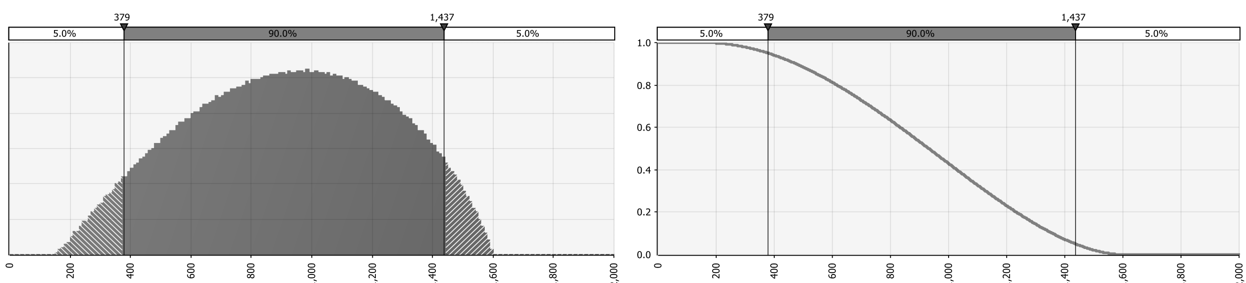

Figure 13 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for spread rate.

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 *S. frugiperda* is around 900 km (with a 95% uncertainty range of 300-1,500 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

- The initial outbreak is in an area of potential establishment in *s*outhern EU, where the pest is expected to overwinter
- The timing of the outbreak influences the opportunity for migration and further spread
- up to 6 generations could occur per year (see Figure 2) based on the available degree days for development

3.3.1.3. Selection of the parameter(s) estimated

The time for detection has been assessed as the number of days 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: days)

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 the time to detection.

3.3.1.6. Uncertainties identified

- All stages, including the adults, may easily be overlooked by growers, due to the resemblance with other Noctuid species present in Europe. In particular, adult females have a faint pattern, which would only attract the attention of specialized collectors and diagnosticians. Without a specific monitoring program for the species, it may take several weeks or longer before an outbreak is detected (and maybe even longer before it is reported to the authorities (depending on the amount of damage caused)).
- To what extent are species-specific pheromone traps used in the Mediterranean member states (MSs) compared to light traps?

- Level of awareness about this pest among MSs
- To find an adult in a trap doesn't mean that there is an established outbreak since it could be a transient population

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: days)

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

Table 12: Summary of the 5 elicited values on time to detection (days)

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	10	60	90	150	240

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 is given not only by the duration of a crop cycle, but also to the different level of attention in looking for this pest depending on the type of hosts (different attention for green maize compared to maize for human consumption). Delays will also occur because: during the winter when population densities may be low, detection in the field may depend on further spread in order to have a wider area affected, insufficient trapping and low awareness.

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

The lower value with rapid detection is due to the deployment of many pheromone traps at the right period of the year.

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

The median value is related to the minimal duration of one production cycle, by the end of which the presence of *S. frugiperda* should have been identified.

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

The precision is mainly driven by the higher confidence in the median than in the extreme values.

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

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

Table 13: Fitted values of the uncertainty distribution on the time to detection (days)

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	10					60		90		150					240
Fitted distribution	8	14	21	32	44	57	70	95	125	143	166	192	224	253	288

Fitted distribution: Weibull(1.7097,118.06), @RISK7.5

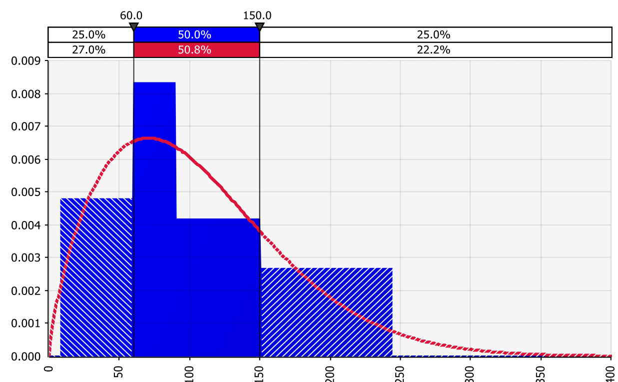

Figure 14 Comparison of judged values (histogram in blue) and fitted distribution (red line) for time to detection.

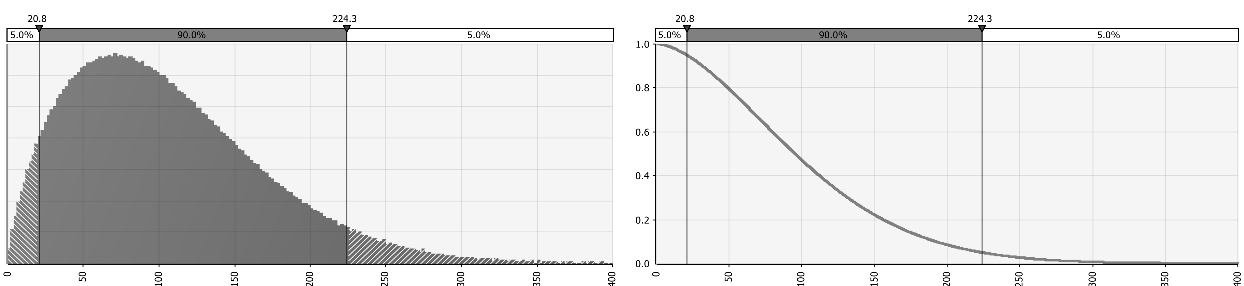

Figure 15 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for time to detection.

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 approximately 3 months (with a 95% uncertainty range of 0.5-8 months).

4. Conclusions

Hosts selection

The complete list of hosts is produced by merging

- the list of host plants defined by EPPO (EPPO, online),
- the list of host species reported by CABI (CABI, 2019)
- the list of species reported in van der Gaag and van der Straten (2017).

The host on which the impact is assessed are

- sweet corn
- grain maize and sorghum
- maize and sorghum used for forage and biofuel production
- rice

Area of potential distribution

Based on the available information on the life history strategies of the species (survival, development and reproduction) and the scenario assumptions introduced for assessing the area of potential distribution we conclude that

- the species can have permanent populations only in southern areas of Europe with the warmest winters: Portugal, Spain, Italy, Malta, Greece and Cyprus. The area of potential establishment corresponds to the area where the species has 5 or more generations per year according to the model from Ramirez-Garcia et al. (1987) and run with JRC climatic data for the period 1997-2017.
- *S. frugiperda* can have transient populations in the EU (the species has a 99° quantile of the estimated spread rate higher than the threshold value f 100 km/year). The 99° quantile of the estimated spread rate is in the order of 1,500 km/year. The area with potential transient populations is calculated as an expansion of the area of potential establishment by a radius of 1,500 km/year the area of potential distribution from its border. The area of potential distribution corresponds to the area of potential establishment plus the area where transient population can occur.

Increased number of treatments

This pest belongs to Case "C" and category "1" due to the availability of effective plant protection products currently applied on maize fields which would require an increasing number of applications or type of products in order to ensure their efficacy against *S. frugiperda*.

Yield and quality losses

Based on the general and specific scenario considered in this assessment, the percentage of yield losses (here with the meaning of proportion of fruits lost due to premature dropping and to unmarketable fruits due to larval infestation at harvest) is estimated to be

- 17% (with a 95% uncertainty range of 1.5-53%) on sweet corn
- 8% (with a 95% uncertainty range of 0.6-30%) on grain maize and sorghum
- 4% (with a 95% uncertainty range of 0.5-11%) on forage maize and biofuel
- 7% (with a 95% uncertainty range of 0.8-22%) on rice

Quality losses have not been included in the assessment because they are considered as full losses and are included under the assessment of 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 *S. frugiperda* is around 900 km (with a 95% uncertainty range of 300-1,500 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 approximately 3 months (with a 95% uncertainty range of 0.5-8 months).

5. References

Abrahams P, Beale T, Cock M, Corniani N, Day R, Godwin J, Murphy S, Rochard G and Vos J, 2017. Fall armyworm status. Impacts and control options in Africa: preliminary evidence note (April 2017). Report by Department for International Development and CABI. Available online: http://www.cabi.org/Uploads/isc/Dfid%20Faw%20Inception%20Report28apr2017final.pdf

Aguirre LA, Hernández-Juàrez A, Flores M, Cerna E, Landeros J, Frías GA and Harris MK, 2016. Evaluation of foliar damage by *Spodoptera frugiperda* (Lepidoptera: Noctuidae) to genetically modified corn (Poales: Poaceae) in Mexico. Florida Entomologist, 99, 276-281.

Ali A, Luttrell RG and Schneider JC, 1990. Effects of temperature and larval diet on development of the fall armyworm (Lepidoptera: Noctuidae). Annals of the Entomological Society of America, 83, 725–733.

Anderson D and Cherry R, 1983. Fall armyworm (Lepidoptera: Noctuidae) damage to fifteen varieties of sorghum. Florida Entomologist, 66, 506-510.

Ashley TR, Wiseman BR, Davis FM and Andrews KL, 1989. The fall armyworm: a bibliography. Florida Entomologist, 72, 152–202. doi: 10.2307/3494982

Barfield CS, Mitchell ER and Poeb SL, 1978. A temperature-dependent model for fall armyworm development 1,2. Annals of the Entomological Society of America, 71, 70–74. doi: 10.1093/aesa/71.1.70

Belay DK, Huckaba RM and Foster JE, 2012. Susceptibility of the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), at Santa Isabel, Puerto Rico, to different insecticides. Florida Entomologist, 95, 476–478.

Blanco CA, Chiaravalle W, Dalla-Rizza M, Farias JR, Garcia-Degano MF, Gastaminza G, Mota-Sânchez D, Maruia MG, Omoto C, Pieralis BK, Rodriguez J, Rodriguez-Maciel JC, Terán-Santofimio H, Terán-Vargas AP, Valencia SJ and Wilink E, 2016. Current situation of pests targeted by Bt crops in Latin America. Current Opinion in Insect Science, 15, 131-138.

Botton M, Carbonari JJ, Garcia MS, Martins JFS, 1998. Feeding preference and biology of *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) on rice and barnyard grass. Anais da Sociedade Entomológica do Brasil 27, 207-212. (in Portuguese, with abstract in English).

Bowling CC, 1978. Simulated insect damage to rice: effect of leaf removal. Journal of Ecological Entomology, 71, 377-378.

Brevault et al. 2018. First records of the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), in Senegal. Entomologia Generalis 37, 129 – 142.

Buntin, G. 2009. Sorghum insect pests and their management. University of Georgia Bulletin, 1283.

Busato GR, Grützmacher AD, Garcia MS, Giolo FP, Zotti MJ and BandeiraJdM, 2005. Exigências térmicas e estimativa do número de gerações dos biótipos "milho" e "arroz" de *Spodoptera frugiperda*. Pesquisa Agropecuária Brasileira, 40, 329-335.

CABI (Centre for Agriculture and Bioscience International), 2019. Datasheet report for *Spodoptera frugiperda* (fall armyworm). Crop Protection Compendium. Last modified 23 April 2019. Available online: https://www.cabi.org/cpc/datasheet/29810.

Cano-Calle D, Arango-Izada RE and Saldamando-Benjumea CI, 2015. Molecular identification of *Spodoptera frugiperda* (Lepidoptera:Noctuidae) corn and rice strains in colombia by using a PCR-RFLP of the mitochondrial gene cytochrome oxydase I (COI) and a PCR of the gene FR (For Rice). Annals of the entomological society of America, 108, 172-180.

Carvalho RPL, 1970. Danos, flutuação da população, controle e comportamento de *Spodoptera frugiperda* (J.E. Smith, 1797) e suscetibilidade de diferentes genótipos de milho, em condições de campo. PhD Thesis, Piracicaba: ESALQ. 170pp.

Chamberlin JR and All JN, 1991. Grain sorghum response to fall armyworm and corn earworm infestation. Journal of Economic Entomology, 84, 619-624.

Cruz I and Turpin FT, 1983. Yield impact of larval infestations of fall armyworm (Lepidoptera: Noctuidae) to midwhorl growth stage of corn. Journal of Economic Entomology, 76, 1052–1054.

da Silva DM, Bueno AD, Andrade K, Stecca CD, Neves PMOJ and de Oliveira MCN, 2017. Biology and nutrition of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) fed on different food sources. Scientia Agricola, 74, 18–31. doi: 10.1590/1678-992X-2015-0160

Dequech STB, Camera C, Sturza VS, Ribeiro LD, Querino RB and Poncio S, 2013. Population fluctuation of *Spodoptera frugiperda* eggs and natural parasitism by *Trichogramma* in maize. Acta Scientiarum-Agronomy, 35, 295–300. doi:10.4025/actasciagron.v35i3.16769.

du Plessis H, van den Berg J, Kriticos DJ and Ota N, 2018. *Spodoptera frugiperda*. CSIRO-InSTePP PestGeography. Canberra

Early et al 2018. Forecasting the global extent of invasion of the cereal pest *Spodoptera frugiperda*, the fall armyworm. Preprint: http://dx.doi.org/10.1101/391847

Early R, Gonzalez-Moreno P, Murphy ST and Day R, 2018. Forecasting the global extent of invasion of the cereal pest *Spodoptera frugiperda*, the fall armyworm. NeoBiota 40, 25–50.

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), Jeger M, Bragard C, Caffier D, Candresse T, Chatzivassiliou E, Dehnen-Schmutz K, Gilioli G, Grégoire J-C, Jaques Miret JA, Navarro MN, Niere B, Parnell S, Potting R, Rafoss T, Rossi V, Urek G, Van Bruggen A, Van der Werf W, West J, Winter S, Gardi C, Aukhojee M and MacLeod A, 2017. Scientific Opinion on the pest categorisation of *Spodoptera frugiperda*. EFSA Journal 2017;15(7):4927, 32 pp. https://doi.org/10.2903/j.efsa.2017.4927

EFSA PLH Panel (EFSA Panel on Plant Health), Jeger M, Bragard C, Caffier D, Candresse T, Chatzivassiliou E, Dehnen-Schmutz K, Gilioli G, Grégoire J-C, Jaques Miret JA, Navarro MN, Niere B, Parnell S, Potting R, Rafoss T, Rossi V, Urek G, Van Bruggen A, Van der Werf W, West J, Winter S, Day R, Early R, Hruska A, Nagoshi R, Gardi C, Mosbach-Schultz O and MacLeod A, 2018. Scientific Opinion on the pest risk assessment of *Spodoptera frugiperda* for the European Union. EFSA Journal 2018; 16(8):5351, 120 pp. https://doi.org/10.2903/j.efsa.2018.5351

EPPO (European and Mediterranean Plant Protection Organization), online. EPPO Global Database. Available online: https://www.eppo.int/ [Accessed: 14 May 2019]

EPPO, 2015. PM 7/124 (1) *Spodoptera littoralis*, *Spodoptera litura*, *Spodoptera frugiperda*, *Spodoptera eridania*. Bulletin OEPP/EPPO Bulletin, 45, 410–444.

FAO (Food and Agriculture Organization of the United Nations), 2018. Integrated management of the fall armyworm on maize – A guide for Farmer Field Schools in Africa. Rome, 2018, 127 pp. Available online: http://www.fao.org/3/I8665EN/i8665en.pdf

Farias PRS, Barbosa JC, Busoli AC, Overal WL, Miranda VS and Ribeiro SM, 2008. Spatial analysis of the distribution of *Spodoptera frugiperda* (JE Smith) (Lepidoptera, Noctuidae) and losses in maize crop productivity using geostatistics. Neotropical Entomology, 37, 321-327.

Fernandes FL, Diniz JFS, Alves FM and Silva LOD, 2011. Injury and spatial distribution of *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) in onion *Allium cepa* (Alliaceae) in Alto Paranaiba, Minas Gerais, Brazil. Entomological News, 122, 257-260.

Figueiredo MLC, Penteado-dias AM and Cruz I, 2005. Danos provocados por *Spodoptera frugiperda* na produção de matéria seca e nos rendimentos de grãos, na cultura do milho. Sete Lagoas: Embrapa/CNPMS, 2005. 6 p. (Comunicado Técnico, 130).

Goergen G, Kumar PL, Sankung SB, Togola A and Tamò M, 2016. First report of outbreaks of the fall armyworm *Spodoptera frugiperda* (J E Smith) (Lepidoptera, Noctuidae), a new alien invasive pest in West and Central Africa. PLoS ONE, 11, e0165632. https://doi.org/10.1371/journal.pone.0165632

Grützmacher AD, 1999. Foliage consumption by *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) on irrigated rice cultivars. Anais da Sociedade Entomológica do Brasil, 28, 519-525.

Herrington D, Schuster G, Lewis A and Porter P, 2013. Mycotoxin Levels in Infested Corn Associated with Fall Armyworm (*Spodoptera frugiperda*) and Corn Earworm (*Helicoverpa zea*). Subtropical Agriculture and Environments. Abstracts Presented in 2013 Meeting. Available online: http://www.subplantsci.org/journal/abstracts/2013-abstracts/

Hogg D, Pitre HN and Anderson RE, 1982. Assessment of early-season phenology of the fall armyworm (Lepidoptera: Noctuidae) in Mississippi [*Spodoptera frugiperda*]. Environmental entomology, 11, 705-710.

IITA (International Institute of Tropical Agriculture), 2016. First report of outbreaks of the “Fall Armyworm” on the African continent. IITA Bulletin, No. 2330. Available online:

Johnson SJ, 1987. Migration and the life history strategy of the fall armyworm, *Spodoptera frugiperda* in the Western Hemisphere. Insect Science Application 8 (4/5/6), 543–549.

Juárez ML, Murúa MG, García MG, Ontivero M, Vera MT, Vilardi JC, Groot AT, Castagnaro AP, Gastaminza G and Willink E, 2012. Host association of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) corn and rice strains in Argentina, Brazil, and Paraguay. Journal of Economic Entomology, 105, 573–582.

Lauer JG, Roth GW and Bertram MG, 2004. Impact of defoliation on corn forage yield. Agronomy Journal 96, 1459–1463.

Lima MS, Silva PSL, Oliveira OF, Silva KMB and Freitas FLC, 2010. Corn yield response to weed and fall armyworm controls. Planta Daninha 28, 103–111.

Luginbill P, 1928. The fall armyworm. USDA Technical Bulletin, 34, 1–91

Meissle M, Mouron P, Musa T, Bigler F, Pons X, Vasileiadis VP, Otto S, Antichi D, Kiss J, Palinkas Z, Dorner Z, van der Weide R, Groten J, Czembor E, Adamczyk J, Thibord JB, Melander B, Cordsen Nielsen G, Poulsen RT, Zimmermann O, Verschwele A and Oldenburg E, 2010. Pests, pesticide use and alternative options in European maize production: current status and future prospects. Journal of Applied Entomology, 134, 357–375.

Mello Filho GA and Richetti A, 1997. Aspectos socioeconômicos da cultura do milho. In: Embrapa. Milho: informações técnicas, Dourados, 1997. p. 162-164.

Mitchell ER, Mcneil JN, Westbrook JK, Silvain JF, Lalannecassou B and Chalfant RB, 1991. Seasonal periodicity of fall armyworm, (Lepidoptera: Noctuidae) in the Caribbean basin and northward to Canada. Journal of Entomological Science, 26, 39–50.

MSU (Michigan State University), online. *Spodoptera frugiperda*. Arthropod Pesticide Resistance Database. Available online: https://www.pesticideresistance.org/display.php?page=species&arId=200 [Accessed: 02 June 2019]

Nagoshi RN and Meagher RL, 2008. Review of fall armyworm (Lepidoptera: Noctuidae) genetic complexity and migration. Florida Entomologist, 91, 546-554.

Nagoshi RN, Goergen G, Tounou KA, Agboka K, Koffi D and Meagher RL, 2018. Analysis of strain distribution, migratory potential, and invasion history of fall armyworm populations in northern Sub-Saharan Africa. Scientific Reports, 8, 3710. doi: 10.1038/s41598-018-21954-1

Pannuti LER, Paula-Moraes SV, Hunt TE, Baldin ELL, Dana L and Malaquias JV, 2016. Plant-to-plant movement of *Striacosta albicosta* (Lepidoptera: Noctuidae) and *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in Maize (*Zea mays*). Journal of Economic Entomology, 109, 1125–1131. doi: 10.1093/jee/tow042.

Pantoja A, Smith CM and Robinson JF, 1986. Effects of the fall armyworm (Lepidoptera: Noctuidae) on rice yields. Journal of Economic Entomology, 79, 1324–1329.

Peairs FB and Saunders JL, 1981. Plant damage and yield response to *Diatraea saccharalis* and *Spodoptera frugiperda* in section cycles of two tropical maize populations in Mexicol. Turrialba, 31, 55-62.

Pogue MG, 2002. A world revision of the genus *Spodoptera* (Guenee) (Lepidoptera: Noctuidae). Memoirs of the American Entomological Society, 43, 212 pp.

Ramirez-Garcia L, Bravo Mojica H and Llanderal Cazares C, 1987. Development of *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) under different conditions of temperature and humidity. Agrociencia, Mexico, 67, 16l–171.

Rose AH, Silversides RH and Lindquist OH, 1975. Migration flight by an aphid, *Rhopalosiphum maidis* (Hemiptera: Aphididae) and a noctuid, *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Canadian Entomologist, 107, 567-576.

Schlemmer, M. 2018. Effect of temperature on development and reproduction of *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Thesis for Masters in Environmental Science at the North-West University, Potchefstroom, South Africa.

Smith IM, McNamara DG, Scott PR and Holderness M, 1997. *Spodoptera frugiperda*. In Quarantine Pests for Europe, 2nd Edn., CABI/EPPO, Wallingford. pp. 1425.

Sosa MA, 2002. Daño por *Spodoptera frugiperda* (Lepidoptera: Noctuidae) en maíz bajo siembra directa en diferentes épocas en el noreste santafesino. Comunicaciones Científicas y Tecnológicas 2002. Available online: www.unne. edu.ar/cyt/2002/cyt.htm

Sparks AN, 1979. A review of the biology of the fall armyworm. Florida Entomologist, 62, 82;87. doi: 10.2307/3494083

Srygley RB and Dudley R, 2008. Optimal strategies for insects migrating in the flight boundary layer: mechanisms and consequences. Integrative and Comparative Biology, 48, 119–133.

Stout MJ, Riggio MR and Yang Y, 2009. Direct induced resistance in *Oryza sativa* to *Spodoptera frugiperda*. Environmental entomology, 38, 1174-1181.

Szwarc D, Vitti Scarel D and Almada MS, 2015. Daño de gusanos “cogollero” y “de la espiga” en maíces Bt, en dos fechas de siembra; Instituto Nacional de Tecnología Agropecuaria; Voces y Ecos, 34, 42-44.

Thomison PR, Nafziger ED, Coulter JA, Zarnstorff ME, Geyer AB and Lindsey AJ, 2016. Response of Corn to Multiple Defoliation Events. Poster Number 165-1520 at “Resilience Emerging from Scarcity and Abundance” 6-9 November 2016, Phoenix.

Tumlinson JH, Mitchell ER, Teal PE, Heath RR and Mengelkoch LJ, 1986. Sex pheromone of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) : Identification of components critical to attraction in the field. Journal of Chemical Ecology, 12, 1909–1926.

Unbehend M, Hanniger S, Vasquez GM, Juarez ML, Reisig D, McNeil JN and Groot AT, 2014. Geographic variation in sexual attraction of *Spodoptera frugiperda* corn-and rice-strain males to pheromone lures. PLoS One, 9, e89255.

Valdez-Torres JB, Soto-Landeros F, Osuna-Enciso T and Báez-Sañudo MA, 2012. Modelos de predicción fenológica para maíz blanco (*Zea mays* L.) y gusano cogollero (*Spodoptera frugiperda* JE Smith). Agrociencia, 46, 399-410.

van der Gaag DJ and van der Straten M, 2017. Assessment of the potential impact of American *Spodoptera* species for the European Union. November 2017. Netherlands Food and Consumer Product Safety Authority (NVWA), Utrecht, Catharijnesingel 59, 3511 GG Utrecht, the Netherlands.

Van Handel E, 1974. Lipid utilization during sustained flight of moths. Journal of Insect Physiology, 20, 2329-2332.

Westbrook JK, Nagoshi RN, Meagher RL, Fleischer SJ and Jairam S, 2016. Modeling seasonal migration of fall armyworm moths. International journal of biometeorology, 60, 255-267.

Wiseman BR and Isenhour DJ, 1992. Relationship of planting dates and earworm developmental parameters and injury to selected maize entries. Maydica, 37, 149-156.

Wiseman BR and Morrison WP, 1981. Components for management of field corn and grain sorghum insects and mites in the United States. USDA-ARS ARM-S-18. 18p.

Wood JR, Poe SL and Leppla NC, 1979. Winter survival of fall armyworm 1 pupae in Florida. Environmental Entomology, 8, 249–252. doi: 10.1093/ee/8.2.249

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**
Abelmoschus	*esculentus*
Acalypha	
Agrostis	
Agrostis	*gigantea*
Agrostis	*stolonifera*
Alcea	*rosea*
Allium	
Allium	*cepa*
Allium	*sativum*
Amaranthus	
Amaranthus	*quitensis*
Amaranthus	*spinosus*
Andropogon	*virginicus*
Arachis	*hypogaea*
Asclepias	
Asparagus	*officinalis*
Asplenium	*nidus*
Atropa	*belladonna*
Avena	*sativa*
Avena	*strigosa*
Beta	
Beta	*vulgaris*
Brassica	
Brassica	*napus*
Brassica	*oleracea*
Brassica	*rapa*
Brassicaceae	
Cajanus	*cajan*
Capsicum	
Capsicum	*annuum*
Capsicum	*frutescens*
Carduus	
Carex	

Carica	*papaya*
Carya	
Carya	*illinoinensis*
Cenchrus	*incertus*
Chenopodium	*album*
Chenopodium	*quinoa*
Chloris	*gayana*
Chrysanthemum	
Chrysanthemum	*morifolium*
Cicer	*arietinum*
Cichorium	*intybus*
Citrullus	*lanatus*
Citrus	*aurantium*
Citrus	*limon*
Citrus	*reticulata*
Citrus	*sinensis*
Codiaeum	*variegatum*
Coffea	*arabica*
Convolvulus	
Convolvulus	*arvensis*
Cucumis	*melo*
Cucumis	*sativus*
Cucurbita	*argyrosperma*
Cucurbita	*maxima*
Cucurbitaceae	
Cydonia	*oblonga*
Cynara	*cardunculus*
Cynodon	*dactylon*
Cyperus	*rotundus*
Dactyloctenium	*aegyptium*
Dahlia	*pinnata*
Dendranthema	
Dendranthema	*grandiflorum*
Dianthus	
Dianthus	*caryophyllus*
Digitaria	
Digitaria	*sanguinalis*
Echinochloa	*colona*
Echinochloa	*crus*
Eleusine	*indica*
Elymus	*repens*
Eremochloa	*ophiuroides*
Eriochloa	*punctata*

Eryngium	*foetidum*
Eucalyptus	
Eucalyptus	*camaldulensis*
Eucalyptus	*urophylla*
Fagopyrum	*esculentum*
Festuca	*arundinacea*
Ficus	
Fragaria	*ananassa*
Fragaria	*chiloensis*
Fragaria	*vesca*
Gladiolus	
Gladiolus	*hybrids*
Glycine	*max*
Gossypium	
Gossypium	*herbaceum*
Gossypium	*hirsutum*
Helianthus	*annuus*
Hevea	*brasiliensis*
Hibiscus	*cannabinus*
Hordeum	*vulgare*
Ipomoea	
Ipomoea	*batatas*
Ipomoea	*purpurea*
Lactuca	*sativa*
Lespedeza	*bicolor*
Linum	*usitatissimum*
Lolium	*multiflorum*
Malpighia	*glabra*
Malus	*domestica*
Mangifera	*indica*
Maranta	
Medicago	*sativa*
Megathyrsus	*maximus*
Melilotus	*albus*
Miscanthus	*giganteus*
Momordica	
Mucuna	*pruriens*
Musa	
Musa	*paradisiaca*
Nicotiana	*tabacum*
Oryza	*sativa*
Panicum	
Panicum	*miliaceum*

Panicum	*virgatum*
Paspalum	
Paspalum	*dilatatum*
Paspalum	*distichum*
Paspalum	*fimbriatum*
Paspalum	*notatum*
Paspalum	*urvillei*
Passiflora	
Passiflora	*laurifolia*
Pelargonium	
Pennisetum	*clandestinum*
Pennisetum	*glaucum*
Phalaris	*canariensis*
Phaseolus	
Phaseolus	*lunatus*
Phaseolus	*vulgaris*
Phleum	*pretense*
Pinus	
Pinus	*caribaea*
Piper	
Pisum	*sativum*
Platanus	*occidentalis*
Plumeria	
Plumeria	*rubra*
Poa	*annua*
Poa	*pratensis*
Poaceae	
Portulaca	*oleracea*
Prunus	*persica*
Psidium	*guajava*
Pueraria	*montana*
Pyrus	*communis*
Raphanus	
Raphanus	*sativus*
Ricinus	*communis*
Rosa	
Saccharum	*officinarum*
Schlumbergera	*truncata*
Secale	*cereale*
Sesamum	*indicum*
Setaria	*italica*
Setaria	*parviflora*
Setaria	*viridis*

Solanum	
Solanum	*aethiopicum*
Solanum	*lycopersicum*
Solanum	*macrocarpon*
Solanum	*melongena*
Solanum	*tuberosum*
Sorghum	
Sorghum	*bicolor*
Sorghum	*caffrorum*
Sorghum	*halepense*
Sorghum	*sudanense*
Spinacia	*oleracea*
Tanacetum	*cinerariifolium*
Taraxacum	*officinale*
Terminalia	*catappa*
Trifolium	
Trifolium	*incarnatum*
Trifolium	*pratense*
Trifolium	*repens*
Triticum	
Triticum	*aestivum*
Turfgrasses	
Urochloa	
Urochloa	*decumbens*
Urochloa	*mutica*
Urochloa	*ramosa*
Urochloa	*texana*
Vaccinium	
Vaccinium	*corymbosum*
Vegetable	*plants*
Vicia	*faba*
Vigna	*unguiculata*
Viola	
Vitis	
Vitis	*vinifera*
Wisteria	*sinensis*
Xanthium	*strumarium*
Zea	*mays*
Zingiber	*officinale*
Zoysia	

Appendix B – Evidence tables

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

Susceptibility	Infestation	Symptoms	Impact	Additional information	Reference	Uncertainties
	Incidence	***Severity***	***Losses***			
Corn at the midwhorl growth stage (10-leaf stage)	Artificial infestation with egg masses on 5, 10, 15, 20, 100% of the plants	Egg masses: on 20% plants → 13.6% reduction in number of kernels on 100% plants→ 13.9% reduction in number of kernels	Egg masses: on 20% plants → 17% yield reduction on 100% plants→ 17% yield reduction	Indiana (US) 2 consecutive years Linear relation between leaf damage rating and the resulting number of kernels	Cruz and Turpin, 1983	Not recent data: not relevant compared to more recent studies
Corn			19-21 % depending from sowing month The damage increases with delaying the sowing date	Argentina No treatments	Sosa, 2002	
Corn			depending from sowing month ○ 85-93 % on corn ○ 44-65% on Bt corn The damage increases with delaying the sowing date	Argentina	Szwarc et al., 2015	
Grain maize			Yield reduction up to 34%.		Lima et al., 2010	Source not cited: most probably Carvalho 1970
Grain maize			At the 30 days of development → 15% At flowering → 34%	Brazil Level of damage influenced by the development phase of the plant at the moment of the attack	Mello Filho and Richetti, 1997 citing Carvalho, 1970	
Corn			20% estimated losses of the	Sub-Saharan Africa	Abrahams et	It is an estimation:

			total production for the region		al., 2017	excluded
Corn			Variability in yields within the study area not significantly correlated with number of caterpillars		Farias et al., 2008	
Grain maize		Plant stand and leaf feeding significantly affected but not significantly correlated to yield	Average loss 13% Max loss 30%	Mexico 2 varieties x 4 selection cycles	Peairs and Saunders, 1981	
Corn			2%: estimated annual loss of field corn crop in the US	US	Wiseman and Morrison, 1981	Source: US Agricultural Research Service 1976 Probably the estimation is done considering the control already in place against *S. frugiperda*. Probably not reflecting current agricultural practices in the US
Grain maize	Each plant artificially infested with 40 or 80 larvae	reductions in ear and plant height and yield significant differences among hybrids	• At the 8-leaf stage → 32.4% • At the 12-leaf stage → 15.4%	Georgia (US) 4 commercial hybrids	Wiseman and Isenhour, 1992	
Corn			4.9% OR an average of 64 kg/ha	1976 Alabama + Illinois + Oklaoma	Wiseman and Morrison, 1981	US Animal and Plant Health Inspection Service 1978
Grain maize	13 defoliation treatments (consisting of either 100 or 50% leaf removal) imposed at 3 stages of development.		Table 2 provides the values of losses for the 13 treatments.	study for determining how much yield loss occurs in corn subjected to multiple defoliation events 3 x 3 m plots planted in a randomized complete block design with four replications in Illinois,	Thomison et al., 2016	Data coming from US: uncertainty about the climate similarity with the EU situation

				Minnesota, Ohio		
Sorghum				Fall armyworm injury to the whorl caused light to moderate whorl injury in nontreated plots; injury was approximately 30% greater in the later planting, possibly reflecting differences in sorghum maturity. Fall armyworm damage delayed panicle development in the second planting by 2-4 d and may have prolonged anthesis.	Chamberlin and All, 1991	
Sorghum			Nearly 8% estimated losses of the total production for the region	Sub-Saharan Africa	Abrahams et al., 2017	No data collected from Africa but estimation based from US data
15 sweet sorghum varieties	Infestations from 68 - 100% in all 15 varieties showing the insect may be an important limiting factor to ethanol production.			Florida	Cherry, 2013 referring to: Andersonand Cherry, 1983	No yield loss
Sorghum			Fall armyworm damage is primarily to foliage, but grain sorghum is very tolerant of defoliation and insecticide control seldom justified.		Buntin, 2009	No yield loss
Forage maize	3 yr at two sites in Wisconsin and one site in Pennsylvania.		figure 1 pag. 1462 Forage yield response to increasing levels of defoliation was quadratic. 100% defoliation at V7 → - 16% V10 → -43% R1 → -70% R4 → -40%	Study to evaluate the effects of defoliation on corn grown for forage production.	Lauer et al., 2004	

			Greater forage yield decreases are measured with early defoliation (V7–V10) than predicted grain yield decreases currently used by hail adjusters.			
Rice			56% estimated losses of the total production for the region	Sub-Saharan Africa	Abrahams et al., 2017	No data collected from Africa but estimation based from US data
Rice at stage 3.0	Artificial infestation with: Year 1: 3rd instar larvae at density 0, 17.5, 35.1, 52.6, 70.2, 87.7 larvae/m^2 for 6-day-infestation period Year 2: 4th instar larvae at density 0, 26.9, 53.8, 80.7, 107.6, 215.1 larvae/m^2	No significant effect on kernel weight or filling	Yield loss given by a combination of reduction in panicle density and weight. Yield loss linearly related to larval density Effects of larval defoliation on mature plant height only detected at density of 215.1 (= 9 larvae/10 plants): 8,511 kg/ha vs 10,267 kg/ha of the control	Louisiana (US) 2 consecutive years	Pantoja et al., 1986	Defoliation recorded during year 1 was a result of cumulative feeding by 3rd and 4th instars. Larval mortality particularly high for some treatments and predators presence probably higher at year 2. Sample size and technique probably affected the lack of significant differences among treatments.
Rice			15-40% of leaf area / plant was removed	Damage produced during the 4- to 6-h exposure to late-instar armyworms	Stout et al., 2009	
Onion	5.2% intensity of attack	Defoliation, weakening of the sheet that favoured destruction of leaves by wind		Brazil First report on onion	Fernandes et al., 2011	Level of infestation/damage on onion probably exacerbated by the migration from Bt maize Not clear what “intensity of attack” means

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

Spread	Additional information	Reference	Uncertainty
almost 50% of the larvae were recovered within the infested row and 91.4% within a radius of 1.1 m 14 days after infestation	Nebraska maize stage: R1 (silking) Row spacing 0.76 cm and plant spacing within rows 0.15 cm Artificial infestation with 200 eggs/plant	Pannuti et al., 2016	Irrelevant to spread which is caused by adults' flight. This information could be more related to potential impact.
> 480 km/ generation	Annual migrations toward NE in the US Prevailing winds and host availability are limiting factors	Luginbill, 1928	inferences based upon the timing of first appearances in progressively northern sites: low-resolution description of migration
Males' tethered flight: 16-30h		Van Handel, 1974	
1600 km/ 30h	Supported by specific climatic circumstances, convergent surface winds and convective storms	Rose et al., 1975	inferences based upon the timing of first appearances in progressively northern sites complemented by extrapolations of likely flight patterns based on synoptic meteorological conditions and seasonal wind patterns: low-resolution description of migration
Trans-Gulf of Mexico migrations > 200km from land	Oil platforms used as resting locations	Johnson, 1987	
Males collected on ships at • 390 km W of Florida and 440 km NW of Cuba • 610 km W of Florida and 610 km NW of Cuba	Persistent favourable winds	Johnson, 1987	
Seasonal migrations between the Antilles and the continental U.S. and between the U.S. and Canada		Mitchell et al., 1991	

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

Category of factors	case	Evidence	Reference
Detection methods		All stages of the pest can be detected visually; use of a hand lens will help detect early stages (eggs and early larval instars).	EFSA PLH Panel, 2017

		Diagnostic standard available key for larvae and adult *Spodoptera* spp. identification based on morphological characteristics	EPPO, 2015
		Adults can be caught with pheromone baited traps (males) and light traps (females and males).	EPPO, 2015
		Specificity of female pheromone is due to geographic (more than strain) differences	Unbehend et al., 2014
		The authors identified female sex pheromone available for monitoring purposes	Tumlinson et al. 1986
		protocol for real-time PCR molecular identification	Cano-Calle et al., 2015
		Real-time PCR is recommended for earlier stages, especially when experience is lacking and when the origin of the larvae is unknown.	EPPO, 2015
Biology of the pest	Life cycle	Oviposition begins shortly after dark and most of the eggs are laid during the first 4h Ovipositional period: 4-17 days and most of the eggs are laid during the first 4-5 days	Johnson, 1987
	Life cycle	Eggs development 2-11 days	Johnson, 1987
	Life cycle	6 larval instars: 10.9-13.5 days	Johnson, 1987
	Life cycle	Pupal phase: 9-45 days	Johnson, 1987
	Life cycle	Total generation time: 1 month during summer, till 3 months during winter	Johnson, 1987
	Life cycle	Diapause not possible in cold winters	Johnson, 1987
	Life cycle	Eggs and larvae on all above ground plant parts, mostly on the underside of leaves. Occasionally, larvae into plant parts. Pupation in the soil.	EFSA PLH Panel, 2017
	Behaviour	Adults can fly up to 9 m above the canopy during their evening movement.	Johnson, 1987
	Flying behaviour	Males' tethered flight: 16-30h	Van Handel, 1974
Host conditions during the period of potential detection	Host preferences	• Duration of larvae-adult stage: maize < oat < wheat < soybean < cotton • Survival larvae-adult: soybean > wheat > maize > cotton > oat • Feeding preference 1st instar after 24h: wheat > soybean > oat > maize > cotton • Larval weight: wheat > oat > maize > cotton > soybean	Da Silva et al., 2017