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Rhagoletis pomonella Pest Report to support ranking of EU candidate priority pests

EFSA (European Food Safety Authority),
Baker R, Gilioli G, Behring C, Candiani D, Gogin A, Kaluski T, Kinkar M, Mosbach-Schulz O, Neri FM, Preti S, Rosace MC, Siligato R, Stancanelli G and Tramontini S

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Correspondence: alpha@efsa.europa.eu

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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 *Rhagoletis pomonella*, the following documents were used as key references: Sansford et al. (2016), Everat (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

Rhagoletis pomonella is a single taxonomic entity "within the *'pomonella* species group' (*R. pomonella*, *R. mendax*, *R. zephyria*, and *R. cornivora*). The strongest feature that distinguishes *R. pomonella* from the other 3 species is its wide host range (Bush, 1966).".

Rhagoletis pomonella (Walsh), the apple maggot fly is considered one of the most important pests of apples in Northeast United States of America as well as in adjacent Canadian apple growing areas. The fly is native to North America and commonly used as an example of speciation over the relatively recent historic time. Native *R. pomonella* populations, before *Malus* spp. (apples) introduction into the New England, were completing developing on *Crataegus* spp. (hawthorn). It seems that soon after apple introduction and extensive cultivation in north America there was a shift (mid 1800's) of hosts for *R. pomonella* with a race adapted and thriving on apples (Cha et al., 2018). Hence, a speciation event in sympatry has been proposed (Bush, 1966) and currently there are two well defined races, the apple and the hawthorn race, well characterized based on a list of biological and behavioural traits. The hawthorn race has wider distribution and extensive overlapping with the apple race. Although detection of the apple maggot fly in wester USA stage are reported, the apple maggot fly is a major quarantine pest in these areas (Sansford et al., 2016). There are usually one or two generations per year (the second usually not complete), with adults emerging from the ground overwintering pupae late in spring. Females, following a period of attaining reproductive maturity and mating, lay eggs in fruit mesocarp where larvae fed by drilling tunnels and destroying the flesh.

2.2. Host plants

2.2.1. List of hosts

Crataegus spp. (hawthorn) has been identified as the natural host of *R. pomonella*. Only when *Malus domestica* was imported into the USA then the pest moved onto this new host. In addition, this pest has been found on other *Malus* species, *Prunus* spp., *Pyrus* spp., and *Vaccinium corymbosum*, as well as wild plant species of the family Rosaceae, such as *Amelanchier*, *Aronia*, *Contoneaster* spp., *Rosa* spp. and *Sorbus* spp.

Appendix A provides the full list of hosts.

2.2.2. Selection of hosts for the evaluation

Although this fruit fly has been recorded on many fruit species, there is not always evidence of its capacity in completing its cycle on them. Currently its main host is *Malus domestica*, on which it completes its cycle and produce relevant damages (see Appendix B.1).

2.2.3. Conclusions on the hosts selected for the evaluation

The complete list of hosts for *R. pomonella* is produced by merging

- the list of host plants defined by EPPO (EPPO, 2019)
- the list of host species reported by CABI (CABI, 2018)

The host on which the impact is assessed is *Malus domestica*.

2.3. Area of potential distribution

2.3.1. Area of current distribution

Rhagoletis pomonella is a North American species with wide distribution in the USA from northeast states to Midwest, east Texas and New Mexico. Although first detections date back to 1951, since 1980s the fly is frequently detected in Oregon and now can be found also in Nebraska, California, Idaho and Utah (Sansford et al., 2016). California, Idaho, Utah, Oregon and Washington North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas are still under quarantine for the apple maggot fly (Yee et al., 2014a). The fly is found in northeast Canada and south-central states such as Saskatchewan and even as west as Vancouver. *Rhagoletis pomonella* populations exist in highlands and recently detections reported in the most southern areas of apple production of Mexico (Rull et al., 2006). *Rhagoletis pomonella* recorded for first time in Newfoundland (Parsons and Sinclair, 2018). The existence of populations with different phenological traits has been proposed.

Most studies suggest that the fly has invaded western USA with introduction of infested fruit and hence there are not native populations switching from ancestral hosts (Hood et al., 2013).

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

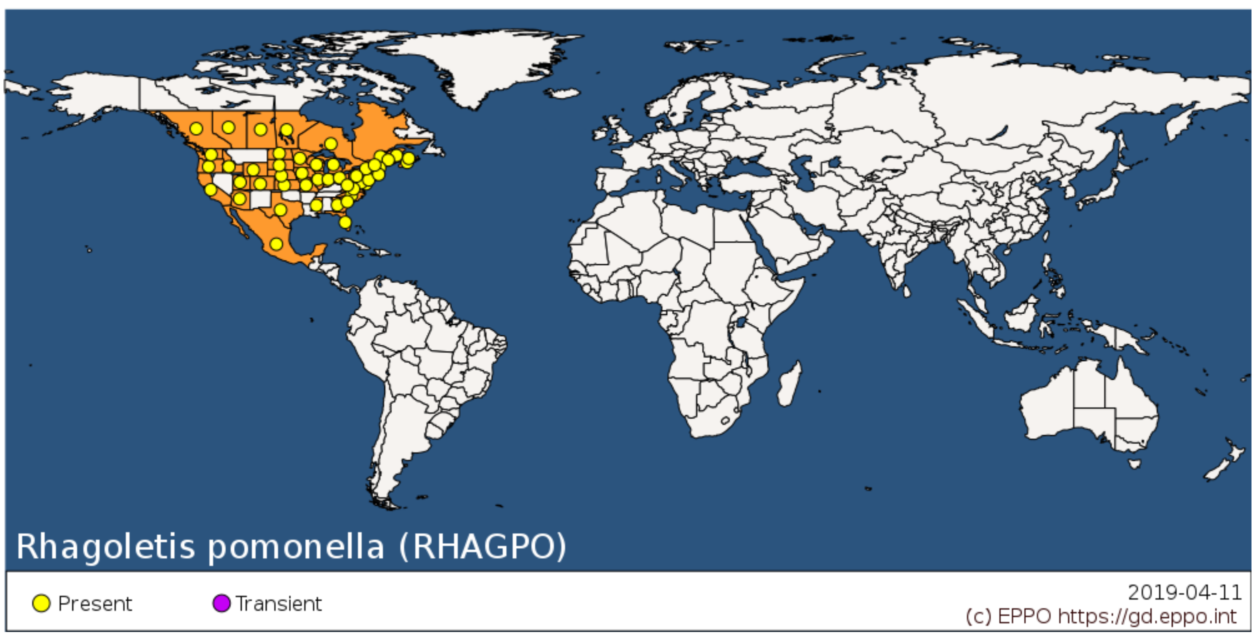


Figure 1 Distribution map of *Rhagoletis pomonella* from the EPPO Global Database accessed 11/04/2019.

2.3.2. Area of potential establishment

Ecological niche modelling is extensively used as a tool to predict geographic areas of potential establishment for a wide variety of insect species (Kriticos, 2003). The CLIMEX and the MaxEnt models have been extensively used either separately or comparatively to predict fruit fly species potential distribution. A MaxEnt model has been developed to predict the potential distribution of *R. pomonella* in China (Geng et al., 2011). Using the CLIMEX model Geng et al. (2011) determined that north eastern parts of China are the most suitable for the establishment of the fly. Few "pockets" with high suitability exist also in mainland areas of central China. Broad range of areas excluding south east and west parts of China are of medium potential for establishment. Recently both the MaxEnt and CLIMEX models to predict the global distribution of the apple maggot fly (Kumar et al., 2016). Kumar et al. (2016) produced maps indicated most parts of central and south Europe as highly favourable for *R. pomonella* establishment. Most parts of Scandinavia and norther edges of UK are unsuitable for the establishment of the apple maggot fly.

CABI (2018) reports the climatic requirements of *R. pomonella* in terms of latitude/altitude ranges, air temperature, rainfall. CLIMEX parameters are provided by Geng et al. (2011. Table 1 p. 577), Kumar et al. (2016. Table 1 p. 2046).

Climatic suitability maps estimated using the MaxEnt and the CLIMEX model are presented by Kumar et al. (2016) in figures 1 and 2 (p. 2047).

2.3.3. Transient populations

Rhagoletis pomonella 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

Based on the CLIMEX model proposed by Kumar et al. (2016) and climate data from JRC (1998-2017) we produced a projection of the area of potential establishment as reported in Figure 2. Most parts of southern and central Europe are highly favourable for *R. pomonella* establishment. Most parts of Scandinavia and northern edges of the UK are unsuitable for the establishment of the apple maggot fly. However, this is not clearly represented in Figure 2, which only shows the potential distribution in the NUTS 2 regions. The area of potential distribution of the pest is equivalent to the area where the main host occurs in the EU. The mean abundance of the pest, the main driver of the pest impact, is assumed to be the same throughout the whole area of potential distribution.

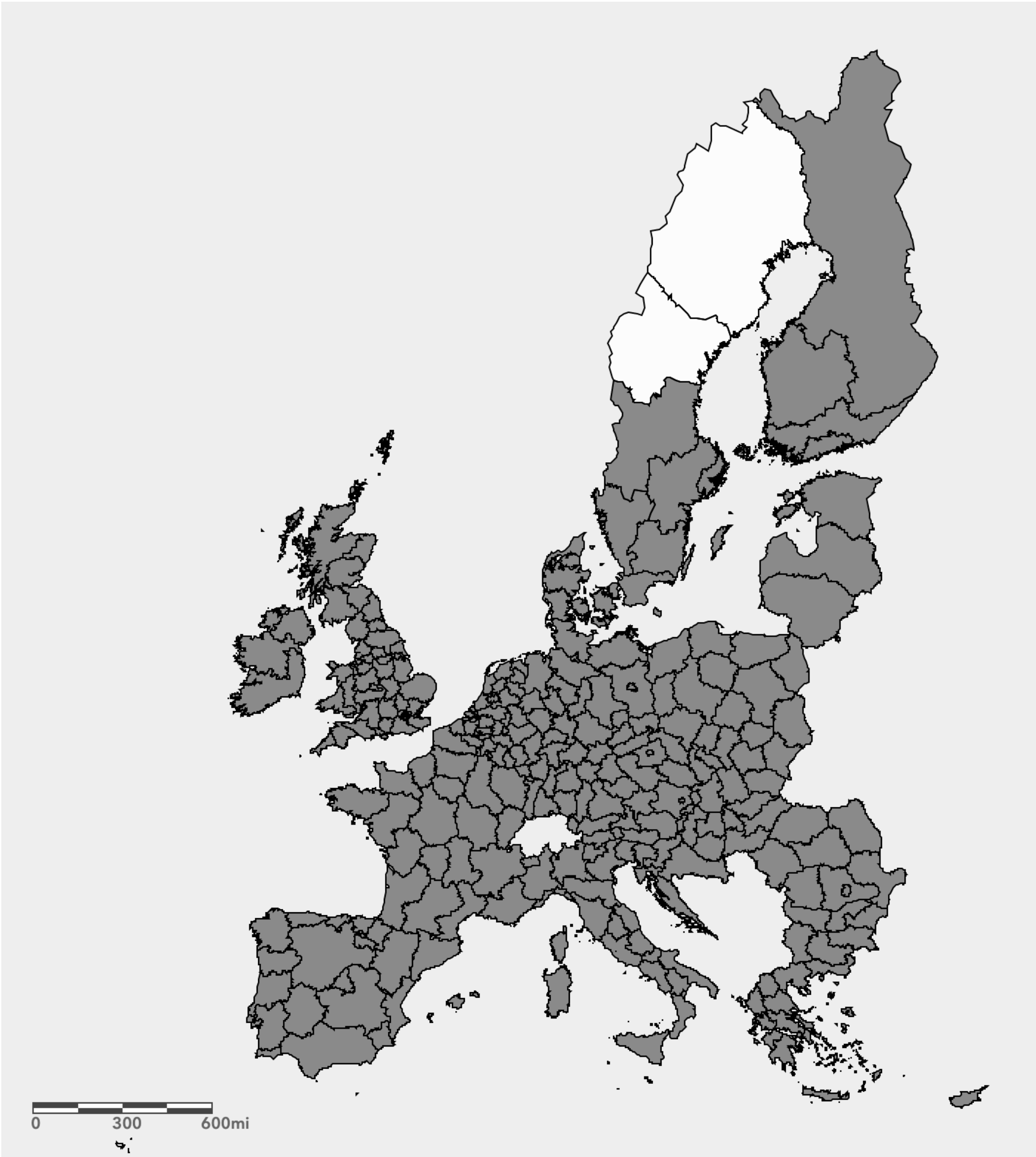


Figure 2 Area of potential establishment for *Rhagoletis pomonella* defined on the basis of a CLIMEX model with the Ecoclimatic Index greater than zero (at least one grid per NUTS2) based on Kumar et al. (2016) and climate data from JRC (1998-2017). This link provides an online interactive version of the map that can be used to explore the data further: https://arcg.is/05i5qX

2.4. Expected change in the use of plant protection products

Phosmet and Spinosad are the most commonly applied insecticides to control the apple maggot fly in California (UC-IPM, 2015). The same PPPs are available in the assessment area, but not in each member state and there may be a need for additional insecticide registrations if *R. pomonella* establishes in Europe. In addition, pesticide applications against maggot fly may interfere with integrated control systems that are implemented in (at least) part of the risk assessment area.

Bait sprays of corn gluten meal as attractant in combination with Spinosad are used as well. The GF-120 Naturalyte bait has been tested (Yee, 2007) but resulted in a lower population decrease than that obtained by cover Spinosad sprays.

Repeated applications of Kaolin (every 2 weeks) reduced field infestation to levels similar to application of Spinosad and Azinphosmethyl in North Carolina (Villanueva and Walgenbach, 2007). In the same study Thiacloprid and Azinphosmethyl were more effective in controlling the apple maggot fly compared with Indoxacarb, Spinosad, Imidacloprid and Thiamethoxam. In the EU, imidacloprid and thiamethoxam may no longer be used on outdoor crops.

Lure and kill systems based on read spheres covered or impregnated with appropriate pesticides have been used as well (Wright et al., 2012). A whole IPM system based on Lure and Kill devices has been tested with success in the past.

Generalist ground dwelling predators may have strong effect on the control of *R. pomonella* populations since they kill larvae seeking oviposition refugia/ pupae pupating/hibernating in the soil.

Entomopathogenic fungi such as *B. basianna* infect *R. pomonella* larvae and pupae with larvae being more susceptible (Muniz-Reyes et al., 2014). There is a list of parasitoids that attach *R. pomonella* but their importance as biological control agents has not been considered so far (Forbes et al., 2010; Muñiz-Reyes et al., 2011; Wharton et al., 2012).

Due to the fact that effective treatments with plant protection products (PPPs) are currently available but an increase in their use would be expected in presence of this pest, the most suitable PPP indicator is Case "C" and category "1" based on Table 1.

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

- All the area of apple production is exposed to the risk
- In case of early infestations the fruit can drop or suffer for cosmetic damage due to deformation during growth and/or secondary infections (which make the fruits inedible); in case of late infestation the fruit does not drop, neither is deformed but is affected by cosmetic damage and/or secondary infections
- Quality losses are not considered since the deformed fruit are considered as a full loss
- Current control practices to protect apple include spraying against codling moth
- One single egg is considered sufficient to cause the full loss of a fruit
- The strain considered is affecting apple

3.1.1.3. Selection of the parameter(s) estimated

The infested apples can:

- Drop prematurely
- Suffer for cosmetic damage due to:
    - the oviposition punctures on the surface of the fruit, which appear sunken and discolored around the outside
    - deformation during growth
- Larval tunnels into the flesh which turns brown
- Secondary infections which make the fruit inedible

Therefore:

- Yield loss in this case corresponds to the proportion of fruits lost due to premature dropping and to unmarketable fruits due to cosmetic damage, larval infestations and secondary infections
- Quality losses have not been included in the assessment because considered as full losses and included under the assessment of yield losses

The assessment of the yield losses is done by comparison with the EKE results of *Anastrepha ludens*.

3.1.1.4. Defined question(s)

What is the percentage yield loss in apple production under the scenario assumptions in the area of the EU under assessment for *R. pomonella*, 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:

- Life span shorter than *Anastrepha ludens*
- Even in case of sanitation measures, pupae will remain in the soil
- This pest can survive in very cold winter

3.1.1.6. Uncertainties identified

- Not clear if *R. pomonella* would go first to cultivated or wild apples
- Sensitivity/resistance of the different apple cultivars grown in Europe
- Effectiveness of currently applied control practices in apple orchard in controlling *R. pomonella* populations, based on treatments application time

3.1.2. Elicited values for yield loss on apple

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

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

Table 2: Summary of the 5 elicited values on yield loss (%) on apple orchards

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	2%	15%	30%	50%	80%

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

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

High population densities can be expected, and they are extremely damaging, this could be the outcome of a failure in the control measure in an orchard infested by Tephritidae (even total loss). Further, also small attacks (a single egg or larva in a fruit) can cause a loss.

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

Control measures in place are effective and have a strong effect in controlling the population abundance. At the edge of potential area of distribution (Northern Europe) the longevity of the adults is short. In many areas (e.g. Northern Europe) environmental conditions could lead to a change in life-history traits (e.g., longevity of the adults) reducing the population density resulting in small infestation.

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

The potential effect of treatments against codling moth is taken into account. However, on average in the EU the currently applied treatment could be not effective against this pest. Report from 10 years observations in Quebec (Vincent and Bostanian, 1988) was taken into account.

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

The uncertainty is mainly located in the lower part of the curve due to the observations collected from Quebec.

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

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 the yield loss (%) on apple

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	2%					15%		30%		50%					80%
Fitted distribution	1.5%	2.3%	3.7%	6.4%	10.1%	14.9%	19.8%	30.5%	42.6%	49.5%	57.4%	64.9%	71.9%	76.4%	80.1%

Fitted distribution: BetaGeneral (1.0092,1.6196,0.01,0.85), @RISK7.5

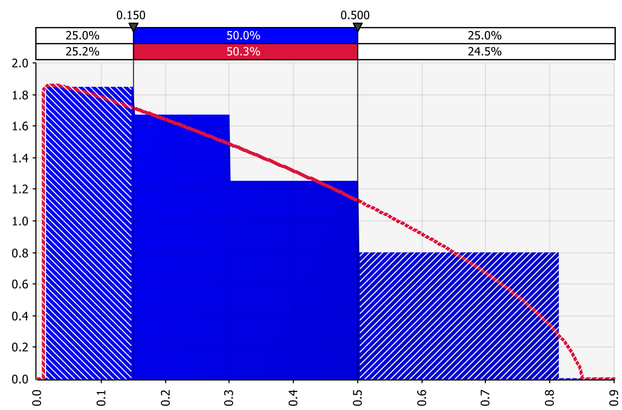


Figure 3 Comparison of judged values (histogram in blue) and fitted distribution (red line) for yield loss on apple.

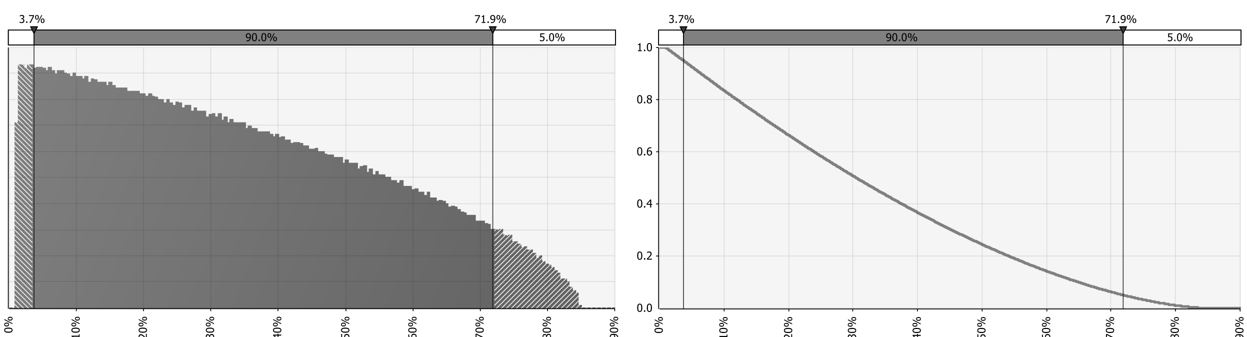


Figure 4 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for yield loss on apple.

3.1.3. Conclusions on yield and quality losses

Based on the general and specific scenario considered in this assessment, the proportion (in %) of yield losses (here with the meaning of proportion of fruits lost due to premature dropping and to unmarketable fruits due to cosmetic damage, larval infestations and secondary infections) is estimated to be 30.5% (with a 95% uncertainty range of 2.3-76.4%) on apple production.

Quality losses have not been included in the assessment because 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

- Initial population is very small number of adults emerging from pupal phase
- Local human assisted movement due to agricultural activity in and among the orchards is taken into account (e.g. pupae dispersed with soil on machineries), but the movement of harvested fruit is excluded
- One flight period

3.2.1.3. Selection of the parameter(s) estimated

The spread rate has been assessed in terms of number of metres per year and refers to the movement of the population and not of the individuals.

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. One general point was made: this pest is not a strong flier and will fly only if necessary.

3.2.1.6. Uncertainties identified

- Evidence missing on the effect of soil displacement in spreading pupae
- Effect of the experimental design on the observed spread values

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: The 5 elicited values on spread rate (m/y)

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	20	100	250	500	2,000

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 takes into account the potential flight capacity of this species (as obtained in flight mill experiment) and a scenario of host plants sparsely distributed that could increase the dispersal for searching new hosts. Favourable wind events are also considered. The species is characterised by short distance flight events; however, they can accumulate over the adult life span (40 days).

In the worst case scenario, the first outbreak is not expected to happen in an orchard but in a private garden or in the natural environment (as they are more likely to be reached by the pest for establishing a new population).

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

In this scenario, the infestation could start from an infested fruit which is not in an orchard but, for example, in garbage. The infestation is patchy and at very low density. The individuals composing this initial population are poor fliers.

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

Even with small populations and availability of hosts, smaller areas will be occupied. Newly established population in the orchards is most likely scenario.

The average scenario is based on an apple orchard, therefore it takes into account very suitable local conditions for the pest not favouring long distance flights.

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

The precision is given by the fact that highest values are the most unlikely to occur.

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	20					100		250		500					2,000
Fitted distribution	16	24	35	53	76	107	142	234	385	511	717	1,031	1,570	2,261	3,454

Fitted distribution: Lognorm (457.24,766.87), @RISK7.5

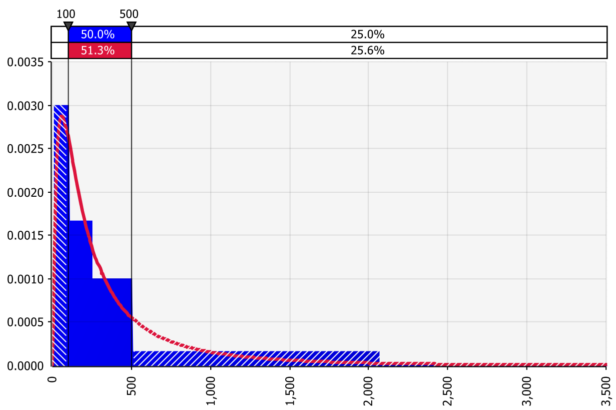
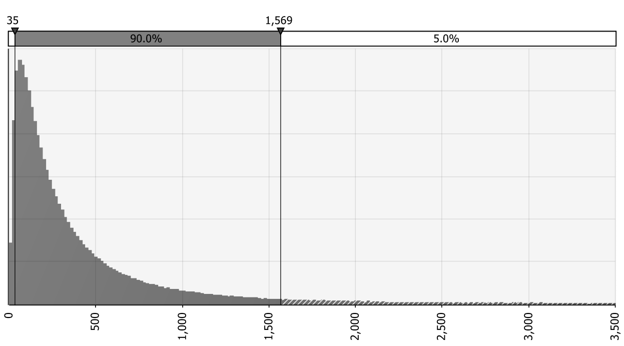


Figure 5 Comparison of judged values (histogram in blue) and fitted distribution (red line) for spread rate.



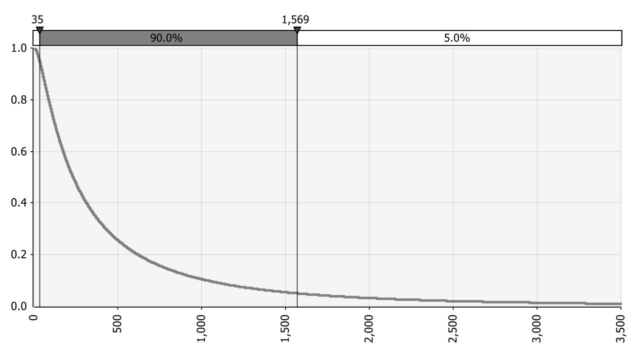


Figure 6 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for spread rate.

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 *R. pomonella* is approximately 230 m (with a 95% uncertainty range of 24 m to 2.3 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

- Initial population is very small number of adults emerging from pupal phase
- Local human assisted movement due to agricultural activity in and among the orchards is taken into account (e.g. soil displacement by machineries), but the movement of harvested fruit is excluded
- One flight period
- The movement of the population and not of the individuals is taken into account
- Weather conditions are favourable to the flight but extreme events (storms and strong winds) are excluded

3.3.1.3. Selection of the parameter(s) estimated

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

3.3.1.4. Defined question(s)

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

3.3.1.5. Evidence selected

The experts reviewed the evidence obtained from the literature (see Table B.3 in Appendix B) selecting the data and references used as the key evidence for the EKE on time to detection. Some general points were made:

- Only specific traps targeted to *R. pomonella* would work
- The adults are small and not easy to spot
- Damaged fruits can be noticed by people working in the orchards

- Easy to be confused with *Rhagoletis cerasi* and *Rhagoletis cingulata*
- With 1.5 treatments per season it is difficult to be able to affect the adult population of *R. pomonella*

3.3.1.6. Uncertainties identified

- Misidentification of signs of presence of *R. pomonella*
- Effect of presence of host species other than *Malus domestica* in the area of potential distribution

3.3.2. Elicited values for the time to detection

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

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

Table 6: The 5 elicited values on time to detection (months)

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	12	36	60	72	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 upper value is due to the fact that an effective trapping system for this species does not exist. The symptoms of *R. pomonella* can be confused with other apple pests (e.g. Tortricidae). This pest requires high infestation rates in order to be noticed. The current insecticide regime could keep the population density low. The outbreak could be in a private garden or on wild vegetation.

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

A shorter time to detection is expected in areas where conditions are suitable for rapid population increase with two generations per year. Since Tephritid species do not normally attack the European apple crop, high density populations of *R. pomonella* may be detected within 12 months.

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 fact that populations at low density can remain long undetected in an orchard. In addition, the estimation takes into account the likelihood that the outbreak starts not in a commercial orchard but in a private garden and is therefore observed first by non-practitioners.

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

The uncertainty is almost equally distributed with a bit lower likelihood for the highest values. Closer to 5 years than to 10 years.

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	12					36		60		72					120
Fitted distribution	9	14	18	25	32	38	45	56	68	75	84	94	105	115	126

Fitted distribution: Weibull (2.3341,65.596), @RISK7.5

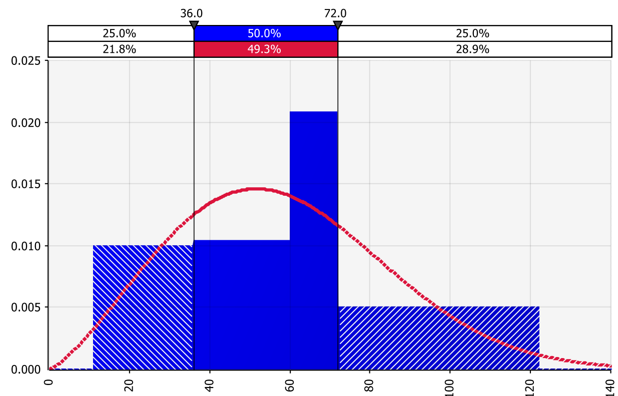


Figure 7 Comparison of judged values (histogram in blue) and fitted distribution (red line) for time to detection.

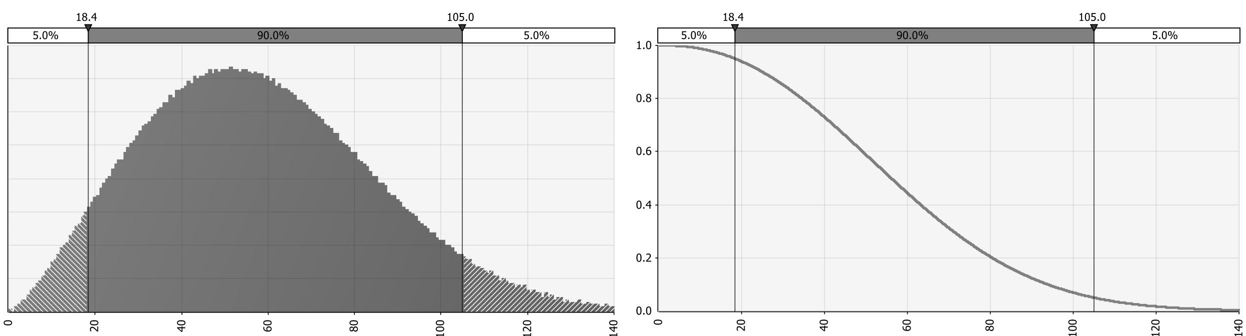


Figure 8 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for time to detection.

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 almost 5 years (with a 95% uncertainty range of 1 – 9.5 years).

4. Conclusions

Hosts selection

The complete list of hosts for *Rhagoletis pomonella* is produced by merging:

- the list of host plants defined by EPPO (EPPO, 2019)
- the list of host species reported by CABI (CABI, 2018)

The host on which the impact is assessed is *Malus domestica*.

Area of potential distribution

Based on the CLIMEX model proposed by Kumar et al. (2016) and climate data from JRC (1998-2017) we produced a projection of the area of potential establishment. Most parts of southern and central Europe are highly favourable for *R. pomonella* establishment*.* Most parts of Scandinavia and northern edges of the UK are unsuitable for the establishment of the apple maggot fly. However, this is not clearly represented in the provided figure, which only shows the potential distribution in the NUTS 2 regions. The area of potential distribution of the pest is equivalent to the area where the main host occurs in the EU. The mean abundance of the pest, the main driver of the pest impact, is assumed to be the same throughout the whole area of potential distribution.

Expected change in use of plant protection products

Due to the fact that effective treatments with plant protection products (PPPs) are currently available but an increase in their use would be expected in presence of this pest, the most suitable PPP indicator is Case "C" and category "1".

Yield and quality losses

Based on the general and specific scenario considered in this assessment, the proportion (in %) of yield losses (here with the meaning of proportion of fruits lost due to premature dropping and to unmarketable fruits due to cosmetic damage, larval infestations and secondary infections) is estimated to be 30.5% (with a 95% uncertainty range of 2.3-76.4%) on apple production.

Quality losses have not been included in the assessment because considered as full losses and 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 *R. pomonella* is approximately 230 m (with a 95% uncertainty range of 24 m to 2.3 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 almost 5 years (with a 95% uncertainty range of 1 – 9.5 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**
Amelanchier	
Aronia	
Aronia	*arbutifolia*
Cornus	*florida*
Cotoneaster	
Cotoneaster	*apiculatus*
Cotoneaster	*coriaceus*
Cotoneaster	*integerrimus*
Crataegus	
Crataegus	*Crus*
Crataegus	*douglasii*
Crataegus	*laevigata*
Crataegus	*mollis*
Crataegus	*monogyna*
Crataegus	*suksdorfii*
Malus	
Malus	*baccata*
Malus	*domestica*
Prunus	
Prunus	*americana*
Prunus	*angustifolia*
Prunus	*armeniaca*
Prunus	*avium*
Prunus	*cerasifera*
Prunus	*cerasus*
Prunus	*domestica*
Prunus	*emarginata*
Prunus	*mahaleb*
Prunus	*persica*
Prunus	*salicina*
Prunus	*virginiana*
Pyracantha	*coccinea*
Pyrus	*communis*
Pyrus	*pyrifolia*
Rosa	
Rosa	*rugosa*
Rosa	*virginiana*
Rosaceae	
Sorbus	*aucuparia*
Sorbus	*scopulina*
Vaccinium	*corymbosum*

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***			
Malus domestica	% fruits sorted at harvest (averaging 1977-1984) 16.89% untreated orchard 0.01-0.19% treated orchards			Quebec	Vincent and Bostanian, 1988	
Malus domestica	3% infestation from only one tree, from one site			Colorado, USA Results from a survey of non-commercial apples at 16 locations in eight counties.	Hood et al., 2014	Field conditions
Malus domestica Early varieties	5 – 8 larvae per fruit			Vancouver, Washington, USA, Field conditions	Mattsson et al., 2015	No data on actual proportion of infested fruit
Malus domestica Late varieties	2 – 3 larvae per fruit			Vancouver, Washington, USA, Field conditions	Mattsson et al., 2015	No data on actual proportion of infested fruit
Malus domestica			78–100% crop losses		Chen and Shen, 2002 cited by Kumar et al., 2016	Not clear the origin of the figure, given the absence of the pest from China
Crategus douglasii, black hawthorn	0.05 – 0.12 larvae per fruit. 43.7% infested trees; <0.009 larvae per fruit			Vancouver, Washington, USA, Field conditions	Mattsson et al., 2015; Yee et al., 2012	No data on actual proportion of infested fruit
Crategus monogyna	0.1 – 0.4 larvae per fruit.			Vancouver, Washington, USA, Field conditions	Mattsson et al., 2015	No data on actual proportion of infested fruit
Crategus suksdorfii	15.4% trees infested; <0.0013 larvae per fruit			Vancouver, Washington, USA, Field conditions	Mattsson et al., 2015; Yee et al., 2012	This species is mentioned but no further data are provided

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

Spread	Additional information	Reference	Uncertainty
213 m in one month	USA Fewer females than males were recovered in all tested distances. Males and females were recovered from the longest distance	Phipps and Dirsks, 1932, 1933)	Flies were marked with a radiator paint and recovered by hand (captured in vials). The observation time of 1 month covers almost the full life flight capacity of the insect
482 m 665 m in around 15 days	USA No information on the sex of the recovered specimens is given	Bourne et al., 1934	Flies were marked with a radiator paint and recovered by hand (captured in vials)
1571 m (1719 yards)	USA, even distribution was reported. No information on the sex of the recovered specimens is given. The release point was out of apple orchards.	Maxwel and Parsons, 1968	Wild flies were marked with a fluorescent dye and were captured in sticky traps. Max distance of recapture. It can be considered a reliable trial, with an impressive number of released individuals
76 m	Mark-release-recapture experiment	Maxwel and Pearsons, 1968	
91 m	Canada, Nova Scotia. Flies were reported to move from adjacent areas to orchards 1 female was recovered at the max distance of 91 m from release point. Females recovered at higher proportions and longer distances compered to males	Neilson, 1971	Wild flies were marked with strontium 89 that picked up by sprayed apple and other foliage with a bait containing also hydrolysed soy. Proportion of less than 5.9% flies picked up the marking
1900-4000 m in 1-2 hours		Sharp, 1978	Flight mills provide interesting information (e.g. comparison between male and female flight capacity) but are overestimations of the pest flight capacity

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

Category of factors	Case	Evidence	Additional information	Reference
Detection methods	Visual symptoms	Oviposition stings on fruits. Deformed fruits		Boller and Prokopy, 1976
Detection methods	Reliability	Adult trapping. Yellow panels and red spheres baited with ammonium carbonate can be used, although differential performances have been reported between east and west USA state		Reynolds and Prokopy 1997; Yee et al., 2014b
Detection methods	Identification	Morphological based on adult features. Identification at larvae stage may be challenging. Molecular methods should be considered to assure correct identification and also to separate		White and Elson-Harris, 1992; Velez et al., 2006

		host races		
Biology of the pest	Pest life cycle	*R. pomonella* is generally considered a univoltine species with obligatory diapause at pupae stage. However, a small proportion of the population can complete two generation per year under specific climatic conditions. Prolonged dormancy and completion of the life cycle in two years has been reported as well	1200 – 1400 DD to beginning of the fly in South Carolina. DD for peak of adult captures varied a lot. Phenology may differ in commercial and abandoned orchards	Meck et al., 2008
Biology of the pest	Pest life cycle	Patterns of adult phenology in the filed differ between the two host races of *R. pomonella*		Lyons-Sobaski and Berlocher, 2009
Biology of the pest	Pest life cycle	Egg incubation period lasts 3 – 10 days. Larvae developmental period varies a lot in response to climatic conditions. Pupal stage (diapausing as well) may last from 2 to 18 months. Individuals that follow prolonged dormancy may have even longer pupae period (2 to 5 years)		EPPO, 2019
Biology of the pest	Pest reproduction	Average pre-ovipositon period 12 – 17 days. Average eggs per female per day 5.43		Hendrichs et al., 1993
Biology of the pest	Feeding and flying behaviour	Adults need sucrose and aminoacids to mature eggs. Natural adult food includes honey dews, pollen and bird faces, other plant exudates. Imigration of adults from wild growing hosts to commercial orchards has been reported		Hendrichs et al., 1993 Rull and Prokopy, 2000
Biology of the pest	Lifespan	Survival >70% at day 30 for both males and females		Hendrichs et al., 1993
Biology of the pest	Infestation progress	Gravid mature females lay eggs under the skin of the fruit in the mesocarp. Hatched larvae drill tunnels and destroy the mesocarp. Secondary infections by fungi and bacteria may further destroy fruits. Infested fruit may be deformed and are not suitable for marketing		Boller and Prokopy, 1976 Weems and Fasulo, 2002
Host conditions during the period of potential detection	Host size	Small unripe and ripe or ripening fruits are infested		
Host conditions during the period of potential detection	Effects on symptom expression	Young unripe fruits usually become deformed. Oviposition stings are pronounced and visible. Oviposition stings may be difficult to detect on ripe fruits. Premature fruit drop may also occur		Everatt, 2018