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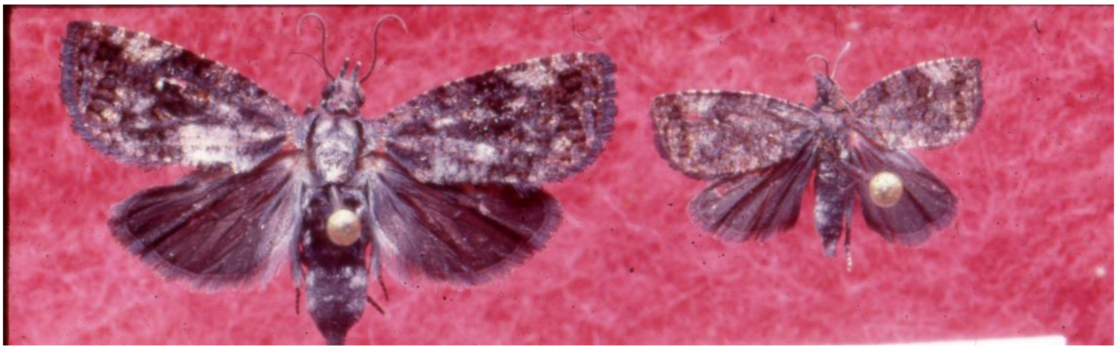
Pest Risk Analysis for

Gymnandrosoma aurantianum (Lepidoptera: Tortricidae), citrus fruit borer, macadamia fruit borer



H. Blanco-Metzler. Adults of *G. aurantianum*, Costa Rica.

September 2020

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The risk assessment follows EPPO standard PM 5/5(1) *Decision-Support Scheme for an Express Pest Risk Analysis* (available at http://archives.eppo.int/EPPOStandards/pra.htm), as recommended by the Panel on Phytosanitary Measures. Pest risk management (detailed in Annex 1) was conducted according to the EPPO Decision-support scheme for quarantine pests PM 5/3(5). The risk assessment uses the terminology defined in ISPM 5 *Glossary of Phytosanitary Terms* (available at https://www.ippc.int/index.php).

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Based on this PRA, *Gymnandrosoma aurantianum* was added to the EPPO A1 List of pests recommended for regulation as quarantine pests in 2020. Measures for *Citrus* fruits are recommended.

Pest Risk Analysis for *Gymnandrosoma aurantianum* (Lepidoptera: Tortricidae)

PRA area: EPPO region
Prepared by: Expert Working Group (EWG) on *Gymnandrosoma aurantianum*
Date: 18-21 November 2019.
Further reviewed and amended by EPPO core members and Panel on Phytosanitary Measures (see below).

Composition of the Expert Working Group (EWG)

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All personal communications in this PRA were obtained in November 2019-January 2020 from the following experts: H. Blanco-Metzler (Universidad de Costa Rica, Costa Rica), R. Parra (University of São Paulo, Brazil), L. Torta (University of Palermo, Italy), N. Üstün (Ministry of Agriculture and Forestry, Turkey).

The first draft of the PRA was prepared by the EPPO Secretariat.

Ratings of likelihoods and levels of uncertainties were made during the meeting. These ratings are based on evidence provided in the PRA and on discussions in the group. Each EWG member provided a rating and a level of uncertainty anonymously and proposals were then discussed together in order to reach a final decision.

Following the EWG, the PRA was further reviewed by the following core members: N. Avendaño Garcia, J.M. Guitian Castrillon, A. Sağlam, E. Guachet, F. Petter, M. Suffert, D.J. Van Der Gaag.

The PRA, in particular the section on risk management, was reviewed and amended by the EPPO Panel on Phytosanitary Measures on 2019-10-22/24 and 2020-03-24/26. The EPPO Working Party on Phytosanitary Regulations and Council agreed that *Gymnandrosoma aurantianum* should be added to the A1 List of pests recommended for regulation as quarantine pests in 2020.

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Summary of the Pest Risk Analysis for *Gymnandrosoma aurantianum* (Lepidoptera: Tortricidae)			
PRA area: EPPO region (Albania, Algeria, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Guernsey, Hungary, Ireland, Israel, Italy, Jersey, Jordan, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Macedonia, Malta, Moldova, Montenegro, Morocco, Netherlands, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tunisia, Turkey, Ukraine, United Kingdom, Uzbekistan)			
Describe the endangered area: Mediterranean coast, as well as Southern Portugal, the Atlantic coast of Morocco, and part of Northern Italy, the Balkans, and the Black sea coast, where *Citrus* are grown in commercial production and various environments (e.g. gardens, urban areas), if host fruits are present all year round. This is the case in some countries of the PRA area, where there are *Citrus* fruit all year round in the field at different stages of maturation (due to the cultivation of various species and varieties). Other hosts would extend the availability of fruit in the field. There is more uncertainty on whether more continental and northern areas where *Citrus* or other hosts are grown would be part of the endangered area, as the climatic conditions may be less favourable for the pest.			
Main conclusions *Gymnandrosoma aurantianum* is a polyphagous pest of fruit trees, which occurs in Central and South America. Economic damage has been reported on *Citrus*, macadamia, cocoa, guava and some other tropical crops. The pest has been recorded on different hosts in different countries (for example, only on macadamia in Costa Rica despite the presence of other hosts in the same area). The reasons for this are not known. The main risk of entry relates to larvae in fruit. The pest has been intercepted on various fruits (commercial consignments and traveller's luggage) in the EPPO region and the USA. The pathway with the highest likelihood of entry is *Citrus* fruit. Entry on macadamia nuts and other fruits were rated low and very low respectively, and there was a high uncertainty attached to entry with other fruits. For macadamia nuts, this was mostly linked to the fact that nuts are imported processed, and that there would be a risk only if they are imported fresh with husks. Fruits transported by travellers in their luggage are also considered a risk. Hosts are widespread in the endangered area. However, the availability of fruit in the field is critical for the life cycle (larvae) and for the establishment of the pest. It is likely that the pest can maintain populations only in areas where host fruits are present all year round. Within the endangered area, *Citrus* fruit are present all year-round in the field at least in Spain and Turkey. However, the pest has a wide host range, and even where *Citrus* fruit are not present all year-round, other fruits may allow the pest to maintain populations. In any case, the gap between availability of *Citrus* fruit on trees (in orchards or other environments) in other countries of the endangered area may only be a couple of months, and there may be other fruits on host plants, such as pomegranate, loquat (*Eriobotrya japonica*) or peach. Even in areas where host fruits are not present all year round, transient populations may establish and cause damage. The magnitude of spread was rated as moderate with a moderate uncertainty. Adults have a low flight capacity. Spread would be mostly human-assisted, through infested fruit and plants, especially with larvae inside fruit. Host fruits and plants for planting with soil or growing medium are traded in large quantities in the EPPO region. In the endangered area, high potential impact is expected mainly where *Citrus* is grown all year-round. *Citrus* and other hosts (known and yet unknown) may be attacked. The presence of *G. aurantianum* will have negative effects on export markets due to interceptions and additional phytosanitary requirements. Overall the EWG considered the phytosanitary risk to the endangered area to be high with a moderate uncertainty. The EWG proposed that phytosanitary measures should be recommended for *Citrus* and other host fruits; however, there is no approved treatment, and the only systems approach identified is not considered to be sufficiently effective (see other recommendations below). Finally, measures for plants for planting with soil or growing medium are listed, although the EWG did not think they were necessary.			
Phytosanitary risk for the <u>*endangered area*</u> (*Individual ratings for likelihood of entry and establishment, and for magnitude of spread and impact are provided in the document*)	High **X**	Moderate ☐	Low ☐
Level of uncertainty of assessment *(see Q 17 for the justification of the rating. Individual ratings*	High ☐	Moderate **X**	Low ☐

of uncertainty of entry, establishment, spread and impact are provided in the document)			

Other recommendations:

The EWG noted that a schedule for cold treatment of *Citrus* fruit, and possibly other hosts, is needed, as well as other types of treatments for host fruit that cannot be subject to cold treatment.

Additional studies would be useful to determine whether *G. aurantianum* is a complex of species, its flight capacity and a number of biological data that are currently lacking.

The NPPOs of the EPPO region may consider adding *G. aurantianum* to field surveys on relevant hosts, especially *Citrus*. Data would also be useful on the availability of host fruit in the field all year-round in EPPO countries.

Stage 1. Initiation

Reason for performing the PRA:
Gymnandrosoma aurantianum (Lepidoptera: Tortricidae) is a pest of citrus and other fruit crops in tropical regions of the Americas (Central America, South America and the Caribbean). It has caused serious damage on *Citrus* in Brazil and severe damage on macadamia in Costa Rica, Guatemala, Venezuela and Colombia. Damage on other subtropical/tropical hosts has also been reported. In the EPPO region, the NPPO of Spain has intercepted *G. aurantianum* on several occasions in consignments of oranges (*Citrus sinensis*) imported from Brazil and Argentina. Considering that this pest could present a serious threat to citrus production, and possibly to other host fruit crops (such as pomegranate, peach and subtropical hosts) in the EPPO region, the NPPO of Spain suggested that *G. aurantianum* should be added to the EPPO Alert List. *G. aurantianum* was also identified as a potential risk for fruit import in the EU project DROPSA[1] (Grousset et al., 2016; Suffert et al., 2018).

G. aurantianum was added to the EPPO Alert List in 2017. In March 2019, the EPPO Panel on Phytosanitary Measures suggested *G. aurantianum* as one of the possible priorities for PRA in 2019 and the Working Party on Phytosanitary Regulation selected the species for PRA in June 2019.

The EPPO standard PM 5/5 *Decision-Support Scheme for an Express Pest Risk Analysis* (EPPO, 2012) was used, as recommended by the Panel on Phytosanitary Measures. Pest risk management (detailed in Annex 1) was conducted according to the EPPO Decision-support scheme for quarantine pests PM 5/3(5).

A national PRA on *G. aurantianum* was prepared in Spain (with the EU as PRA area) (MAPA, 2018) and the EPPO PRA on the related Tortricidae species *Thaumatotibia leucotreta* were referred to (EPPO, 2013).

PRA area: EPPO region (map at www.eppo.org).

Stage 2. Pest risk assessment

1. Taxonomy

Taxonomic classification. Domain: Eukaryota; Kingdom: Metazoa; Phylum: Arthropoda; Class: Insecta; Order: Lepidoptera; Family: Tortricidae; Genus: *Gymnandrosoma*; Species: *Gymnandrosoma aurantianum* Lima, 1927.

Synonyms. *Acharneodes cnemoptila* Meyrick, 1930; *Cryptophlebia cnemoptila* Diakonoff, 1959; *Argyroploce torticornis* Meyrick, 1931; *Argyroploce sideroptera* Meyrick, 1932; *Gymnandrosoma torticornis* Clarke, 1958; *Ecdytolopha torticornis* Powell et al., 1995; *Gymnandrosoma pithecolobiae* Busck, 1934; *Ecdytolopha aurantiana* White & Tuck, 1993 (Adamski & Brown, 2001)

EPPO Code: ECDYAU

Common names
English: citrus fruit borer, macadamia nut borer (EPPO, 2017), orange fruit borer (Molet et al., 2018).
Portuguese: bicho furão, bicho-furãodos-citros, mariposa-dos-laranjais, mariposa das laranjas (Nakayama, 2018).
Spanish: polilla de la naranja (Sinavimo, 2019), polilla del naranjo (Urretabizkaya et al., 2010), gusano barrenador del fruto (Gomez Orellana et al., 2008), barrenador de la nuez de macadamia (Blanco-Metzler et al., 1993), taladrador de la nuez de macadamia (Tortós, 1991).

Notes. The species was first identified in Brazil by Bondar in 1915, as being *Tortrix citrana* Fernald. It was then described as the new species *Gymnandrosoma aurantianum* in 1927 by Lima, and later named *Ecdytolopha aurantiana*. In the redescription of the *Ecdytolopha* and *Gymnandrosoma* genera, it was moved to *Gymnandrosoma* (Adamski & Brown, 2001).

[1] Strategies to develop effective, innovative and practical approaches to protect major European fruit crops from pests and pathogens

The insect collected in Costa Rica was initially identified as being *Cryptophlebia leucotreta*, then reidentified as *Ectydolopha torticornis* and later synonymized with *E. aurantianum* (H. Blanco-Metzler, Universidad de Costa Rica, pers. comm., 2019). The name *E. torticornis* was widely used in the literature, and the synonymy with *G. aurantianum* was then formalized (Adamski & Brown, 2001).
All three names *Gymnandrosoma aurantianum*, *Ecdytolopha aurantiana* and *Ecdytolopha torticornis* are used throughout the literature on this pest.

Morphological and host differences were observed between the specimens in Costa Rica and other parts of South and Central America:

- *G. aurantianum* is reported to attack different hosts in different parts of its range. In Costa Rica, it has only been reported infesting macadamia, despite the fact that macadamia plantations are mainly established in the Atlantic Region where other known hosts are also found, such as cocoa and citrus plantations, as well as scattered guava and litchi (Blanco-Metzler, 1994; Blanco-Metzler, pers. comm. 2019).
- In Costa Rica, Tortos (1991) found two morphological characters of *E. torticornis*: a difference in the number of frenula between males and females (three for the females, one for the males); and the possibility to sex the pupae because the males have two knobs in the 9th segment of the abdomen. These features are not mentioned in descriptions of *G. aurantianum*, in particular in the latest taxonomic description of the species, which stated *E. torticornis* as a synonym of *G. aurantianum* (Adamski & Brown, 2001).

It is not known if the differences above are biological/ecological (e.g. relating to host preference), or relate to the existence of a complex of species. **Although *E. torticornis* in Costa Rica presents some differences, it is considered in this PRA as a synonym of *G. aurantianum*, in line with the current taxonomic knowledge.**

2. Pest overview

2.1 Morphology

- Eggs are ca. 1.2 mm long, flattened, and circular to ovoid in shape, pale white, darkening to reddish-brown as development occurs (Blanco-Metzler, 1994).
- Larvae are eruciform, with a cream/pale yellow body. The head is pale yellow to pale orange with a red-brown patch. The last larval instar measures ca. 15-19 mm (Adamski & Brown, 2001; Yamamoto et al., 2006 citing others). Newly-hatched (neonatal) larvae measure 5 mm (Yamamoto et al., 2006 citing Prates & Pinto 1988, 1991).
- Four to five larval instars have been observed (Batista Pereira, 2008; Blanco-Metzler, 1994; Garcia 1998 cited in Gómez Torres, 2005; Leandro, 2012). It is noted that intraspecific variability in the number of instars is not an exceptional phenomenon (Esperk et al., 2007).
- Pupae are fusiform, 9-12 mm long and 2.5-3 mm wide, rounded at the anterior and posterior ends (Adamski & Brown, 2001). Newly formed pupae are pale yellow, later becoming brown (Blanco-Metzler, 1994).
- Adults have a wingspan of ca. 11-18 mm (Molet et al., 2018; White & Tuck, 1993) and are ca. 10 mm long (Gomez Orellana et al., 2008). Adults are brown with indistinct reddish-brown and black markings. A conspicuous white dot is present on the distal one-third of the forewing in most individuals (Gilligan & Epstein, 2014). The base segment of the antenna of the male is flattened.

Photos of the different life stages are provided in Annex 2 and EPPO Global Database (https://gd.eppo.int/taxon/ECDYAU/photos).

2.2 Life cycle

Duration and number of generations

In the literature, the complete life cycle is reported to range from 27 to 96 days. The duration of the life cycle and individual life stages as reported in the literature are summarized in Table 1. These durations vary in the field and in experiments. Temperature, relative humidity (Bento et al., 2004; Fundecitrus, 2007), attacked host and variety (Bento et al., 2004), and fruit maturity (Parra et al., 2004; White, 1999 citing Parra et al., 2001) are parameters that can effect duration of the life cycle. The effect of abiotic and biotic factors is discussed in sections 2.3 and 2.4.

In experiments on macadamia in the laboratory, the duration of the life cycle was 36 days (23°C, 80% RH); given this duration, it was noted that there may be up to 10 generations per year in favourable environmental conditions and with food availability (Blanco-Metzler et al., 1993). In Brazil, *G. aurantianum* is reported to have 7-8 generations per year in the different regions (map in Fundecitrus, 2007). Consequently, *G. aurantianum* can rapidly build-up populations. On *Plukenetia volubilis*, the average life cycle took 73 days (Leandro, 2012), and would lead to fewer generations.

Table 1. Duration of life stages reported in the literature

Abbreviations: Lab = laboratory; temp. = temperature; RH = relative humidity

Stage	Laboratory with conditions, or general statement (i.e. source not known, conditions not known)	Host/diet, duration of the life stage (reference)
Eggs	- Lab. 23°C; 80% RH - Lab. Average temp.: external ca. 25°C, internal (fruit) 27°C*. Average RH: ca. 87% - General statement - Lab. 27 ± 2ºC; 65 ±10% RH; 14 h photophase.	- *Macadamia*, Mean 5-6 days (Blanco-Metzler, 1994) - *Plukenetia volubilis*, 5-10 days (Leandro, 2012) -*Citrus*, 3-5 days [Fundecitrus, 2007; Garcia & Parra, 1999 citing Nakano & Soares (1995) and Mendes (1997)] - *Artificial diet*, 4-7 days (Garcia & Parra, 1999)
Larvae	- Lab. 23°C; 80% RH - Lab. Average temp.: external ca. 25°C, internal (fruit) 27°C*. Average RH: ca. 87% - General statement - Conditions not specified	- *Macadamia*. 1st, 2nd and 3rd instars: 3-4 days. 4th instar (incl. pre-pupa): 3-9 days (Blanco-Metzler, 1994). - *P. volubilis* (means). Total larval stage: ca. 35 days. 1st instar: 1.5 days; 2nd: 4 days; 3rd: 6.45 days; 4th: 9.5 days; 5th: 13.40 days; pre-pupa: 3 days (Leandro, 2012). - *Citrus*. 14-30 days (Fundecitrus, 2007) - *Citrus*. 17-24 days on green fruits; ca. 16 days on ripe fruits (Parra et al., 2004 citing Parra et al., 2001)
Pupae	- Lab. 23°C; 80% RH - Lab. Average temp.: external ca. 25°C, internal (fruit) 27°C*. Average RH: ca. 87% - General statement - General statement - General statement	- *Macadamia,* 7-15 days (Blanco-Metzler, 1994) - *P. volubilis* mean 12 days (Leandro, 2012) - *Citrus*, 9-21 days (Fundecitrus, 2007) - *Citrus*, 12-20 days (Gómez Torres, 2005, citing others) - *Citrus*, 10-12 days (Urretabizkaya et al., 2010)
Adult	- Lab. 27±2°C; 60 ±10% RH; 14h photophase - Lab. 23°C; 80% RH - Lab. 25°C; RH not specified - Lab. Average temp.: external ca. 25°C, internal (fruit) 27°C*. Average RH: ca. 87% - General statement - General statement	- Males ca. 20 days, females ca. 26 days (Parra et al., 2004 citing Garcia, 1998) - raised from macadamia, up to 16 days (Blanco-Metzler, 1994) - raised from *Sapindus saponaria*, ca. 10 days; lower for adults reared from field-collected larvae (White, 1999). - raised from *Plukenetia volubilis*, 11-23 days (average 16 days) (Leandro, 2012) *Note: in experiments above, adults were fed on artificial diet (such as honey water)* - Females up to 25 days, males up to 19 days (Vianna, 2015). - 14-21 days (Fundecitrus, 2007)
Complete life cycle	- Lab. 23°C; 80% RH - Lab. Average temp.: external ca. 25°C, internal (fruit) 27°C*. Average RH: ca. 87% - Lab. 25°C; RH not specified - General statement - General statement - General statement	- *Macadamia,* 36 days (Blanco-Metzler, 1994; Blanco-Metzler et al., 1993) - *Plukenetia volubilis*, 52-96 days (average ca. 73 days) (Leandro, 2012) - *Sapindus saponaria*, ca. 37 days (White, 1999) - 32-60 days, depending on temperature and attacked variety (Bento et al., 2004; Fundecitrus, 2007). - 32-35 days (Garcia, 1998 cited in Gómez Torres, 2005) - 27-61 days depending on fruit maturation stage, temperature, relative humidity, soil, citrus variety (Vianna, 2015)

* The reasons for the differences of 2°C between the external and internal temperature of fruit, which appears to be high, are not explained in the publication.

Adults and eggs

The longevity of adults is reported to range from 10 to 26 days (see Table 1). Adults are inactive during the day (Bento et al., 2001, 2004; Blanco-Metzler, 1994; Vianna, 2015). In field cage experiments, during the day most adults were found in the lower and middle crown of citrus trees (70-80% of males and females), resting on the surface of leaves (ca. 92%), sometimes on fruits (ca. 5%) and branches (ca. 3%) (Bento et al., 2001). In the middle of the night, adults were also mostly inactive. Limited numbers of males and virgin females were recorded on weeds or on the ground/screens during the experiment (Bento et al., 2001).

In Peru, adults were observed feeding on the nectar of flowers of various plants near infested *Plukenetia volubilis* plantations, and on other substances providing appropriate nutrients (Leandro, 2012). Others report that adults are believed to feed on the weed canopy (Blanco-Metzler, 1994). In laboratory experiments (at 25 ± 2ºC, RH 60 ± 10% and photoperiod 14h) where adults were given either a 10% honey solution or water, Milano et al. (2010) observed a slight diminution of the longevity of *G. aurantianum* adults when only water was available (in the order of 1 day according to figures in the article), but no significant effect on their fecundity and fertility. It is therefore possible that adults may be able to survive, reproduce and lay eggs in the absence of food, provided water is available. However, the lifespan and reproduction capacity will also vary depending on abiotic conditions (see below) and may, for example, be lower in cool conditions.

Adults are mostly active at dusk (when mating and egg-laying occurs) and at dawn (Bento et al., 2001; Blanco-Metzler, 1994; Leandro, 2012; Parra et al., 2004). In field cage experiments on citrus trees, most adults moved at dusk to the upper crown (top third), where mating occurred (Bento et al., 2001). The female produces a sex pheromone (Leal et al., 2001). In a greenhouse experiment, ca. 80% of the mating behaviour occurred on the 3rd and 4th day after emergence, and 95% within 7 days (Bento et al., 2001).

Egg-laying can start a few days after emergence. In laboratory experiments on macadamia, females started laying eggs 2 days after emergence (Blanco-Metzler, 1994). A mean pre-oviposition period of 2-3 days is mentioned for *Citrus*, with egg-laying lasting for 11 days on average (Parra et al., 2004 citing Garcia, 1998 – laboratory experiments). In experiments where larvae were raised on fruit of *Sapindus saponaria* (forest tree in Trinidad) in the laboratory, egg-laying peaked 6 days after emergence (White, 1999).

Fecundity of females reported in the literature varies widely (sometimes expressed in total number of eggs, sometimes in number of viable eggs). In experiments with larvae on artificial diet, resulting females laid on average approximately 140-200 eggs during their lifetime (with about 70% viability) (Garcia & Parra, 1999). The same authors note that Nakano & Soares (1995) obtained 30-70 eggs per female. In experiments with macadamia, 2-74 eggs per female were oviposited (2-58 eggs per female were fertile) (Blanco-Metzler, 1993). In laboratory experiments on *Plukenetia volubilis*, females laid 70 to 200 eggs (Leandro, 2012). Finally, in experiments on *Sapindus saponaria* (White, 1999), females raised in the laboratory laid ca. 87 eggs, while females raised from larvae collected in the field laid 14-58 eggs.

On *Citrus* trees, females had a preference for laying eggs at 1-2 m above ground (Parra et al., 2004 or Gómez Torres, 2005, both citing Garcia, 1998). On macadamia, eggs were laid mostly in the lower and middle part of the tree crown, up to 3 m from the ground (Blanco-Metzler et al., 1993, 2001), possibly because nut production is highest there or because it is closer to the feeding places of the adults (Blanco-Metzler et al., 2001). On *Plukenetia volubilis*, eggs were mostly laid in the middle third of the plants (Leandro, 2012).

Eggs are mostly laid on the surface of the fruit (Blanco-Metzler, 1994; Leandro, 2012; Parra et al., 2004) (and most references in this PRA).

- On *Citrus*, females usually lay only 1 egg per fruit (Arthur et al., 2016; Vianna, 2015). In small pest populations, ripe *Citrus* fruits are preferred, but in high population levels, fruits at different maturation stages may be attacked, including green fruit (Parra et al., 2004; Parra, 2016, citing Parra et al., 2001). Attacks on green fruit may also occur in case of early infestation in an orchard (Fundecitrus, 2007).
- On macadamia in the field, eggs were laid individually on the surface of the nut (middle part), mostly in the narrow space between adjacent nuts within a cluster. Egg-laying occurred only on nuts above 8 mm diameter; nuts of a diameter of about 24 mm were preferred. Females preferred immature nuts (with soft shells), which allow larvae to penetrate the shell and feed on the kernel, while mature nuts (with hard husks) were less attractive (Blanco-Metzler, 1994). The majority of nuts (ca. two thirds) contained 1 or two

eggs but up to 8 eggs per nut was recorded. No eggs were found on fruit petioles, leaves or branches (Blanco-Metzler, 1994). Females sometimes laid eggs on nuts that already carried eggs or larvae, or on damaged nuts (Blanco-Metzler, 1994).
- On *Theobroma cacao* there may be over 20 entry holes per fruit. The pest mainly attacks fruits that start changing colour to ripe fruit, and may attack well-developed green fruits, but a small proportion of growing green fruit is also attacked (Nakayama, 2018).
- On *Plukenetia volubilis*, egg-laying occurred from the beginning of the fruiting stage, until physiological maturation of the fruits, but not at flowering or on fruits that were already mature (Leandro, 2012).

In some publications, it is mentioned that eggs may be laid on leaves. For example in orange, 'occasionally on leaves' (Nakayama, 2018 or Gómez Torres, 2005, citing Garcia 1998, Garcia & Parra, 1999). However, the EWG considered that this is an occasional behaviour. This is not the normal behaviour of females. Successful development of larvae would require that they reach a fruit close-by, and this is less likely if eggs are on leaves than if they are on the fruit. Adamski & Brown (2001) also note that specimen data show that larvae infrequently feed on stems and leaves, but this may be linked to specimen 'raised from citrus leaves', in the absence of fruit.

The duration of the egg stage as reported in the literature ranges from 3 to 10 days (see table 1).

Larvae
The duration of the larval stage as reported in the literature ranges from 12 to 30 days (see table 1 for different hosts and different conditions).
- On *Citrus*, the first-instar larvae are only at the surface of the fruit for a short period (i.e. when they are vulnerable for example to insecticides or predators)**.** They needed on average 3 h 40 min to enter the fruit (range 2 to 7 hours) (Parra et al., 2004, citing Carvalho, 2003). The same author demonstrated that after 48 hours, about 50% of the small larvae reach the pulp, and larvae mortality could reach 32% during the process (possibly linked to the pH of the fruit). The entry point is located ca. 4.5 cm from the hatching point; within 2-3 days of entry, excrements appear on the rind of the fruit around the entrance hole (Vianna, 2015, not citing the source).
- On macadamia (all from Blanco-Metzler, 1994), the newly hatched larva moves at the nut surface to find an appropriate place to tunnel into the nut. One larva, observed in the field, needed ca. 50 minutes from hatching to disappearing completely into the husk. Most larvae were observed to feed mainly on the husk, but if the shell had not hardened they continued tunnelling into the kernel. Larvae hatching from eggs laid on mature nuts (shell hardened) feed only on the carpel (outside layer of the shell) and do not cause damage to the kernel. Larvae are found mostly singly, but when the pest is abundant, it is possible to find up to 3-4 larvae in a nut. When there is more than one larva per nut, they are usually different instars stages (i.e. eggs were laid on already infested nuts); unlike *Thaumatotibia leucotreta* (EPPO, 2013), cannibalism was not observed. Larvae react negatively to light and shelter wherever they can.
- On *Plukenetia volubilis* in the field, there was only 1 larva in 75% of infested fruit, and 2 or 3 in the remaining 25% (Leandro, 2012).
- On *Byrsonima crassifolia*, when conditions are no longer favourable to its feeding, larvae may move to nearby fruit, and fruits very close to each other tend to be folded (Plate 8; Photo 44.1 Gomez Orellana et al., 2008). This fact is probably linked to insufficient resources in one fruit (small fruit, with little flesh). *Note: this is the only reference found in the literature of larvae moving between fruits at the larval stage.*

Pupae
On *Citrus*, pupation occurs in the soil. Before fruit fall, larvae produce a thread to descend to the ground (Fundecitrus, 2007). Pupation takes place at the base of the plant, in a cocoon made of web, fragments of soil and plant debris (Gómez Torres, 2005 citing others). Other authors give detail on pupation in the soil (e.g. Leite et al., 2005 citing Carvalho, 2003; Parra et al., 2004). In laboratory experiments, *G. aurantianum* pupated at the same depth in humid or dry medium (between 0-1.5 cm) (Bento, 2008). In this PRA, this was used as an estimate for the depth at which pupae are found in the field.

Parra et al. (2004) mention that about 80% of pupations occur in the soil, i.e. about 20% occur elsewhere, while others consider that the latter is a rare occurrence ('a few pupate in the fruit' in White & Tuck (1993); 'normally in the soil, but may also pupate inside the fruit' in Fundecitrus, 2007) or do not mention it (Cabrera-Asencio et al., 2013).

Note: Molet et al. (2018 citing Blanco-Metzler, 1994) mention that larvae may 'crawl down the trees branches and trunk to pupate', however this observation in Blanco-Metzler (1994) related other species (*Cryptophlebia*).

On macadamia, pupae are found mostly in the nuts (Blanco-Metzler, 1994; Blanco-Metzler et al., 1993). Larvae sometimes spin silken webs between several nuts in a cluster, producing a cocoon in which they pupate (Blanco-Metzler, 1994). When in fruit, pupae close to emergence have almost a third of their body protruding from the nut. In the laboratory, pupation occurs on almost any substrate (Blanco-Metzler, 1994).

2.3 Effect of abiotic factors

Various abiotic and biotic factors (see section 2.4) influence the presence of the pest. Following a review of the literature and expert opinion discussions during the EWG, it was concluded that it is not possible to explain how these factors relate to different levels of impact in areas where the pest is present.

Regarding abiotic factors, temperature, relative humidity and soil are reported to play a role in the life cycle and abundance of the pest.

A thesis is abundantly cited in relation to the role of temperature and relative humidity in laboratory experiments in Brazil (Garcia, 1998). It was not available for this PRA, but its results are cited by others.

Temperature

In the field, mating and egg-laying are related to physiological changes in adults triggered by the decrease in light and temperature, and increase in relative humidity at dusk (Carvalho et al., 2015, citing Bento et al., 2001). In a study to develop a prediction model for the presence of *G. aurantianum* based on monitoring data collected through sexual pheromone traps, site temperature had the second highest influence on the presence of adults (soil type had the first – see *Soil* below) (Reis Jr. et al., 2005).

Temperature has an effect on the longevity and viability of all life stages (Parra et al., 2004, citing Garcia, 1998). An average temperature of 30°C is reported as being the most suitable for development for Brazil (Fundecitrus, 2007). In surveys using monitoring of males (Reis Jr. et al., 2005) (see *Soil* below), the peak of abundance occurred at temperatures of 22-25 °C depending on the variety of host.

The effect of temperature on the duration of the life cycle in experiments conducted with artificial diet at 60% RH (Garcia, 1998) is summarized in Parra (2016) (table 2) and complete data is given in table 3. In these experiments, the overall viability (live individuals) was 45-61% at 18-30°C. It was much reduced at 32°C (3%) mostly due to a low viability of larvae (ca. 48% on average) and pupae (ca. 8% on average). Temperature between 18-32°C did not have much effect on the viability of eggs, and between 18-30°C on the viability of larvae and pupae. At 18°C, the viability of eggs, larvae and pupae was still ca. 76%, resulting in an overall viability of 45%.

Table 2. from Parra (2016)

G. aurantianum life cycle duration.

Temperature (°C)	Duration (days)
18	61.8
20	56.5
22	50.2
25	35.3
28	27.7
30	27.4
32	27.2

Table 3. Extract from Parra et al., 2004. Duration (days) and viability (%) for the egg, larva, and pupal stages, and biological cycle (egg-adult) of *G. aurantianum*, reared on artificial diet and on different temperatures. RH: 60 ± 10%; photophase: 14 h (Adapted from Garcia, 1998).

	Egg		Larva		Pupa		Egg-Adult	
Temperature (°C)	Duration (days)	Viability (%)	Duration (days)[1]	Viability (%)	Duration (days)	Viability (%)[2]	Duration (days)[1]	Viability (%)[3]
18	10,6 ± 0,1 a (10 - 11)	76,3 ± 9,4 a	30,6 ± 0,5 a (25 - 49)	78,0 ± 4,5 a	20,9 ± 0,2 a (13 - 25)	76,6 ± 5,7 a	61,8 ± 0,5 a (55 - 76)	45,7 a
20	8,1 ± 0,1 b (8 – 10)	83,7 ± 4,5 a	30,3 ± 0,5 a (26 - 46)	79,0 ± 5,1 a	18,0 ± 0,2 b (14 - 21)	83,5 ± 4,4 a	56,5 ± 0,6 b (51 - 79)	55,2 a
22	7,3 ± 0,1 c (7 - 9)	83,8 ± 5,5 a	25,9 ± 0,3 b (21 - 39)	86,0 ± 4,6 a	17,2 ± 0,2 c (14 - 21)	84,8 ± 5,2 a	50,2 ± 0,4 c (43 - 61)	61,1 a
25	4,8 ± 0,1 d (4 - 7)	93,8 ± 3,1 a	18,8 ± 0,3 c (16 - 25)	77,5 ± 5,7 a	11,8 ± 0,1 d (10 - 14)	80,6 ± 5,5 a	35,3 ± 0,4 d (30 - 45)	58,6 a
28	4,3 ± 0,2 e (4 - 6)	95,2 ± 4,8 a	13,9 ± 0,2 e (11 - 22)	69,0 ± 6,1 a	9,5 ± 0,1 e (6 - 12)	76,5 ± 8,0 a	27,7 ± 0,1 e (25 - 38)	50,3 a
30	4,1 ± 0,1 e (3 - 5)	90,5 ± 8,4 a	14,0 ± 0,2 e (12 - 19)	71,0 ± 5,5 a	9,3 ± 0,1 e (7 - 11)	77,5 ± 6,8 a	27,4 ± 0,3 e (23 - 33)	49,8 a
32	3,8 ± 0,1 f (3 - 5)	81,2 ± 8,5 a	16,6 ± 0,3 d (12 - 23)	48,0 ± 5,1 b	9,4 ± 0,4 e	8,3 ± 3,92 b	27,2 ± 0,9 e (925 - 31)	3,3 b

[a]Means followed by a common letter vertically do not differ significantly among themselves by Tukey test at the 5% probability level; values between parentheses indicate the variation interval.
[1]Data transformed to log (X + 0.5)
[2]Data transformed to log (X + 2)
[3]Data transformed to square root of (X + 3)

Minimum and maximum temperatures
There is no information on the lower temperature threshold for survival or development of the pest. In an experiment at 18°C, 45% of the eggs reached the adult stage, but it is not known at which temperature the pest would be unable to complete its life cycle (Parra et al., 2004). In experiments in the laboratory, temperature thresholds were found to be ca. 9-10°C for all life stages (Parra et al., 2004, citing Garcia, 1998). However, this figure relates to a model, and it is not clear to the EWG how this was obtained and what the lower temperature threshold of the pest in the field is. The EWG considered that the threshold of 9-10°C mentioned in Parra et al. (2004) is not useful in this PRA.

There is no information either on the higher temperature threshold for survival or development of the pest, other than that the overall viability was much reduced at 32°C (3%) (see above).

Relative humidity
A relative humidity of 30-50% decreases the longevity and oviposition capacity of adults (Leite et al., 2005 and Gómez Torres, 2005, citing Garcia 1998). In experiments at 27°C and 30% RH, no eggs were laid during the lifetime of the females, and the longevity of adults was reduced (Table 4). In dry seasons, there may be a high number of adults (i.e. males trapped) with no damage observed on fruit, due to the reduction in the pests ability to lay eggs at relative humidity below 50% (Fundecitrus, 2019). In high temperature and low relative humidity, adults do not fly (Vianna, 2015).

Table 4. Extract from Parra et al., 2004. "Fecundity, egg viability, and longevity of males and females of the citrus fruit borer, *G. aurantianum* under different relative humidities. Temperature, 27 ± 2ºC; Photophase, 14 hours (Adapted from Garcia 1998)."

Humidity (%)	Fecundity (eggs/female)	Egg viability	Longevity (days)[a]	
			Males[b]	Females[c]
30	0.0	0.0	5.0 ± 0.3 c (3 - 10)	6.5 ± 0.34 c (4 - 12)
50	3.9	96.1	9.3 ± 0.8 b (4 - 29)	12.9 ± 0.9 b (4 - 27)
70	34.1	96.0	16.4 ± 1.0 a (3 - 31)	19.4 ± 0.7 a (6 - 29)
90	53.6	92.9	14.9 ± 0.4 a (8 - 25)	16.8 ± 0.5 a (11 - 24)

[a]Means followed by a common letter vertically do not differ significantly among themselves by Tukey test at the 5% probability level; values between parentheses indicate the variation interval.
[b]Data transformed to log (X + 0.5)
[c]Data transformed to square root of (X + 0.5)

Soil
Soil characteristics directly influence the duration of the pupal phase and pupa survival, and indirectly influence larvae survival by changing the characteristics of the fruits (incl. pH; Reis Jr et al., 2005). In a study in over 500 sites in São Paulo State (Brazil) to develop a prediction model for the presence of *G. aurantianum*, soil type had the highest influence on the presence of the pest, followed by site temperature, *Citrus* variety and age of plants; the use of chemicals for *G. aurantianum* control had minor effect (Reis Jr. et al., 2005).

Saturated soils or dry soils affect the pupae and decrease emergence (Leite et al., 2005 citing Carvalho, 2003; Parra et al., 2004). Intermediate moistures are the most suitable (Parra et al., 2004). In laboratory experiments, emergence was higher in soils with a high sand content (Bento, 2008). **Note. Information on the type of soil are mentioned here but are not mentioned further, because similar to other PRAs, it is not possible to take soil type into account at the scale of the EPPO region.**

2.4 Effect of biotic factors
In the literature, tree variety and age, phenology (fruit maturity), orchard environment and the hosts present are mentioned as factors influencing the life cycle in combination with abiotic factors.
- In surveys, the *Citrus* variety in combination with soil, temperature and age of plants influenced the peak of abundance of *G. aurantianum* adults (Reis Jr. et al., 2005).
- In macadamia, significant differences in the percentage of nuts damaged was observed on different clones and trees within the same clone (based on ca. 348,000 nuts inspected for damage over three years). Differences in nut damage between clones were not linked to tree architecture or to nut shape, size or colour, but to food quality (prohantocyanidines content and husk toughness) (Blanco Metzler et al., 2013).
- On cocoa, differences between cultivars are also observed. Field observations indicated that *G. aurantianum* attacks cocoa fruits with rough surface more often (Nakayama, 2018).

The development stage/degree of maturity of the fruit and its pH (which are partly related to the host variety), also influence the duration of the larval stage (Vianna, 2015). In laboratory experiments on *Sapindus saponaria* (White, 1999), variability in development rates, longevity of adults and fecundity were attributable partly to the degree of maturity of the host fruit. In *Citrus*, the duration of the larval stage was longer and viability lower on green fruit (pH 2.5-3) (17-24 days; 46-68% viability) than on ripe fruits (pH 4.6-5.1) (16 days; 74-85% viability) (Parra et al., 2004 citing Parra et al., 2001). It is noted that larvae can enter highly acid *Citrus* fruits. In Brazil on *Citrus*, larger populations in spring are favoured by the abundance of ripe fruits associated with an increase in temperature and relative humidity (Parra et al., 2004). Populations are lower in the autumn (although conditions are still favourable), because there are fewer fruit at a suitable development stage (Bento et al., 2004). Finally, on macadamia the level of infestation is closely related to the percentage of immature nuts, and decreases as the availability of immature nuts decreases (Blanco-Metzler, 1994).

In part of its range, where fruit of suitable development stages are available all-year round and the climatic conditions are favourable, *G. aurantianum* is present in the crops all-year round. In Brazil, surveys during 2 years using pheromone trapping showed that the pest is present throughout the year in all citrus-growing regions evaluated regardless of the season, as long as there are fruits in the plants (Parra et al., 2004). In Guatemala, macadamia crops are in constant production once they reach physiological maturity, and there may be attacks of the pest all year round (Primo Miranda, 2003 citing Reyna, 1992). In Peru, once a crop of *P. volubilis* has been infested, adults are found all year-round, because flowering and fructification is constant (Leandro, 2012).

Finally, the local environment plays a role. In Brazil, attacks were reported to generally start close to forests, where the pests probably attacks wild hosts (Parra et al., 2004). In a field experiment in an orange orchard, the sites with the greater numbers of fruits attacked were adjacent to areas cultivated with citrus and forest, and the pest moved to new orchards as fruit at the appropriate maturation stage become available (Carvalho et al., 2015). For *Plukenetia volubilis*, adults are reported to feed on plants outside orchards and move to their host *P. volubilis* to lay eggs (Leandro, 2012).

2.5 Effect of market prices

In Brazil and Costa Rica, the harvesting frequency, which in part depends on market prices, influences *G. aurantianum* populations. On *Citrus*, in years with lower prices growers may not harvest fruit, or harvest only part of a crop; such orchards may then constitute future infestation foci for neighbouring orchards. Similarly, late harvesting to meet the needs of the juice industry may favour lingering foci in the field (Parra et al., 2004). Similarly for macadamia, the frequency of harvest increases in case of good market prices, leading to decreased populations (H. Blanco-Metzler, pers. comm., 2019-11).

2.6 Dispersal capacity of adults

No detailed study was found on the dispersal capacity of adults. However, *G. aurantianum* is reported to be a poor flier (Chamberlain 1989 cited in Blanco-Metzler, 1994; Batista Pereira, 2008). Adults show limited flight activity, and short distance migration has not been observed (Blanco-Metzler, 1994). The original observation that it is a poor flier was based on a patchy distribution of infested trees in orchards, which could indicate that trees vary in susceptibility to pest attack (Blanco-Metzler, 1994, citing Chamberlain, 1989). Alternatively, if adults are able to find fruit at short distances, they may not need to fly much.

2.7 Nature of the damage

Direct damage is caused by larvae feeding in the fruit (*Citrus*, Fundecitrus, 2007; White & Tuck, 1993; *Plukenetia volubilis* Leandro, 2012*; Melicoccus bijugatus* Cabrera-Asencio et al., 2013). Larvae may also reach the seeds (White & Tuck, 1993; *Plukenetia volubilis*, Leandro, 2012; macadamia, Blanco-Metzler, 1994; *Theobroma cacao* – Nakayama, 2018). In one case reported in Lima (1945), larvae fed only in the seed and not on the pulp (of one *Annona cherimoya* fruit).

On *Theobroma cacao* pods, *G. aurantianum* is mentioned among species that cause superficial damage (End et al., 2014). Normally, larvae tunnel only in the epicarp (outer part of the fruit 'shell'), most do not extend beyond the mesocarp (hard and lignified middle area of the fruit 'shell'), and do not reach or feed on the beans. Nevertheless, in outbreaks on cocoa varieties with thinned shelled fruit in Bahia, Brazil, most larvae have been observed to tunnel beyond the mesoderm and attack the beans, causing direct damage (Nakayama, 2018).

Larval galleries are used for secondary infestation by other organisms, such as fungi, bacteria, beetles, fruit flies (*Citrus* White & Tuck, 1993; Gilligan & Epstein, 2014; *Byrsonima crassifolia* Gomez Orellana et al., 2008; *Macadamia* Primo Miranda, 2003), which cause the fruit or nut to rot.

Larvae may not be able to survive in the infested fruit or nut. For example, survival in macadamia nuts depends on dry matter content of the husk and prohanthocyanidine content (Blanco Metzler et al., 2013). On *Citrus*, even if larvae do not survive in the fruit (e.g. in green fruit with a low pH), they still cause damage, leading to fruit rot (Parra et al., 2004 citing Parra et al. 2001). Similarly, even when feeding is superficial on cocoa pods, damage occurs because of an acceleration of the ripening process, especially when several larvae are present, and of invasion of galleries by secondary pests, which accelerates fruit rot (Nakayama, 2018).

Finally, fruits or nuts may fall prematurely (Blanco-Metzler et al., 2007; Cabrera-Asencio et al., 2013; Fundecitrus, 2007; Leandro, 2012; Lima, 1945; White & Tuck, 1993). For *Citrus*, it is noted that fallen fruit often no longer carry the larvae, which have moved to the soil to pupate (Fundecitrus, 2019).

No information was found on the nature of damage on other host fruits, but it is supposed to be similar (damage to the flesh, seeds, fruit rot, possibly premature fall, secondary infestation by other organisms).

2.8 Detection and identification

Signs and symptoms of infestation

Signs and symptoms of infestation are on fruit. However, at early stages of infestation, on all hosts, they are not readily visible externally. The entry hole is minute (ca. 1.5 mm on *Melicoccis bijugatus* - Cabrera-Asencio et al., 2013). Symptoms become visible at later stages of infestation:

- *Citrus*. abnormal coloration and/or fruit fall (Fundecitrus, 2007; White & Tuck, 1993). Necrotic area around the entry hole (CARM, 2015; White & Tuck, 1993). Frass extruding from the hole (picture in Fundecitrus, 2007), and sticking to the rind of the fruit (Fundecitrus, 2007, 2019), bleaching at entry hole.
- *Macadamia*. Enlargement of the entry hole, which becomes more visible, frass emerging from the entry hole, pupae with one third of the body protruding from the nut (Blanco-Metzler, 1994).
- *Plukenetia volubilis*. First light brown spots on the fruit, becoming dark brown and expanding externally, which may eventually cover the whole fruit surface; abnormal maturation. Fruits attacked at early development stages may be smaller, deformed and soft (Leandro, 2012).
- *Melicoccus bijugatus, Theobroma cacao*. Changes in fruit colour and rot (Cabrera-Asencio et al., 2013; Nakayama, 2018).

Detection

The presence of adults is not easy to detect visually in the field (small size, remain inactive on the plant during the day, mimetic on branches) (Blanco-Metzler, 1994; Parra et al., 2004, Gómez Torres, 2005 citing others). Males can be trapped using pheromone traps. The sex pheromone of *G. aurantianum* has been identified (Leal et al., 2001). Traps have been commercially available in Brazil since 2002 (Bento et al., 2016). Details on monitoring using pheromone traps are given in section 12.4.

Symptoms on fruit are difficult to detect at early stages of infestation and low levels of infestation (USDA, 2003). Eggs are small and there is often only one egg per fruit, making detection difficult. On *Citrus* and other fruit, frays extruding from the entry hole is a good indicator of the presence of the pest (Batista Pereira, 2008; Vianna, 2015). Such frass starts appearing within 2-3 days of larval entry in the fruit (Vianna, 2015, not citing original sources). However, this extruding frass may break off in some conditions (wind, dry or wet conditions) (MAPA, 2018).

Other symptoms may also be observed later in an infestation (see above). USDA (2003) note that fruit infested by *G. aurantianum* are probably easier to detect (at sorting or inspection etc.) than fruit infested by other internal pests, such as fruit flies.

Possible confusion with fruit flies infestations

The main difference between symptoms on fruit for fruit flies and for *G. aurantianum* is that frass of *G. aurantianum* hardens in the rind, while the site of damage by fruit flies is soft and rotted (Fundecitrus, 2007, 2019).

Identification

Morphological identification of adults and larvae is possible (pupae of different species of *Gymnandrosoma* cannot be distinguished) (Adamski & Brown, 2001). A taxonomic expert in the family Tortricidae is needed to confirm identification (Gilligan & Epstein, 2014). A key to *Ecdytolopha* and *Gymnandrosoma* adults and larvae, as well as descriptions of adults and last instar larvae of *G. aurantianum* are provided in Adamski & Brown (2001). Illustrated nomenclature of adult genitalia can be found in Adamski & Brown (2001) and Gilligan & Epstein (2014). Males can be distinguished from other species of *Gymnandrosoma* through external characters (on antenna and tibia), while females need to be dissected (Gilligan & Epstein, 2014). Larvae of *Gymnandrosoma* can be separated from those of *Ecdytolopha* by the distance between various setae (details in Gilligan & Epstein, 2014). A setal map is given in Adamski & Brown (2001). Finally, Brown (2011) provides an online interactive tool to determine if a larvae is a Tortricidae and its possible identity (based on species intercepted in the USA) depending on the host fruit and its geographical origin (http://idtools.org/id/leps/tortai/keys/TortAILarvae.html).

In Brazil, the species was originally misidentified as being *Tortrix citrana* (Lima, 1945). The specimens collected in Costa Rica were initially misidentified as *Cryptophlebia leucotreta* (H. Blanco-Metzler, pers. comm., 2019-11). The pest is very similar to other species in *Ecdytolopha* and *Gymnandrosoma*, and there have also been cases of misidentification with other *Gymnandrosoma* species (Adamski & Brown, 2001).

The genera *Ecdytolopha* and *Gymnandrosoma* are not represented in the EPPO region, based on records in Adamski & Brown (2001). Neither are the closely-related genera mentioned in Adamski & Brown, *Cryptophlebia* and *Pseudogalleria*. Only *Thaumatotibia* is represented in the EPPO region, with *T. leucotreta* present with a limited distribution in Israel. *T. leucotreta* is a quarantine pest for many EPPO countries and would be targeted at import inspection. It has a number of host plants in common with *G. aurantianum*, such as *Citrus paradisi*, *C. reticulata*, *C. sinensis*, *Litchi chinensis*, *Prunus persica*, *Mangifera indica*, *Macadamia*, *Psidium guajava*, *Punica granatum* (EPPO, 2013).

Molecular identification. Barcodes are available for a specimen from Costa Rica (http://v4.boldsystems.org/). There are also sequences from several specimens of other *Ecdytolopha* and *Gymnandrosoma* species in GenBank. However, it is not clear if the data available would be sufficient for a reliable molecular identification.

3. Is the pest a vector? **Yes** ☐ **No** ✓

4. Is a vector needed for pest entry or spread? **Yes** ☐ **No** ✓

5. Regulatory status of the pest

In the EPPO region, *G. aurantianum* is a quarantine pest for Morocco (based on the lists of regulated pests on the International Phytosanitary Portal - IPP, www.ippc.int and EPPO Global Database - EPPO, 2019). It was added to the EPPO Alert List in 2017 (EPPO, 2017).

Regarding non-EPPO countries, *G. aurantianum* is a quarantine pest for the USA and Panama (from the lists of regulated pests on the IPP, 2017 and 2018 respectively). *E. torticornis* is on the quarantine list of Paraguay (2016). Not all national lists of regulated pests were checked, and *G. aurantianum* may be regulated in other countries.

In Mexico, *G. aurantianum* is included in a work plan for the import of lemons from Argentina, involving the NPPOs and the industry (Anonymous, 2018), and a risk analysis for the import of macadamia nuts from Guatemala led to a recommendation that mitigation measures should be applied to *E. torticornis* (SENASICA, 2017). *G. aurantianum* was not a quarantine pest for Mexico (2018 list of regulated pests on the IPP). See note * in section 6. In Chile, *G. aurantianum* is included in a work plan between NPPOs for the import of lemons from Brazil (SAG, 2012).

6. Pest distribution

G. aurantianum occurs only in the Americas. The records in Table 6 range between latitudes from ca. 19°N to 34°S.

Table 6. Global distribution of *G. aurantianum*

Region	Distribution	Additional details, references and uncertainties
North America	Mexico*	Adamski & Brown, 2001 (2 specimens collected in 1923-1924 in Colima State)
South America	Argentina	Entre Rios, Misiones (NE Argentina), Tucumán (NW) (Adamski & Brown, 2001; Lima, 1945). Not yet in Corrientes according to Cáceres (2006) [province located between Entre Rios and Misiones].
	Bolivia*	Razowski & Wojtusiak (2013)
	Brazil	First observed in 1915, and is thought to occur in all states where citrus are grown (Vianna, 2015). Records found for 16 federative units (out of 27):

		Alagoas, Amazonas, Bahia, Distrito Federal, Espírito Santo, Goiás, Maranhao, Mato Grosso, Minas Gerais, Pará, Paraná, Rio de Janeiro, Rondônia, Santa Catarina, São Paulo (Adamski & Brown, 2001), Rio Grande do Sul (Gómez Torres, 2005 citing Prates & Pinto, 1988, 1991 and Prates et al. (1995)
	Colombia	García (2005)
	Ecuador	Noboa et al. (2018)
	French Guiana*	Adamski & Brown, 2001 (incl. specimens collected in 1906, 1985)
	Peru	Leandro (2012)
	Suriname*	Adamski & Brown, 2001 (3 specimens collected in 1927)
	Uruguay#	USDA (2012) citing Bentancourt and Scatoni (2006)
	Venezuela	Delgado Puchi, 2005
Central America	Costa Rica	First report, misidentified as *Cryptophlebia* [*Thaumatotibia*] *leucotreta*)(Lara, 1987)
	El Salvador	Gomez Orellana et al., 2008
	Guatemala	Primo Miranda (2003)
	Honduras*	Adamski & Brown, 2001 (1 specimen from 1973)
	Nicaragua*	Adamski & Brown, 2001 (3 specimens incl. 1 collected in 1908)
	Panama*	Adamski & Brown, 2001 (1 specimen collected in 1965)
Caribbean	Cuba*	Adamski & Brown, 2001 (several specimens, collected in 1930, 1990)
	Dominican Republic	Perez-Gelabert (2008, citing SEA, 1999)
	Puerto Rico	Cabrera-Asencio et al. (2013)
	Trinidad and Tobago	White & Tuck (1993); White (1999)

* The validity of these records (country and pest identity) is not in doubt, but the current status of *G. aurantianum* in the country is uncertain. There is also no information on whether it is a pest. These records are from specimens (re)identified by Adamski & Brown (2001) or Razowski & Wojtusiak (2013), and there is no link to a host fruit. Some are based on old collection records (e.g. Mexico, 1922-23), and some specimens are indicated as collected in the natural environment ('rain forest' for French Guiana). For some of these countries, the pest was also detected in another country on fruit from these origins (in Nicaragua on oranges produced in Panama - Adamski & Brown, 2001; in the USA in passenger luggage from Mexico and Cuba – see Table 8). However, there are always uncertainties linked to such findings (esp. whether the specimen came from the country mentioned). *G. aurantianum* is on the A1 list of regulated pests of Panama (i.e. of pests absent from the country), and there is a work plan in Mexico in 2018 for lemons from Argentina (the pest is not on the 2018 quarantine list of Mexico - see section 5).

Bentancourt and Scatoni (2006) was not available when preparing this PRA (book), but it is cited as: '*G. aurantianum* was found in isolated fruits from domestic groves in Uruguay (Bentancourt and Scatoni, 2006)'. *G. aurantianum* in Uruguay is also mentioned in COSAVE-IICA (1999).

<u>Uncertain record</u>

Records of presence of *G. aurantianum* in the countries below are considered uncertain.

- **Belize**. Molet et al. (2018) mentions Belize, but the references cited in relation to the distribution of the pest do not refer to Belize. USDA (2003) cites White (1999), who cites White & Tuck (1993), who do not mention Belize.
- **Jamaica**. Interception in the USA in passenger luggage (see Table 8). Considered uncertain here given uncertainties inherent to interceptions (identification, fruit may not originate from the same country as the passenger).
- **Barbados** (Molet et al., 2018 citing Adamski & Brown, 2001). The only specimen mentioned for Barbados in Adamski & Brown (2001) was in 'cacao bean pod intercepted from Barbados in New York'. Considered uncertain due to the same uncertainties on interceptions as above.
- **Dominica** (Fennah, 1942; Molet et al., 2018 citing Agricultural Department of Dominica, 1923). This record is repeated in a few publications. White & Tuck (1993) note that 'a species of *Ecdytolopha* apparently different from Brazilian specimen' has been recorded on orange [and *Simarouba amara*] in Dominica. Adamski & Brown (2001) attributed the record from Fennah (1942) (based on re-examination of specimens) to *Gymnandrosoma trachycerus*. Agricultural Department of Dominica (1923) may have

referred to that other species, although this cannot be ascertained. No other record was found for *G. aurantianum* in Dominica.

- **Haiti**. Perez-Gelabert (2008) lists pests present in 'Hispaniola' (i.e. Dominican Republic and Haiti), and cites two references: the first one, Razowski, (1999), mentions one male collected in the Dominican Republic. The second one, SEA (1999), appears to relate only to the Dominican Republic; it was not available in full, and it was not possible to check if it mentions Haiti.
- **General.** Adamski & Brown (2001) note that *G. aurantianum* probably occurs on citrus in other South American countries. The South American countries not recorded above are Guyana, Paraguay (where *G. aurantianum* is a quarantine pest) and Chile (where the pest is regulated – see section 5). The EWG noted that the pest may still be absent from Chile due to geographical isolation, but that Guyana and Paraguay are surrounded by countries where the pest occurs. In Argentina, *G. aurantianum* is widely distributed in Noroeste according to Urretabizkaya et al. (2010) and Lima (1945), but a record was found only for Tucumán.

No other reference was found for the uncertain records above.

7. Host plants and their distribution in the PRA area

G. aurantianum has been recorded on a wide diversity of fruit plants, woody or herbaceous, cultivated or in the wild, belonging to various families. In several cases, authors make the hypothesis that *G. aurantianum* has passed from native to exotic cultivated hosts, such as macadamia in Costa Rica (Blanco-Metzler, 1994).

All species in Table 7A and Table 7B were recorded as hosts in the field (i.e. no experimental hosts have been reported).

- Table 7A contains species for which the literature confirms that the pest can complete its life cycle on the host (i.e. as known from observations in the field or because adults were reared from fruit infested in the field).
- Table 7B contains uncertain hosts, i.e. species which are listed as hosts in the literature, but there is no specific evidence that the pest can complete its life cycle (in some cases, there are records of interceptions on fruit of these species in the USA).

Some hosts are only recorded in older literature and do not appear in recent literature on outbreaks. When impact is mentioned in recent literature, it relates mainly to orange, mandarin, macadamia, cocoa and *Plukenetia volubilis*. Many confirmed or uncertain hosts are exotic to the Americas (incl. *Macadamia integrifolia*, *Citrus* spp., *Mangifera indica*, *Prunus persica* and *Punica granatum*).

There are differences in hosts attacked depending on countries, especially in Costa Rica, and the reasons for this are not known (see also *Taxonomy* and section 12).

Regarding *Citrus* spp., *G. aurantianum* has been recorded on many species, and it is considered likely in this PRA that other *Citrus* may be hosts. In addition, due to the wide host range and the fact that *G. aurantianum* has passed onto new hosts in the Americas, it is not excluded that it may be able to attack other fruit plants if the fruit is suitable for its development.

Oranges, mandarins, pomegranate and peach (the latter is an uncertain host) are the hosts with the widest presence in the EPPO region. Some more tropical hosts are present with a limited distribution in the EPPO region. Details on the presence of hosts in the EPPO region are given in section 9.1. The presence of hosts in the EPPO region is noted in Tables 7A and 7B according to their use, to give an idea of the scale of fruit presence (which is essential for the life cycle). *All hosts may also occur in botanical gardens, indoors or outdoors depending on environmental conditions, and may fruit or not (this is not repeated in the table).*

- *In the wild.* The conditions would be favourable to the plant, fruit would occur.
- *Cultivated for fruit production*. In areas of optimal conditions for the plant, the host may be cultivated commercially in orchards as well as for domestic use (e.g. small orchards, individual trees in gardens etc.). The plant may also be cultivated for domestic use outdoors in a wider area, where conditions are not optimal for the plant, but it may still produce some fruit.
- *Cultivated as ornamental (e.g. in private and public gardens, as street trees)*, i.e. the main purpose being ornamental. In some areas, the plant may fruit normally; in others it may survive, but not produce fruit.

The availability of host plants to the public to be planted as fruit plants or ornamentals was verified using general Internet searches to check availability in nurseries.

Table 7A. Hosts of *G. aurantianum*
Information in the literature confirms that the pest can complete its life cycle on the host (i.e. as known from observations in the field or because adults were reared from fruit infested in the field).).

Host	**Presence in PRA area (Yes/No/Not known)** (See section 9.1 for details)	Reference
Annona cherimola	**Yes.** Cultivated for fruit production, including commercial, in a very limited part of the region. Available as ornamental/fruit plant in nurseries.	Cabrera-Asencio et al., 2013 citing sources
Averrhoa carambola	**Yes.** Cultivated for fruit production, including commercial, in a very limited part of the region. Available as ornamental/fruit plant in nurseries	Cabrera-Asencio et al., 2013 citing sources
Byrsonima crassifolia	**Not known,** No evidence found of commercial cultivation or of availability as ornamental/fruit plants in nurseries, but seeds and fruit bonsais can be ordered on the Internet.	Gomez Orellana et al., 2008
Citrus spp.	**Yes.** See details for individual species below.	Cabrera-Asencio et al., 2013 citing sources
Citrus aurantifolia (small-fruited acid lime)	**Yes.** Cultivated for fruit production, incl. commercial, in a very limited part of the region. Available as ornamental/fruit plant in nurseries**.** .	Lima (1945)
Citrus limon (lemon)	**Yes:** Widely cultivated for fruit production, incl. commercial, in part of the region. Available as ornamental/fruit plant in nurseries	Lima (1945)
Citrus x paradisi (pomelo)	**Yes:** Cultivated for fruit production, incl. commercial, in part of the region. Available as ornamental/fruit plant in nurseries	Lima (1945)
Citrus reticulata (mandarin)	**Yes:** Widely cultivated for fruit production, incl. commercial, in part of the region. Available as ornamental/fruit plant in nurseries	Noboa et al. (2018)
Citrus sinensis (orange)	**Yes:** Widely cultivated for fruit production. Available as ornamental/fruit plant in nurseries	Cabrera-Asencio et al., 2013
Cojoba arborea (as *Pithecellobium arborea*)	**Not known.** No evidence found of commercial cultivation, nor of availability as ornamental/fruit plants in nurseries, but seeds can be ordered on the Internet	Adamski & Brown, 2001
Cupania vernalis	**Not known.** No information found	Cabrera-Asencio et al., 2013 citing sources; Brown et al., 2008 (referring to a collection), Adamski & Brown, 2001
Eriobotrya japonica	**Yes.** Cultivated for fruit production, including commercial, in a very limited part of the region. Available as ornamental/fruit plant in nurseries	Cabrera-Asencio et al., 2013 citing sources
Macadamia integrifolia	**Yes.** Cultivated for fruit production, including commercial, in a very limited part of the region. Available as ornamental/fruit plant in nurseries	Cabrera-Asencio et al., 2013 citing sources; Soares de Matos et al., 2019
Melicoccus bijugatus	**Yes.** Available as ornamental/fruit plant in nurseries. No evidence found of commercial cultivation.	Cabrera-Asencio et al., 2013 citing sources
Plukenetia volubilis	**Not known.** No evidence of commercial cultivation, nor of availability as ornamental/fruit plant in nurseries, but seeds can be ordered on the Internet	Leandro, 2012

Host	Presence in PRA area (Yes/No/Not known) (See section 9.1 for details)	Reference
Psidium guajava	**Yes.** Cultivated for fruit production, including commercial, in a very limited part of the region. Available as ornamental/fruit plant in nurseries.	Adamski & Brown, 2001; Pereira 2008
Punica granatum	**Yes.** Wild in Central Asia, widely cultivated in part of the EPPO region. Available as ornamental/fruit plant in nurseries	Adamski & Brown, 2001; Brown et al., 2008 – see Not hosts below
Sapindus saponaria	**Yes.** Available as ornamental/fruit plant in nurseries. No evidence found of commercial cultivation.	White, 1999
Theobroma cacao	**Yes.** Available as ornamental/fruit plant in nurseries. No evidence found of commercial cultivation.	Adamski & Brown, 2001; Brown et al., 2008, Nakayama, 2018

Table 7B. Uncertain hosts. No evidence was found if the pest completes its life cycle on these plants. It is noted that interceptions have been reported from the USA for the species marked with *.

Host	Presence in PRA area (Yes/No/Not known) (See section 9.1 for details)	Reference
Annona squamosa	**Not known.** No information found on whether it is cultivated commercially. Mentioned as 'introduced' in a few countries (CABI ISC)	Nakano & Soares 1995 cited in Cabrera-Asencio et al., 2013
Annona cherimola x *A. squamosa*	**Yes.** Cultivated for fruit production, including commercial, in a very limited part of the region. Available as ornamental/fruit plant in nurseries.	Brown et al. (2008)
Carya illinoiensis	**Yes.** Cultivated, including commercial, in a very limited part of the region (e.g. NE Italy, Turkey mainly Antalya; L. Montecchio, N. Üstün, pers. comm.). Available as ornamental/fruit plant in nurseries	White (1999) citing GCONCI, 1997
*Litchi chinensis**	**Yes.** Cultivated for fruit production, including commercial, in a very limited part of the region. Available as ornamental/fruit plant in nurseries	Lima, 1945 (*Nephelium litchi*), White, 1999 citing GCONCI, 1997
*Mangifera indica**	**Yes.** Cultivated for fruit production, including commercial, in a very limited part of the region. Available as ornamental/fruit plant in nurseries	Nakayama, 2018 citing Zucchi et al., 1993; Nakano & Soares, 1995; White, 1999 citing GCONCI, 1997
Persea americana	**Yes.** Cultivated for fruit production, including commercial, in a limited part of the region. Available as ornamental/fruit plant in nurseries.	White (1999), (Batista Pereira, 2008)
*Pithecellobium dulce**	**Yes.** Available as ornamental plant in nurseries. No evidence found of commercial cultivation.	Adamski & Brown, 2001; Brown et al., 2008
*Prunus persica**	**Yes:** Widely cultivated for fruit production Available as ornamental/fruit plant in nurseries	Adamski & Brown, 2001; Brown et al., 2008

G. aurantianum was also intercepted in the USA with fruit of other species not mentioned as hosts in the literature Due to uncertainties linked to interceptions, these were not added to the tables above: *Inga edulis* (available as ornamental in the EPPO region), *Citrus tangerina* (cultivated commercially in the EPPO region), *Phaseolus vulgaris* (widely cultivated throughout the EPPO region).

Not considered hosts in this PRA:

- *Musa*. Adamski & Brown (2001) note that the record for *Musa* originates from the description of *Argyroploce torticornis* published by Meyrick in 1931, but that the specimens' labels indicate collection on cocoa. *Musa* or *Musa acuminata* are repeated in many publications, but this is considered an error perpetuated from Meyrick 1931 (Brown et al., 2008; Molet et al., 2018).

- *Cocos nucifera* is mentioned in Parra et al. (2004) citing Meyrick 1931. Adamski & Brown (2001) mentioned that Meyrick's specimen were on *Theobroma cacao* (see *Musa* above).
- *Simarouba amara*. This host record from Dominica is repeated in several publications citing Fennah (1942). Fennah (1942) was later attributed to another species, *G. trachycerus* (see *Uncertain records* in the Distribution).
- *Punica* sp. (Adamski & Brown (2001), specimen in Cornell University collection). The family Punicaceae includes two species, *P. granatum* and *P. protopunica* (Holland et al., 2009). *P. granatum* is the cultivated species, also introduced into the Americas. *P. protopunica* is endemic to Yemen (Socotra Isl.) and introduced into Hawaii; it is not a fruit tree (https://www.worldwidefruits.com/punica-protopunica---socotran-pomegranate.html). Only *P. granatum* is considered a host in this PRA.
- *Macadamia* sp. Interceptions in the USA (Brown, 2011). The known host is *Macadamia integrifolia*. Other *Macadamia* sp. are not used for nut production. *M. tetraphylla* is used as a rootstock. Consequently, the interception was probably on *M. integrifolia*).
- *Robinia* (Noboa et al., 2018, citing Adamski & Brown, 2001). This is assumed to be a citation mistake. *Robinia* is not mentioned as a host under *G. aurantianum* in Adamski & Brown (2001).

8. Pathways for entry

G. aurantianum can move internationally with fruit, as shown by interceptions in commercial consignments and travellers' luggage (see details in sections 8.1.1 and 8.1.2 respectively). Importation of fruit containing larvae in luggage is considered a likely pathway of introduction into the USA (Molet et al., 2018). In addition, host plants may also be infested.

For the purpose of assessing the entry pathways, all known and uncertain hosts in tables 7A and 7B are considered. Information on the life cycle of the pest which are relevant to the pathways are detailed in section 2.

The EWG reviewed the EPPO Secretariat's tree of pathways (in preparation) to determine which pathways were relevant for the pest. The following pathways for entry of *G. aurantianum* are discussed in this PRA. Pathways in bold are studied in section 8.1; other pathways were considered to present a very low likelihood of entry of *G. aurantianum*, and are considered in section 8.2.

- **Host fruit and associated packing material**
- **Travellers' luggage**
- **Host plants for planting (except cuttings, seeds, tissue culture, pollen) with or without soil or growing medium**
- **Containers (used to transport hosts or as contaminant)**
- Tissue cultures, pollen, cuttings
- Soil and growing medium on its own
- Soil attached to used vehicles, machinery and equipment
- Wood with bark and isolated bark of host plants
- Wood packaging material
- Cut branches of hosts
- Stored products/dried plant parts
- Processed commodities made from host material
- Contaminant on other commodities ('hitchhiking')
- Natural spread

When reviewing the EPPO Secretariat's tree of pathways, the EWG noted that the following pathways had no relevance for the pest (in particular the hosts of *G. aurantianum* are not used to produce such commodities) and did not need to be mentioned in this PRA: bulbs, corms, tubers, rhizomes; underground plant parts; cut flowers, cut foliage, leaf vegetables (incl. herbs); international mail items; animals.

8.1 Pathways studied

Examples of prohibition or inspection are given only for some EPPO countries (in this express PRA the regulations of all EPPO countries were not fully analysed). Similarly, the current phytosanitary requirements of EPPO countries in place on the different pathways are not detailed. The EU and Morocco, where many of the hosts are reported, were chosen as examples. However, EPPO countries would have to check whether their current requirements are appropriate to help preventing the introduction of the pest.

Although specific requirements are currently in place for certain commodities in certain EPPO countries, each pathway was also assessed without such requirements in place, and assuming that fruits and plants for planting are being imported from infested areas.

8.1.1 Host fruit and associated packing material

Table 8

Pathway	**Host fruit and associated packing material**
Coverage	Fruit commodities moving in trade from host species where the pest occurs. The fruits species concerned are discussed in the row 'Plants concerned'. This pathway includes fruit with or without green parts (leaves and peduncles) associated. It also covers crates or boxes used for packing host fruit. Fruit carried by travellers are covered separately (8.1.2)
Pathway prohibited in the PRA area?	No. In the EU, import of citrus fruit with peduncles or leaves from countries where the pest is present are prohibited, but this would not affect the presence of *G. aurantianum*.
Pathway subject to a plant health inspection at import?	Partly. In the EU, fruit of *Citrus* and their packaging are subject to inspection. Specific requirements in place may bring more focus at inspection on fruit from where the pest occurs: for example for *Citrus* fruit in relation to Tephritidae or pathovars of *Xanthomonas citri*, reported from South America. As of 14th December 2019, all fruit except *Ananas comosus*, *Cocos nucifera*, *Durio zibethinus*, *Musa* and *Phoenix dactylifera* is subject to inspection at import in the EU (EU Implementing regulation 2019/2072). All fruit is subject to inspection in Morocco (Arrêté n°593-17, 2017). Where fruit is inspected, packing material accompanying fruit would also be checked. The related species *Thaumatotibia leucotreta* is a quarantine pest for many EPPO countries and inspections would target it. Although it has common hosts with *G. aurantianum*, it has no common country of origin.
Pest already intercepted?	Yes. - In Spain, there have been 5 interceptions (4 from Brazil, 1 from Argentina) of *G. aurantianum* (larvae) in *Citrus sinensis* fruits between 2009 and 2019 (notified as *Ecdytolopha aurantianum;* EUROPHYT, 2019). - In the USA, *Ecdytolopha* and *Gymnandrosoma* spp. (not identified to species) were intercepted 393 times with fruit in 1985-2003, but only 6 times with fruit in cargo (and never in *Citrus* fruit consignments) (USDA, 2003). *G. aurantianum* was intercepted since the late 2000s in commercial consignments of *Theobroma cacao* pods from Ecuador, and *Melicoccus bijugatus* from the Dominican Republic. It is also mentioned as intercepted on *Litchi chinensis* (Brown, 2011) without indication of whether in commercial consignments or travellers' luggage. Other interceptions were made in travellers' luggage (see details in 8.1.2). - one specimen in Adamski & Brown (2001) found in Nicaragua on oranges produced in Panama, and three specimens found in the UK in macadamia nut from Costa Rica in 1988. In both cases it is not clear if it relates to commercial consignments.
Plants concerned	Hosts in section 7. There is an uncertainty on whether the pest completes its life cycle on the hosts listed in Table 7B. *G. aurantianum* has been intercepted in the USA (in passenger luggage) on *Inga edulis*, *Citrus tangerina*, *Phaseolus vulgaris*, which are not recorded as hosts. The host status of *I. edulis* and *P. vulgaris* is more uncertain, no specific information is given below. *Citrus tangerina* is covered to a certain extend below by considering other *Citrus* hosts.
Most likely stages that may be associated	**Fruit.** Eggs and larvae may be associated. Eggs may remain if the fruit is stored in cool conditions; otherwise, because the egg stage has a short duration, eggs may have already hatched into larvae. Pupae may be associated: * if they were in the fruit when picked (association with fruit is mentioned in the literature for some hosts, but for others such as *Citrus*, the pupae are often in the soil), or * if they have been produced during storage or transport, i.e. mature larvae close to pupation were in the fruit when picked. Larvae are reported to pupate on any surface.

Pathway	Host fruit and associated packing material
	USDA (2003) report interceptions of pupae of *Ecdytolopha* or *Gymnandrosoma* in fruit in 2 cases. **Packing material** may carry pupae if larvae pupate during transport or storage. Adults are unlikely to be associated with the fruit at harvest, but may emerge from the fruit during transport, provided it is long enough (the duration of the pupal stage may reach 20 days, and may be longer in unfavourable conditions – i.e. cooled – see Survival below).
Important factors for association with the pathway	In the field, *G. aurantianum* is more likely to be associated with some species, such as *Citrus*, *Macadamia*, *Theobroma cacao*, depending on the origin of the fruit. The pest is reported in cultivation mostly on *Citrus* (at least Brazil, Argentina, Ecuador), macadamia (at least Costa Rica, Guatemala, Venezuela, Colombia), *Theobroma cacao* (at least Brazil, Venezuela). It is not clear what the situation is in other countries, or for other hosts in the countries specified above. *G. aurantianum* is present year-round in the crops in countries for which detailed information is available (information is lacking from others). Association with macadamia nuts in trade is very unlikely. The only possible association would be if there is a trade of fresh macadamia nuts with husks, and exporting with the husk intact is not a known practice (in particular, it increase the weight to be transported). Adamski & Brown (2001) examined 3 specimens from macadamia nuts exported to the UK (but they do not specify if they were alive at the time of finding, nor if they were in a commercial shipment). Macadamia nut is normally commercialized when it is already processed (H. Blanco-Metzler, pers. comm., 2019-12). The United Nations Economic Commission for Europe standards for traded macadamia nuts (inshell) and kernels (shelled) (UNECE, 2010, 2011) provide that the moisture content of the kernel should not exceed, respectively, 10% (inshell) and 2% (shelled), they should be free from pests, and 'free from damage caused by pests, including the presence of dead insects and/or mites, their debris or excreta'. EPPO (2013) notes that macadamia nuts are vacuum-packed at kernel moisture below 1.5%. Larvae of *G. aurantianum* would not survive such low humidity. Harvest and post-harvest practices (picking/harvesting, sorting, brushing, washing, waxing, packing) may dislodge or damage life stages at the surface of the fruit (e.g. eggs, neonatal larvae for fruit) (USDA, 2003, 2015). In laboratory experiments using *Plukenetia volubilis*, Leandro (2012) noted that first instar larvae at the fruit surface are very sensitive to fruit manipulation. Later larval instars are in the fruit and are protected from most post-harvest treatments; however, symptoms on fruit (discoloration, frass) makes them less likely than fruit flies to remain undetected during the post-harvest culling phase, also supported by the relatively few findings, whereas intensive inspections are conducted on cut fruit to detect fruit flies (USDA, 2003). Fruit rot would also progress in storage and transport. Nevertheless, interceptions show that infested fruit may not be detected in the exporting country. Detection would depend on the level and stage of infestation, and on the intensity of inspection. Infestations at early stages are less likely to be detected, and later infestation may also remain unnoticed (pupae intercepted in the USA). At least in Brazil, and probably in other countries, there may be measures in place to avoid infestation of consignments for fruit exported to countries which regulate the pest. Their nature is not known, nor whether they are applied for all other destinations and for other hosts (regulations appear to mostly target *Citrus*). If there is an infestation in an orchard, large numbers of eggs will have been laid (each female may lay 50-100 eggs, in different fruits). However, the number of larvae per packed fruit is likely to be low: in most cases there is only one larva per fruit. In interceptions of *Ecdytolopha* sp. or *Gymnandrosoma* sp. in fruit in the USA, there were mostly only one larva (or pupa) (ca. 68% of cases for all hosts and 92%

Pathway	Host fruit and associated packing material
	for citrus hosts - 11 interceptions where one larva was found; 1 interception where two larvae were found) (USDA, 2003). For cocoa pods, where there may be several larvae, End et al. (2014) mention that the necrotic galleries near the surface are unlikely to be overlooked during visual inspection prior to shipping; however, this publication deals with germplasm exchange, and not commercial exchange of big consignments. There have been interceptions on cacao pods. Commercial cocoa is probably not exported as pods (beans or paste).
Survival during transport and storage	Interception on fruit cargo show that life stages in fruit can survive transport and storage, at least on *Citrus*, *Melicoccus bijugatus* and *Theobroma cacao* (known interceptions on cargo). Fruit in international trade is commonly transported under controlled conditions (lower temperature and/or controlled atmosphere). If eggs or neonatal larvae are present on the fruit, it is not known how they will be affected by such conditions. Adults are reported to be able to survive with water without food and reproduce; however it is not known how they will be affected by transport temperatures. *Citrus* fruit is often transported in controlled conditions with low temperature. GDV (2016a, b & c cited in the Dropsa project) mention ranges of transport temperatures as follows: 5-10°C for oranges; 0-8°C for mandarins (noting considerable variation depending on variety and country of origin); 6-9°C for clementines; oranges may be stored for a duration of 4-16 weeks in suitable temperature/humidity conditions, and longer in controlled atmosphere. Larvae of *G. aurantianum* are inside the fruit and, therefore, are protected to some extent from the low temperatures (USDA, 2003, 2015). It was considered here that larvae in fruit, as well as pupae if produced during transport, would be able to survive normal transport temperatures. Mortality in transport may be high, but a small proportion of individuals may survive. *Citrus* is detailed here as a ‘worst case’ for the pest (low temperatures, long storage and transport). Many tropical fruits are more sensitive to long storage and low temperatures, and storage and transport conditions would probably be more favourable to the pest. In some EPPO countries, all fruit would be subject to an inspection (e.g. in the EU), but probably with different intensities depending on the fruit species, quarantine pests they may carry, and origin. The use of cold treatment to impede the spread of *G. aurantianum* in oranges ‘is said to be inadequate’ (USDA, 2003 citing Faria et al., 1998).
Trade	There is a trade of host fruit from countries where the pest occurs into the EPPO region. The figures below (from FAOStat, imports reported by EPPO countries for 2016) give an indication of the existence of a trade for confirmed hosts in Table 7A. Trade patterns may change over time, and there is also an uncertainty on which commercial crops are infested where the pest occurs. In addition, fruit for which no trade is recorded at the moment may become popular in the future. Data was not extracted for countries with uncertain records. Detailed data is given in Annex 3. - ‘lemons and limes’. over 390000 tonnes (t) from 15 countries where the pest occurs to 40 EPPO countries, incl. ca. 243000 t from Argentina, 86000 t from Brazil, 54000 t from Mexico - ‘oranges’. Over 140000 t oranges from 12 countries where the pest occurs to 24 EPPO countries, incl. ca. 55000 t from Argentina, 38000 t from Uruguay, 24000 t from Brazil, 10000 t from Peru - ‘tangerines, mandarines, clementines and satsumas’. Over 94000 t from 11 countries where the pest occurs to 20 EPPO countries, incl. ca. 52000 t from Peru, 28000 t from Argentina, and 13000 from Uruguay. - ‘grapefruit incl. pomelos’. Over 15000 t from 10 countries where the pest occurs to 15 EPPO countries, incl. ca. 14500 t from Mexico For *Citrus*, the trading period depends on the varieties, but oranges and mandarins mature in autumn to spring where they grow. Oranges and mandarins from the Southern hemisphere would generally reach the EU in June-November, oranges from the Northern hemisphere generally from November to June. This is also the period where *Citrus* fruit from the EU and Mediterranean countries are mostly available, although in

Pathway	Host fruit and associated packing material
	part of the EPPO region, there are *Citrus* fruit all year round (see section 9.2). In addition: - *Melicoccus bijugatus*. Europe imports some quantities (not specified) (Janick & Paull, 2008). The fruit has limited success in the international market (pulp difficult to separate from the seed, only small quantities of edible pulp) (Bystrom, 2012). - *Plukenetia volubilis* is mostly consumed locally (seeds). However, oil produced from the seeds was used for cosmetics, and has become popular as food in Europe and Asia due to its high omega-3 content (approved by the EU in 2013). Currently, it seems to be imported as oil, and not as fruit/seeds (but the situation may change). - Macadamia nuts are imported without husk (with shell or not) (https://www.cbi.eu/market-information/processed-fruit-vegetables-edible-nuts/macadamia-nuts/). No details on trade volumes are given here. - Fruits of *Byrsonima crassifolia* are reported as being used locally, and no indication of international trade was found (by general internet search), but both cultivation and trade may develops in the future. The species above are relevant for the pathway travellers. Finally, some hosts are not used for their fruit and are very unlikely to be traded as such: *Sapindus saponaria* (although the use of nuts 'soap nuts' as alternative to washing powder is mentioned on the Internet), *Cupania vernalis*, *Cojoba arborea*.
Transfer to a host	For transfer to occur, at least one male and one female should emerge from the fruit/or packing material, mating occurs and the female finds a suitable host. Male(s) and female(s) should be introduced relatively close to each other. The sex pheromone would help individuals find each other, but has a limited range (at least half of the distance recommended for spacing traps, i.e. 175 m) (Fundecitrus, 2007). Alternatively, several infested fruit should be discarded together, the larvae complete their development, at least a male and a female emerge, the male find a female and mating occur, and the female fly to a suitable host. Adults are reported to be sensitive to relative humidity (RH) below 50% (under which their ability to lay eggs is reduced), and larvae and pupae to temperatures above 30°C. However, the humidity and temperature outdoors in part of the EPPO region where hosts are grown are suitable (incl. the Mediterranean area); there is an uncertainty for other areas); the RH would also be higher in irrigated crops (see section 9.3). Because the conditions in the discarded fruit may not remain favourable for the larvae during their whole lifetime (or they may be predated upon), transfer would be more likely if it has already reached the late larval instar or stage. If the pest reached the EPPO region in winter, it would need to find fruit (there does not seem to be a life stage allowing for long periods without fruit). In part of the EPPO region, there will be host fruit all year-round in the field at different stages of maturation (see section 9.2 , and the pest can also attack green fruits). Hosts are cultivated in part of the EPPO region, and in other areas may be scattered as ornamentals. It is not known if *G. aurantianum* would be able to use new hosts. The adults apparently have a limited flight capacity, and it is not known if they could fly longer and find a host. Finding hosts may be easier if the pest arrives close to nurseries where various species are grown. Host fruit are imported for consumption or processing, and transfer to a host is generally considered unlikely (the pest will be destroyed during processing or damaged fruit will be identified and discarded by processors, retailers or the final consumer in a closed waste bin). Infested fruit would also continue degrading during transport and storage, in particular the fruit may rot, and may be discarded before reaching the consumer. It is unlikely that there are several larvae in a fruit, or that the same consumer buys several infected fruits (this may be higher for processing). However, damaged fruit may be discarded in a compost pile, close to hosts.

Pathway	Host fruit and associated packing material
	EPPO (2013 citing EFSA, 2007) reports that 'fruits and vegetables intended for processing (e.g. for juice, jam, etc.) are less subject to inspections, but the phytosanitary import regulation makes no such differentiation'. As fruits and vegetables intended for processing are commonly of lower quality, they are therefore more susceptible to be infested. However, larvae will be destroyed during processing. If infested fruits are discarded before processing, the pest may survive if no effective waste disposal procedure is in place, particularly if they are discarded outdoors. Generally, transfer may be more likely if fruit arrives in areas close to production facilities (e.g. for repacking), where damaged fruit may be discarded in open bins close to crops, and a larger quantity of damaged fruit may be discarded. The risk is therefore higher where imported fruit is stored or repacked (very) close to production facilities, which is known to be the case in some places (see below). In the PRA on *Thaumatotibia leucotreta* (EPPO, 2013), it was mentioned that in some cases in the Netherlands consignments of inferior quality, especially citrus, are sorted and upgraded to marketable quality by specialized companies. These consignments are stored under cold conditions, but the wastes are often disposed of in open containers that stay outside for several days. In the Mediterranean part of the PRA area, part of citrus consignments from countries where [*T. leucotreta*] is present are imported for sorting, re-packing and further distribution. Sorting and packing facilities are located in the vicinity of *Citrus* fruit production areas thus ensuring host availability. During the sorting/repacking process, culled infested fruit may be discarded outdoors on compost piles.
Likelihood of entry and uncertainty	***Citrus* fruit** – moderate-high likelihood (suitable conditions in at least part of the EPPO region; fruit processing/packing facilities close to *Citrus* growing areas in the Mediterranean area; eggs, larvae or pupae may be associated; large number of individuals potentially transported along the pathway (as if there is infestation in an orchard, many fruit will be infested); trade exists; has been intercepted; current regulations not sufficient; may not be detected at early stage of infestation; however, circumstances making transfer difficult in areas of EPPO other than the Mediterranean area) with moderate uncertainty (only few interceptions, whether there are measures applied at origin) **Macadamia nuts** – low likelihood (not 'very low' because of interceptions) with moderate uncertainty (whether all macadamia are exported without husk, no data on trade). **Other fruit** – very low (trade volumes lower than citrus, and hosts that are traded are probably occasional; few interceptions in the USA; some hosts, including uncertain hosts, are probably occasional; no measures to detect infestation, difficult to detect), with high uncertainty (host status not clear for some hosts, association, transfer to hosts, trade volumes, whether there are measures applied at origin)

8.1.2 Travellers' luggage

Table 9

Pathway	Travellers' luggage
Coverage	Travellers from where the pest occurs may carry fruit, as well as plants (although this is less likely than fruit). This pathway also covers the luggage itself or bags used to pack the material. Transport of soil on its own is unlikely, and for it to be infested it would have to have been collected below host plants (i.e. fruit crops), which is even less likely. Soil is not considered further here. The most obvious travellers covered by this pathway are those travelling by plane. Airline luggage is a known pathway for introduction of alien insect species in the USA (Liebhold et al., 2006, fruit presumed to be largely represented because to be consumed during the journey or as gifts). However, this pathway also covers ship, cruise or leisure boats. Travellers are not only tourists, but also crews, nationals from countries where the pest occurs residing in the EPPO region, or from EPPO countries residing in a country where the pest occurs, etc.

Pathway	Travellers' luggage
	Fruit is likely to be intended for consumption (similar to studies in South Africa, own consumption for next of kin or friends (Ramasodi, 2008). Visits to the home country and bringing typical products or to preserve their home culture is also known in the case of products of animal origin (De Melo et al., 2014). Passengers may bring fruit to eat during their journey, and have leftovers at arrival. Transport of live specimen for collection is unlikely because the pest is not visually interesting.
Pathway prohibited in the PRA area?	No
Pathway subject to a plant health inspection at import?	No. In the EU, there have been occasional luggage checks in some EU countries. According to EU Regulation 2016/2031 (entering into force on 14 Dec. 2019), seaports, airports and international transport operators should make information available to passengers concerning prohibitions, requirements and exemptions. As of 14th December 2019, all fruit entering the EU will require a phytosanitary certificate with the exception of: *Ananas comosus, Cocos nucifera, Durio zibethinus, Musa* and *Phoenix dactylifera*. In Turkey, passengers are allowed to bring in 3 kg of fruit; a PC is required for larger quantities (N. Üstün, pers. comm., 2019-11).
Pest already intercepted?	Yes. In the USA, intercepted at many occasions since the late 2000s in luggage in fruit of: *Psidium guajava*, *Theobroma cacao*, *Inga edulis*, *Prunus persica*, *Byrsonima crassifolia*, *Punica granatum*, *Mangifera indica*, *Citrus tangerina*, grapefruit (species not indicated), *Melicoccus bijugatus*, *Phaseolus vulgaris*, *Pithecellobium dulce* (Molet et al., 2018). Also intercepted in commercial fruit consignments (see 8.1.1). Also intercepted on *Litchi chinensis* (whether in commercial consignments or passenger luggage is not indicated) (Brown, 2011).
Plants and plant products concerned	Hosts in section 7. There is an uncertainty on whether the pest completes its life cycle on the hosts listed in Table 7B. *G. aurantianum* has been intercepted in the USA (in passenger luggage) on *Inga edulis*, *Citrus tangerina*, *Phaseolus vulgaris,* which are not recorded as hosts. The host status of *I. edulis* and *P. vulgaris* is more uncertain, no specific information is given below. *Citrus tangerina* is covered to a certain extend below by considering other *Citrus* hosts.
Most likely stages that may be associated	**Fruit.** Fruits may carry live larvae. In most species, there is often only 1 larva per fruit. Pupae may be associated: * if they were in the fruit when picked (association with fruit is mentioned in the literature for some hosts, but for others such as Citrus, the pupae are often in the soil), or * if they have been produced during storage of the fruit or its transport, i.e. if larvae very close to pupation were in the fruit when picked. Travel is unlikely to be long enough to allow development to pupa (this is possible for ship transport, but fruit has a limited viability and is unlikely to remain in luggage through long transport times). Passenger air travel is known to contribute to the introduction pressure of invasive alien species, and to the lesser extend seaports (Early et al., 2016). Eggs are not likely to be associated. Even if present at picking, they are likely to have hatched already and are unlikely to be associated with the fruit in luggage (unlike for commercial consignments for which storing at lower temperatures would slow development and delay hatching). Adults are unlikely to be associated with the fruit when picked, and are unlikely to emerge during transport (for the same reason as above). **Plants.** These would presumably be of small size, and unlikely to have fruited, and therefore unlikely to carry any life stage. Only fruit bonsais may carry fruit (such as reported for *Byrsonima crassifolia*). However, it is not known if the pest would lay eggs on such fruit, and if they would provide enough food for larval development. Seeds were not assessed here (see Plants for planting).
Important factors for	Interceptions show that larvae may remain associated with fruit. The presence or absence of green parts (leaves and peduncles) with

Pathway	Travellers' luggage
association with the pathway	the fruit does not significantly affect the likelihood of association of the pest. If the fruit originates from commercial orchards, operations at harvest and post-harvest may limit the association of life stages (similar to the 'Host fruit and associated packing material' pathway). However, fruit transported by passengers may come from local production or gardens etc., where the pest may not be controlled. The fruit may also not be washed. If there is an infestation in a garden, large numbers of eggs may have been laid (each female may lay 50-100 eggs, in different fruits). Travellers may look at the fruit to make sure it is in a good state but may not notice early infestations. This would be the same for plants with fruits. *G. aurantianum* is present all year-round in some countries (information is lacking from others). Detection at arrival would depend on luggage inspection, which is currently not done on a regular basis in many EPPO countries.
Survival during transport and storage	Larvae and pupae would survive. Interceptions on fruit in passenger luggage show that life stages are present in fruit in luggage. For air travel, travel time would be too short to affect survival, and the fruit would not be transported in cool conditions. If produced in transport, pupae will remain in the container (e.g. bags, suitcase etc.) that contains the fruit. Damage to the fruit may be noticed during long transports (e.g. ship) as infestation progresses and fruit may be discarded before reaching destination.
Trade	There is no detail on the movement of fruit with passengers into countries of the EPPO region. Volumes would be lower than commercial consignments. There is frequent tourism from the EPPO region to countries where the pest occurs, such as Brazil, Ecuador, Argentina and Cuba. Decreased costs of travel have led in recent years to an increased air travel. There are also large communities originating from countries where the pest occurs, which may visit their country and bring fruit back. More exotic fruit may be transported because they are difficult to find or expensive on European markets (e.g. *Byrsonima crassifolia*– interceptions in the USA or *Plukenetia volubilis*). As detailed below, transfer is unlikely if the passengers carry one or few fruits, but is more likely if they carry more. This is not excluded especially for fruits that may not be easy to find in EPPO countries.
Transfer to a host	Hosts are widespread in the EPPO region. Infested fruit will likely be discarded in a bin but may be thrown outdoors. Transfer would depend on whether the life stages in the fruit (most likely larvae, more rarely pupae) would be able to complete development to adults, whether climatic conditions would be favourable, and on the presence of hosts nearby. The conditions for a successful transfer would be the same as for fruit consignments. However, in most fruit, there is often only one larva, so the traveller should have discarded several infested fruits for transfer to succeed. If adults have emerged during transport (which is unlikely), there should be at least one male and one female, able to fly out from the luggage undamaged to outdoors (very unlikely), and to find a host. The pest is present all year-round at origin, and may be brought to the EPPO region at seasons where transfer is possible. It cannot be excluded that transported fruits are used for planting seeds, however, this would not lead to transfer of the pest to a host. *G. aurantianum* has a wide host range and may be able to transfer to a fruit that is not known as host yet.
Likelihood of entry and uncertainty	Low likelihood (pest can be present, may be lots of fruit transported during flights with probability that carry some pests, but difficult to transfer, mostly one larvae per fruit, and would need one male and one female, volumes carried per person would be lower than trade volumes, risk to part of the EPPO region only, fruit more intended for consumption) with moderate uncertainty (difficult to quantify volume, some fruit eaten during transport)

8.1.3 Host plants for planting (except cuttings, seeds, tissue culture, pollen) with or without soil or growing medium

Table 10

Pathway	**Host plants for planting (except cuttings, seeds, tissue culture, pollen) with or without soil or growing medium**
Coverage	This pathway covers plants for planting in pots or similar (including bonsais), as well as plants with bare roots. Tissue culture, pollen and cuttings are considered in section 8.2. **Seeds.** Larvae of *G. aurantianum* are recorded to feed on seeds of some species (e.g. *Macadamia*, *Theobroma cacao*, *Plukenetia volubilis, Annona, Citrus*). On macadamia nuts, larvae may feed on the kernel; pupae may be associated to the nut, but close to emergence they were observed to have almost a third of their body protruding from the nut and would therefore not be associated with kernel. Information is missing to assess this pathway in details: i.e. * no information available for most hosts; * not known if larvae can be completely inside the seed and escape detection for some hosts. * not known if seeds for planting of some hosts would be exchanged still enclosed in the fruit (in which case the pest would remain in the fruit). * not known if the main hosts are traded as seeds for planting purposes (i.e. for fruit cultivation), even if the seeds of at least some hosts are available through Internet sale (*Byrsonima crassifolia*, *Cojoba arborea*, *P. volubilis*). Seeds would normally be carefully chosen and infestation of the fruit/seeds may be observed. Because of the lack of data, seeds were not considered further in this pathway. In any case, the probability of entry with seeds would be lower than for plants, with a higher uncertainty.
Pathway prohibited in the PRA area?	Yes in part, in some countries: Import of plants for planting of *Citrus* are prohibited in the EU from all third countries, as well as in Morocco (except fruits and seeds – arrêté du 22 mai 1951). Similar prohibition are probably in place in some EPPO *Citrus*-producing countries. In the EU, trees and shrubs for planting originating in countries where *G. aurantianum* is present should be free from fruits. Import of plants for planting of *Prunus* (i.e. *P. persica*) other than dormant plants free from leaves, flowers and fruit from non-European countries are prohibited in the EU. In Morocco, import of *Prunus* plants is subject to authorization (arrêté n°824-93, 1993). In Turkey, import of *Citrus*, *Prunus* and hosts plants of *Xylella fastidiosa* are prohibited from infested areas of countries where *X. fastidiosa* occurs. For other hosts, in the EU there is no prohibition but some requirements make association less likely (see below).
Pathway subject to a plant health inspection at import?	Yes, partly, in some EPPO countries. In the EU, there would be inspection to ensure compliance with phytosanitary import requirements. Depending on the species and its origin, and for certain quarantine pests, some EPPO member countries make specific requirements for host plants included in section 7. In the EU, there are specific requirements for e.g. *Eriobotrya*, *Prunus*, growing medium associated with plants, deciduous trees and shrubs generally, and bonsais. Specific requirements include for specific pests: pest free areas; inspections for symptoms at the site of production; treatment of plants. The growing medium associated with plants should be treated or found free from pests. Trees and shrubs should be free from plant debris, free from flowers and fruits, have grown in nurseries, have been inspected at appropriate times and prior to export, and found free from bacteria or virus symptoms, and either free from signs of other pests or treated. Deciduous trees and shrubs should be dormant and free from leaves. In Morocco, all plants for planting are subject to inspection at import (arrêté n°593-17).
Pest already intercepted?	No evidence found of interception on plants for planting
Plants concerned	Hosts of *G. aurantianum* (see section 7) with an uncertainty for hosts in Table 7B
Most likely stages that may be associated	Eggs and larvae are mostly associated with fruit, very rarely with leaves (and in that case it is unlikely that they would complete development in the absence of fruit). Pupae may be associated with soil or growing medium, more rarely with fruit or other plant parts.

<table>
<tr><th>Pathway</th><th>Host plants for planting (except cuttings, seeds, tissue culture, pollen) with or without soil or growing medium</th></tr>
<tr><td></td><td>Adults are unlikely to remain with the plants through the disturbances linked to harvesting and packing (They may be present if produced during transport and storage – see below).</td></tr>
<tr><td>Important factors for association with the pathway</td><td>Eggs, larvae or pupae would be associated only if those are old enough to have already fruited. Plants for planting would in most cases be young plants that would not be bearing fruit. Ornamental Citrus are commonly traded with fruit (MAPA, 2018) (but their import is prohibited into many EPPO countries). At least Byrsonima crassifolia or ornamental Citrus are used as fruit bonsais. The pest could complete its development on bonsais only if those carry fruit of a sufficient size.

The pest is reported mostly on some hosts in fruit production, and the situation in nurseries is not known. In Puerto Rico, a commercial fruit tree nursery of Melicoccus bijugatus was found infested (Cabrera-Asencio et al., 2013). No such reference was found for Citrus or other hosts, nor for Brazil, but it was not excluded here.

Dormant plants or plants without fruit are unlikely to carry life stages. Similarly the presence of leaves is not considered important for the likelihood, as life stages are mostly on fruit, and development would not be completed on leaves.

Consequently:
-Plants with fruit with soil or growing medium may carry eggs, larvae and pupae (the later more often in the soil or growing medium)
-Plants without fruit with soil or growing medium may carry pupae (eggs and larvae unlikely), but only if the plant has already produced fruit (including if those were removed).
-Association is very unlikely for bare-rooted plants without fruit (even if there are leaves).
- Bare-rooted plants with fruit could carry eggs and larvae, but this is an unlikely commodity (washing the soil or growing medium from plants with leaves and fruit would compromise their viability, they would not be traded without soil or growing medium).

Any requirements made regarding dormancy, soil or growing medium associated with plants and absence of fruit (e.g. in the EU) would greatly lower the likelihood of association of G. aurantianum.</td></tr>
<tr><td>Survival during transport and storage</td><td>Hosts would be transported in conditions favourable to the plants. Life stages in the fruit and in the soil or growing medium can survive. Adults, or newly emerged adults could survive without feeding and could find water on the plants. The pest is not likely to multiply in transport and storage, as this will be short in comparison with its life cycle.
Transport may occur under cool conditions, which would not impact survival but probably slow development.</td></tr>
<tr><td>Trade</td><td>No detailed data are available for import of host plants for planting from South America into the EPPO region. In the EU, the import of some genera is prohibited from countries where the pest is present (see above).
For the period 2000-2011, ISEFOR data (regarding imports from non-EU countries into the EU – Eschen et al., 2017) indicate the following imports. However, these data are incomplete and there is a high uncertainty concerning the import volumes of plants for planting of host plants of G. aurantianum into the EPPO region.
<table>
<tr><th>Species</th><th>Number of pieces (year country)</th></tr>
<tr><td>Annona</td><td>300 (2010 Costa Rica), 112 (2012 Dominican Rep.)</td></tr>
<tr><td>Citrus[#]</td><td>19 (2000 Brazil), 1 (2001 Brazil), 249583 (2004 Mexico)</td></tr>
<tr><td>Theobroma</td><td>4 (2007 Costa Rica)</td></tr>
<tr><td>Mangifera and Mangifera indica* (M. indica is an uncertain host, Table 7B)</td><td>1 (2000 Dominican Rep.) 10 (2001 Dominican Rep.), 15485* (2002 Costa Rica), 72* (2010 Dominican Rep.)</td></tr>
</table></td></tr>
</table>

Pathway	Host plants for planting (except cuttings, seeds, tissue culture, pollen) with or without soil or growing medium
	Prunus (*P. persica* is an uncertain host, Table 7B) — 936 (2001 Suriname), 10170 (2003 Suriname) *It was noted that the pest has not been recorded on the hosts above in Costa Rica. # As *Citrus* plants for planting were prohibited in the EU from such origins, such consignments would be rejected. This nevertheless shows the existence of possible origins for such plants for planting.
Transfer to a host	In the context of import inspections, visual examination of the plants may detect larval damage on fruit. However, detection may be difficult on large plants. Pupae would not be detected. Adults, if they fly, may be detected. The commodity is intended for planting, and the pest may continue its development on the plants, if the conditions (especially relative humidity) are appropriate. This would be less likely for plants used in habitations indoors (e.g. bonsais).
Likelihood of entry and uncertainty	**Plants for planting with soil or growing medium.** Low likelihood (if there are fruit, eggs, larvae, pupae may be associated; but normally young plants are traded without fruit; plants would need to have fruited; may be requirements in place for other pests), with moderate uncertainty (no information on trade volumes, proportion of trees traded with fruit, management practices e.g. growing medium in nurseries). Bare-rooted plants: very low likelihood, with a low uncertainty. This pathway was consequently added to section 8.2. Note: the likelihood of entry on Host seeds could not be assessed (see under 'Coverage' above), but it would be lower than for plants for planting with soil or growing medium.

Containers (used to transport hosts or as contaminant). Theoretically, the pest could be a contaminant of containers used to transport host fruits in bulk. Larvae emerging from fruit are reported to pupate on any substrate. In addition, adults may be attracted by light at loading of containers at export (although there is no evidence). There is no information to assess and rate this pathway.

8.2 Pathways with a very low likelihood of entry

The uncertainty was assessed to be low for all pathways below.

- **Tissue culture, pollen, cuttings**. No life stage is associated with tissue culture or pollen. If eggs or young larvae were associated with leaves on cuttings (which is a rare event), they would not be able to pursue and complete their development (in the absence of fruit).
- **Bare rooted plants**. As a result of the pathway study under 8.1.3.
- **Soil and growing medium on its own.** Soil or growing medium associated with plants for planting is covered under the plants for planting pathway (section 8.1.3), and soil associated with vehicles, machinery and equipment is developed below. Import of soil on its own is prohibited in many EPPO countries from the countries where the pest occurs (e.g. in the EU, Turkey), and the pathway is closed in these EPPO countries. The following relates to countries where the pathway is not closed. The only life stage that may be associated are pupae, and only if the soil originates from a fruit producing field/orchard. It is unlikely that such soil is used as a commodity. Pupae would survive, at least if they are close to the surface; in the field, they are in the above layer of the soil, 0-1.5 cm deep (Bento, 2008). The pupal stage lasts for about 20 days. If adults emerge during transport and storage, they may not survive if they are too deep in the soil mass, and they may also not find sufficient water. Soil would be used outdoors. However, adults may have difficulties to emerge if they are deep in the soil mass. Transfer to a host plant will depend on where the soil will be used.
- **Soil attached to used vehicles, machinery and equipment.** Pupae may contaminate soil attached to used machinery and equipment. The pupae occur at shallow depths in the soil (0-1.5 cm). However, there is probably very little movement of used machinery from the countries where the pest occurs into the EPPO region and, if there is, it is probable that such equipment would undergo phytosanitary procedures such as decontamination. This pathway is covered by an International Standard for Phytosanitary Measures (ISPM 41) (FAO, 2017).
- **Wood with bark and isolated bark of host plants.** Eggs and larvae are not on the wood or bark, and if they were, they would not be able to pursue their development. Pupae are occasionally reported associated with stems: in *Macadamia*, because nuts carrying pupae may remain associated with lichen and moss on the trunk when they fall. However, most hosts, including macadamia, are fruit trees, and are unlikely to be traded as wood or bark. Macadamia nuts remaining in the lichen or moss would be dislodged when handling and processing the wood.
- **Wood packaging material**. No life stage is associated.
- **Cut branches of hosts**. Eggs and larvae may be associated if there are fruit. It is not known if cut branches of hosts may be traded internationally with fruit, but it is not probable. The cut branches would rapidly lose their decorative value as the fruit would fall and dry, and at least for *Citrus*, leaves would also dry rapidly.
- **Stored products/dried plant parts**. Pot pourri commonly contain pieces of citrus fruit. However these are dried and any egg or larva associated would not survive.
- **Processed commodities made from host fruit.** These commodities made from host fruit (e.g. fruit juice, pulp, dried fruit, canned fruit) are processed to a degree that would not allow survival of any life stage present. The life stages of *G. aurantianum* would not be associated to other processed commodities.
- **Contaminant on other commodities ('hitchhiking').** Hitch-hiking of pupae is considered in section 8.1 in relation to fruit packaging and containers, and above in relation to used machinery, vehicles and equipment. No other form for hitchhiking is considered to have some likelihood.
- **Natural spread**. *G. aurantianum* is present only in the Americas, and cannot spread naturally to the EPPO region.

Rating of the likelihood of entry	*Very low* ☐	*Low* ☐	*Moderate* ☐	***High*** **X**	*Very high* ☐
Rating of uncertainty			*Low* ☐	***Moderate*** **X**	*High* ☐

9. Likelihood of establishment outdoors in the PRA area

9.1 Host plants in the EPPO region

Details on hosts and production areas in the EPPO region are provided in Annexes 4 and 5 respectively.

The most widespread hosts in the EPPO region are *Citrus* and *Punica granatum* (pomegranate), as well as the uncertain host *Prunus persica* (peach). As detailed in Annexes 4 and 5, the Mediterranean Basin, but also Central Asia to Georgia and Russia are the main areas of commercial production. *Citrus* spp. are grown on 450000 ha. The main known *Citrus* hosts in the EPPO region are *C. sinensis*, *C. reticulata* and *C. limon*, with a small cultivation of *C. x paradisi* and *C. aurantifolia*. *Punica granatum* is grown in the same areas (no detailed data was available). Pomegranate is present in the wild and cultivated in Central Asia, and it is widely planted around the Mediterranean Basin and in the Middle East. The uncertain host *Prunus persica* (peach) is also widely grown with a commercial area of 37000 ha. It is cultivated commercially in similar areas to *Citrus* and pomegranate, but also further North, through Central Europe to Poland and Germany. *Citrus*, pomegranate and peach may also be cultivated for fruit for domestic production or ornamental purpose in areas that are less or not optimal for commercial production.

A number of tropical hosts are cultivated for fruit production in the EPPO region on limited areas, such as *Annona cherimola*, *Averrhoa carambola*, *Eriobotrya japonica*, *Macadamia integrifolia*, *Psidium guajava*, as well as some uncertain hosts, such as *Annona cherimola* x *A. squamosa, Carya illinoiensis, Litchi chinensis, Mangifera indica, Persea americana*. Limited areas present conditions that are suitable for the cultivation of tropical hosts for fruit, and possibly mostly for species that also can tolerate drier conditions. Andalusia (on the coasts of Malaga and Granada) is the only producing area within the European continent that has developed a commercial tropical fruit production (Peláez, 2017 – news article), the value of the harvested production in 2015 reaching more than 100 million euros (all tropical fruits, not only hosts). Tropical crops are also grown in Israel, and to a lesser extend in the south of Italy (e.g. Sicilia, Calabria) and in Morocco (possibly other North African countries). Conditions may also be appropriate locally in other countries of the Mediterranean area and Black Sea, but no data was found. Tropical hosts would also be grown on some islands of Portugal and Spain (Canary Isl., Madeira). Tropical hosts may also be grown for domestic fruit production in the same areas, and as ornamentals elsewhere. Most are available in nurseries (see table in section 7), including some species for which no evidence of commercial cultivation, such as *Melicoccus bijugatus*, *Sapindus saponaria* or *Theobroma cacao*.

The EWG considered that the pest may be able to attack other fruit crops if introduced into the EPPO region (e.g. *Prunus* that are not recorded as hosts and are widely cultivated in the EPPO region) (see section 7).

Hosts are perennial, which is an advantage for establishment. The presence of fruit on host plants is critical for establishment, and this is analysed in section 9.2.

9.2 Biological considerations

The main biological constraint for the establishment of the pest is the availability of fruit. No life stage is reported to be able to withstand long periods without fruit. Larvae need fruit to complete their development. No pupal diapause has been recorded, which would allow survival in unfavourable conditions. Adults may survive for 25 days. In order to maintain populations, the pest would need the presence of host fruit in the field all year-round. It is noted that the pest can attack fruit independently from the stage of maturation; for example green and ripe *Citrus* fruit may be attacked.

- In some countries of the PRA area (at least Spain and Turkey), there are *Citrus* fruit all year round in the field at different stages of maturation (due to the cultivation of various species and varieties). Various species and varieties of *Citrus* are also grown for fruit or as ornamentals in gardens and cities, which may also contribute to the availability of fruit all year-round. Other hosts would also extend the availability of fruit in the field.
- In other areas information was not available. However, the pest has a wide host range and, even where *Citrus* fruit are not present all year-round, there may be other fruit that would allow the pest to maintain populations (for example in Israel or Morocco where tropical hosts are also grown). In some Mediterranean countries, the gap between availability of *Citrus* fruits in orchards may only be a couple of months, and there may be other fruit, for example pomegranate, loquat (*Eriobotrya japonica*) or peach. For example in part of Sicily (Italy), *Citrus* fruit of different species and cultivars are present on trees for at least 10-11 months (L. Torta, University of Palermo, pers. comm. 2019-11).
- In areas further to the north or more continental, it is not known whether fruit would be available all year round.

The pest may have several generations and female fecundity is high in favourable conditions.

In the literature, soil (type and humidity) is mentioned as an abiotic factor that influence the pest: duration and survival of pupae, survival of larvae (by changing the characteristics of the fruits). Like for other PRAs, it is not possible to take soil type into account at the scale of the EPPO region. In addition, it is not possible to know whether this factor is more or less important than for similar pests that have pupae in the soil. Temperature and relative humidity are considered in the literature as major abiotic factors, and are considered below.

9.3 Climatic suitability

Plant hardiness (maps in Annex 6)
Within its current area of distribution, *G. aurantianum* occurs in the plant hardiness zones 9 to 13 (from Uruguay northwards). Zone 10 is represented marginally in the EPPO region, on a limited part of the Mediterranean coast. Zone 9 is also Mediterranean, reaching more inland and extending to the Western coast of Europe, as well as the Black Sea coast.

In the USA, the potential distribution of *G. aurantianum* was estimated using 'the degree-day model reported by Garcia, 1998 as cited in Parra et al., 2004' (USDA, 2015). Areas where *G. aurantianum* could complete 7 generations were considered as favourable for permanent establishment based on the biology of the pest in Brazil. Consequently, establishment was considered possible in the USA in the plant hardiness zones 6-11. In the EPPO region, zones 6-8 cover most of the EPPO region, to the South of Scandinavia in the north and Russia in the East. (see map in Annex 6). However, it is not clear how the model in Garcia (1998) was obtained, and what the lower temperature threshold of the pest in the field is (as mentioned in section 2). The EWG considered that the hardiness zones defined in the USA based on the model appear to be too wide for the EPPO region given the biological data available.

In addition a degree-day model would not take into account rainfall and relative humidity. Relative humidity is an important factor as below 50% RH, it decreases the longevity and oviposition capacity of adults. Rainfall would influence soil conditions and therefore pupation; saturated soils or dry soils affect the pupae and decrease emergence (see section 2.3).

Köppen-Geiger (maps in Annex 7)
Most of the distribution of *G. aurantianum* in South America and the Caribbean is under tropical and humid subtropical climatic zones that are not present in the EPPO region. However, *G. aurantianum* is present in Southern Brazil, Uruguay and Northern Argentina where the prevalent climatic zone is Cfa (Humid subtropical - Mild with no dry season, hot summer). The climatic zone Cfa in the EPPO region is limited to parts of Northern Italy, the Balkans and the Black Sea coast.

The pests also occurs in Brazil in the states of São Paulo and Rio de Janeiro, which both include limited parts under the climatic zone Cfb (Marine west coast - Mild with no dry season, warm summer), but in the absence of detailed data, it is not known if *G. aurantianum* occurs in these limited areas. In the EPPO region, Cfb is the prevalent climate from Western Europe (to UK and coastal Norway in the North) to the Black-Sea in the South-East. It is not clear if the biological data in section 2 support its presence in such climates.

The only Mediterranean-type climate in South America is Csb (warm temperate, fully humid, warm summer), but *G. aurantianum* is not recorded in these areas. Csb is present in center-eastern Chile and in the corresponding areas across the border in Argentina. The EWG has considered under section 6 that the absence of *G. aurantianum* in Chile could be due to geographical isolation, i.e. the absence of the pest does not mean that the conditions are not appropriate in those areas.

The other prevalent climate in the Mediterranean part of the EPPO region (Csa) does not occur in the known distribution of *G. aurantianum*, and comparison is therefore not possible.

From the available data on distribution, it is also not possible to determine if the pest occurs in the limited parts of its distribution where climatic zones similar to EPPO occur (e.g. Bsk in Brazil, which is present in part of Southern Spain, North Africa, Turkey). It is assumed not to occur in the zone Cfc in Colombia and Venezuela, which has a limited presence in the EPPO region in Scotland and Norway.

Temperature and relative humidity
Temperature is less critical to the life cycle than relative humidity. Although temperature patterns are different between the origin and the EPPO region, the EWG concluded that temperature in some parts of the EPPO region would be appropriate to support the life cycle of the pest (see also 2.3).

Relative humidity below 50% decrease oviposition and longevity of adults. It is noted that at 50% RH, egg-laying was greatly reduced, but still happened, which may be relevant for establishment (see section 2.3). A comparison in relation to relative humidity was attempted for areas and locations where the pest occurs and *Citrus*-producing areas and Andalusia (tropical hosts) in the EPPO region.

- Maps of annual RH for Europe and South America (Annex 8 – section 1) show that the annual relative humidity is above 50% in areas of the EPPO region where Citrus is grown, and around 75% in some areas. It is around/above 75% in most of the pest distribution in South America, and possibly ca. 50% in limited parts (such as Tucuman, NW Argentina).
- The monthly average humidity in some major Citrus and hosts growing areas in EPPO countries, although lower than in São Paulo State, is close to 60% even in June-July (Annex 8 – section 2).
- Daily values over the year (2019) where considered for some locations in the same areas as above (Annex 8, section 3). They show that days below 50% are spread differently throughout the year, but in most of the locations considered in the EPPO region, there were fewer days below 50%, or there were no extended period below 50 %, compared to São Jose do Rio Preto [São Paulo, State], where the pest is registered to have 8 generations per year (Fundecitrus 2007). The location with most days below 50% RH was Murcia (major lemon-growing area in Spain). The extreme RH are more pronounced, with for example a range of 15-100 % in Larache (Morocco, Tanger-Tetouan-Al Hoceima region), versus 30-90(+)% in Sao José do Rio Preto.

In addition, the EWG noted that:

- a relative humidity below 50% would need to last for a longer period in order to affect the pest (especially because of the relatively long life of females). Data for Sao Jose do Rio Preto, where the pest is reported to reach 8 generations per year, show consecutive days below 50% from August to October (Citrus production period).
- at all locations considered in the EPPO region, the average daily RH may be over 90 % at some periods.
- adults are most active at dusk and at dawn, when the RH is higher than during the day, and spend the day protected on leaves or other parts of the tree (where the RH is higher than on the outside of the tree).
- larvae (inside the fruit, the pest are not affected by the external climatic conditions) or pupae (the most protected life stage) would not be influenced by external conditions.

Finally, where temperatures may be suitable in the EPPO region, the crops are grown under irrigation. The relative humidity in irrigated crops would be higher than the average values above. Areas where host plants are not irrigated or not regularly irrigated in dry areas would be unsuitable for the survival of pupae and for adult activity.

9.4 Conclusion of establishment
Based on biological data, the EWG considered that conditions would be suitable for establishment on the Mediterranean coast, in the Cfa zone (part of Northern Italy, the Balkans, and the Black Sea coast), as well as in Southern Portugal and the Atlantic coast of Morocco (see section 9.3). Citrus crops are grown in these areas, and other hosts are also present (see section 9.1). Fruit would be available all year round at least in part of this area (see section 9.2).

There is more uncertainty regarding establishment in more continental and northern areas where *Citrus* or other hosts are grown, as the climatic conditions may be less favourable for the pest.

In the absence of suitable fruit throughout the year, the pest may form a transient population, and then disappear. This would also be the case in the part of the EPPO region where climatic conditions are not suitable during part of the year.

- Mediterranean coast, Southern Portugal and the Atlantic coast of Morocco, as well as part of Northern Italy, the Balkans and the Black Sea coast, in places where host fruit is present all year round. Uncertainty: whether the conditions are appropriate at the specific location at the time of pest entry, presence of host fruit all-year round, status of uncertain hosts and whether the pest would find new hosts

Rating of establishment outdoors	*Very low* ☐	*Low* ☐	*Moderate* ☐	*High* ***X***	*Very high* ☐
Rating of uncertainty			*Low* ☐	*Moderate* ***X***	*High* ☐

- rest of the EPPO region. Uncertainty: status of uncertain hosts, whether the pest would find new hosts, whether the relative humidity is appropriate in such areas, the fact that according to hardiness zones, the establishment area is wider.

Rating of establishment outdoors	*Very low* ☐	*Low* **X**	*Moderate* ☐	*High* ☐	*Very high* ☐
Rating of uncertainty			*Low* ☐	*Moderate* **X**	*High* ☐

10. Likelihood of establishment in protected conditions in the PRA area

Hosts are generally not grown in protected conditions, but there are some specialized productions. For example, for early fruit production, peach trees (uncertain host) are grown commercially under tunnels in Jordan (EPPO PRA on *Phytoplasma phoenicium*, which considered *Prunus* hosts). It was not investigated further whether other host fruit, including tropical plants, are grown commercially under protected conditions in the EPPO region.

The management of temperatures under protection (e.g. polytunnels, glasshouses) maintains average temperatures between 20 and 35°C. Protected conditions, such as in nurseries, tropical greenhouses e.g. in botanical gardens may offer appropriate conditions for the development of the pest. In these conditions, adults are more likely to find each other. Host trees may also be temporarily grown under protected conditions in nurseries, and the pest could establish a transient population if fruit is available. Large trees bearing fruit may occasionally be grown in nurseries. The pest control methods applied in protected conditions may help detection and have an impact on survival of the pest, e.g. adults if insecticide sprays are applied. If the pest has not established outdoors, outbreaks could be eradicated.

The infested commodity would need to be placed close to hosts grown in protected conditions. Fruit may be repacked in or close to areas where crops are produced in protected conditions. However, the frequency by which this will happen is considered to be very low. Imported infested plants may be brought directly into protected conditions (e.g. nurseries).

However, availability of fruit is critical. The pest is not expected to survive in the long term in the absence of fruit (see section 9.2). Fruit may be present all year round in nurseries or botanical gardens where a wide range of host species and varieties are present.

The rating below took account of the following: establishment is possible only if fruit is available throughout the year, hosts are normally not cultivated under protected conditions in the EPPO region, damage is more likely to be noticed, management measures applied in nurseries or botanical gardens may affect the pest.

Uncertainty. lack of information on commercial greenhouses and nurseries, whether there are fruit all year round.

Rating of establishment in protected conditions	*Very low* ☐	*Low* **X**	*Moderate* ☐	*High* ☐	*Very high* ☐
Rating of uncertainty			*Low* ☐	*Moderate* **X**	*High* ☐

11. Spread in the PRA area
Adults can fly but appear to be poor fliers. Flight may contribute only to local spread from orchard to orchard. It is not known if adults would be able to reach orchards that are not adjacent or close to each other. In part of the EPPO region (especially the Mediterranean area), there is a widespread presence of host fruit trees such as *Citrus*, peach and tropical hosts, which could help local spread of the pest.

Human-assisted movement could be through infested fruit and plants, especially with larvae inside fruit. If there is an infestation in an orchard, many fruits could be infested due to the egg-laying patterns of the females (potentially many eggs laid in different fruits). There is a large trade of *Citrus* fruit and peaches from the southern part of the EPPO region to other countries, as well as some tropical fruit. In 2015, 16000 tons of mangoes were exported from Andalusia to other European countries, and some other tropical fruit were also exported to the European markets (Peláez, 2017). However, as for entry, transfer to suitable hosts needs to occur for the pest to establish further away. Where fruit waste from processing or damaged fruit is discarded close to orchards, this may allow new foci to arise.

Similarly, if a nursery producing plants for planting with fruit (for fruit production or as ornamentals) was infested, there may be many larvae in fruit, or pupae in the soil or growing medium. The exchange of trees with fruit may not be subject to the same requirements for absence of fruit within the EPPO region (e.g. within the EU).

Larvae or pupae may be dislodged from fruit during harvest, and remain in harvesting crates or trucks, or in post-harvest facilities, and emerging adults may reach hosts in the close vicinity.

In conclusion, the likelihood of natural spread is low, but that of human-assisted spread is high, and the magnitude of spread was rated as moderate.
Uncertainty: natural spread capacity, whether able to fly the distance between suitable hosts.

Rating of the magnitude of spread	*Very low* ☐	*Low* ☐	***Moderate* X**	*High* ☐	*Very high* ☐
Rating of uncertainty			*Low* ☐	***Moderate* X**	*High* ☐

12. Impact in the current area of distribution
12.1 Direct impact on fruit production
The pest has had impact on fruit production in Central and South America. Once larvae have entered the fruit, it is unfit for sale and consumption and processing (*Citrus* Bento et al., 2016 citing Bento *et al.*, 2001; Parra et al., 2004; *Melicoccus bijugatus* Cabrera-Asencio et al., 2013). Even if the attack does not succeed and the larvae die, the fruit cannot be sold, and may have started rotting (Parra et al., 2004). Superficial damage does not prevent using macadamia fruit (Blanco-Metzler, 1994) or seeds of *Theobroma cacao* (Nakayama, 2018).

Impacts below are classified by host fruit. Information is missing from many countries where the pest occurs, and for many hosts. It is possible that in some countries *G. aurantianum* is not present in commercial fruit production, and only attacks native hosts or fruit hosts in other situations (native environment, gardens, parks, cities, etc.).

Citrus
Two original reports of damage (White, 1999, White & Tuck, 1993), with damage as high as 40-50%, are cited throughout the literature. This seems to represent older situations, pre-dating integrated control.

- In Argentina, no information was found on the current situation. Severe infestations were observed in Tucúman at the end of the 1930s on orange, mandarin and other citrus species. Within 3-4 weeks, in an orchard containing 2000 trees orchard (2nd production year), more than 30000 fruits fell and 15-20000 more were visibly infested on the trees (Lima, 1945). The same publication considered the pest widespread in North-West Argentina. According to several sources of 2007-2008 cited in USDA (2015), *G. aurantianum* has never been reported to infest lemons in Northwest Argentina.

- **In Brazil**, G. *aurantianum* was first observed to cause damage to citrus trees in São Paulo State in 1915 (Bento et al., 2001, citing Lima, 1927). By the mid-1980s, it had been found in 54 municipalities of São Paulo State and in 10 other Brazilian States, which resulted in reduced citrus production in these regions (Bento et al., 2001, citing others). *G. aurantianum* remained a minor pest until the end of the 1980s (Parra et al., 2004) and then became a limiting factor to citrus production and often reached economic damage levels in São Paulo State. It is mentioned amongst emerging pests in the State of Espirito Santo (Vianna, 2015).
  Damage due to *G. aurantianum* in São Paulo State were estimated at 50 million USD per year during the 1990s (Bento et al., 2001 citing Anonymous, 2000; Cabrera-Asencio et al., 2013 citing Revista Citricultor, 2016; Leite et al., 2005 citing Fundecitrus, 2000). Yield losses up to 50% were reported in São Paulo State (Leite et al., 2005 citing Prates 1992; Bento et al., 2001, citing Garcia et al., 1998; Garcia & Parra, 1999 citing Citricultura 1996). Outbreaks could compromise up to 1-2 boxes fruit per tree (about 350 fruits per plant) in heavy infestations (Leite et al., 2005 citing references from the 1980s-1990s; Nakayama, 2018, citing Fundecitrus, 2000 and 2003; Parra et al., 2004 citing Pinto 1994, 1995; Prates & Pinto 1988a, b, 1991; Bento et al., 2004 citing Pinto, 1995). At that time, control relied on pesticides when the first attacked fruits were observed, which did not control the pest and eliminated natural enemies, thereby increasing losses (Parra et al., 2004). Following the implementation of a new integrated management strategy based on pheromone traps, surveys carried out on *Citrus* in the States of São Paulo and South Minas Gerais, showed that losses were on average 0.6 to 1 fruit/plant (Bento et al., 2001, 2004 citing others).
  For an area covering 56600-79100 ha of citrus (20.4 to 29.4 million trees) in Central-Southern Brazil, it was estimated that the long-term use of sex pheromone traps in 2002-2013 had resulted in citrus growers avoiding accumulated pest losses of 132.7 million to 1.32 billion USD in gross revenues, considering potential crop losses in the range of 5 to 50%. Over 38000 traps were sold each year (Bento et al., 2016).
- **In Ecuador**, *G. aurantianum* was known from orange and has recently been reported on mandarin during a survey of insect-infested fruit (Noboa et al., 2018). The authors mention that economic losses of up to 40% may occur. It is not clear if this relates to the situation in Ecuador, or to the general statement from White and Tuck (1993 below, Trinidad), which has been widely used in the literature.
- **In Uruguay**, the pest was mentioned as being occasional and not of potential economic importance (COSAVE-IICA, 1999). '*G. aurantianum* was found in isolated fruits from domestic groves in Uruguay' (Bentancourt and Scatoni, 2006 cited in USDA, 2012). Note that these publications do not specify that these observations were on *Citrus* (or other hosts), but USDA (2012) is a PRA on *Citrus* fruit. It is noted that Uruguay is at the Southern limit of the current distribution of the pest in South America, and may be beyond the limits of optimal conditions as, because the pest is not of potential economic importance there, despite the presence of *Citrus* production. However, the reasons for this are not known, and it cannot be concluded whether this is due to climatic conditions or other factors.
- **In Trinidad**, White (1999) mentions that the pest had 'recently' become a serious pest of citrus. Local infestations had occurred each year since 1991; prior to this, the last recorded occurrence was in 1936 (citing Pickles, 1936). Losses of 2 to 40% were reported in one major orchard in Trinidad in the growing season of 1992-1993 (White, 1999). The pest affected mostly oranges and 'portugals', and to a lesser extent grapefruit (White & Tuck, 1993).
- **In the rest of the Caribbean,** reports of damage are generally old, and no information was found on the current situation. In a review of pests and diseases of fruit production in the Caribbean, IICA (1986) considered *G. aurantianum* amongst pests of minor or local importance on citrus.
- No information was found for *Citrus* in **Central America**.

Macadamia

- **In Costa Rica**, damage due to *G. aurantianum* (then known as *E. torticornis*) on macadamia was first observed in 1986 (Blanco-Metzler, 1994 citing Lara 1987). Macadamia is a plant of relatively recent introduction in Costa Rica (1952), has been grown commercially since 1965 and more intensively planted afterwards (Blanco-Metzler, 1994). During 3 sampling years, nut production decreased and percentages of nut damage by clone ranged from 5 to 10%, with 27.5% damage in one year (Blanco-Metzler, 1994). Increased maximum nut damage have been reported since the first report in Costa Rica: 16% by Lara (1987), 28% by Masis and Campos (1990), and 39% by Blanco-Metzler *et al*. (1992) (cited in Blanco-Metzler et al., 2007). Other sources indicate infestations of 12-39% in the shell/hulls and 1-7% in the almond/nut (Primo Miranda, 2003, citing Blanco, 1993). Predation of larvae whilst the macadamia nuts are on the ground significantly reduces the abundance of *G. aurantianum* (Blanco-Metzler et al., 2009). Management strategies that have been put in place (see section 12) have reduced the impact of the pest below its economic damage threshold (H. Blanco-Metzler, pers. comm., 2019).

- **In Guatemala**, *G. aurantianum* was considered as the main pest of macadamia and caused yield reduction (Primo Miranda, 2003). In a trial on control with *Beauveria bassiana*, all trial treatments presented 30% damage prior to trial start [presumably 30% of nuts infested, although this is not clear]. The use of insecticides has led to increased costs, resistance development, pesticide residues in fruits, environmental impact (Primo Miranda, 2003). No recent data was found.
- **In Venezuela**, *G. aurantianum* has been reported as the main pest attacking macadamia crops, but damage levels have not been investigated (Briceño & Sharkey, 2000 citing Arizaleta et al., 1997).
- **In Colombia**, damage (incl. to the exocarp and mesocarp) of approximately 60% have been reported in the past, with yield reduction (due to damage to the endocarp) of 11%; integrated management reduced damage to below 6% (citing a source from 1992; García, 2005).
- **In Brazil,** *G. aurantianum* has recently been reported on macadamia. Commercial production of macadamia nuts is recent, and few studies have investigated the insects associated with this crop (Soares de Matos et al., 2019).

Melicoccus bijugatus

- **In Puerto Rico,** *G. aurantianum* was first found in an agricultural research station, later in a commercial nursery. Damage was 1.7% (one out of 60 fruit) in September 2009, and reached an estimated 5% in September 2011 (Cabrera-Asencio et al., 2013).

Theobroma cacao

- **In Brazil**, *Theobroma cacao* was already known as a host since *G. aurantianum* was first identified. No outbreak was reported in Bahia State in 1950-2012 [main production area in Brazil (CIBA, 2019)]. In May 2013, unusual symptoms were observed and surveys confirmed epidemic levels in certain plantations, with infestation levels reaching 80% (Nakayama, 2018). Damage is not only superficial, as generally observed on cocoa (see section 2.5). Losses still need to be quantified, but the damage observed raised concerns due to fruit rot and direct feeding on beans (Nakayama, 2018).
- **In Colombia**, *Gymnandrosoma aurantianum* is not a main pest on *Theobroma cacao* (Muñoz et al., 2018).
- **In Venezuela**, *G. aurantianum* has been reported as a pest of cocoa in the centre and east of the country (Delgado Puchi, 2005). No details are given, and none of the references mentioned were available for this PRA.

Plukenetia volubilis

- **In Peru**, *G. aurantianum* has become a key pest of *Plukenetia volubilis*, and causes economic losses. Percentages of infestation of 17% fruit were observed (Leandro, 2012).

Psidium guajava

- **In Brazil,** Pereira (2008) mentions that plantations of guava and other hosts should be avoided in a radius of 400 m around *Citrus* groves. This tends to support that guava and others are also attacked, but possibly damage is not important.

For other hosts or countries, no information was found. Of specific interest for the EPPO region, the record of *Prunus persica* (uncertain host) originated from Venezuela (1 specimen in 1999, Adamski & Brown, 2001) (the pest also attacks *T. cacao* in this country). The record for *Punica granatum* arose from Brazil (Adamski & Brown, 2001; specimen in 1931). No details were found.

12.2 Impact on export markets

The occurrence of the pest can be an obstacle to exports to some countries (Garcia & Parra, 1999). *G. aurantianum* is currently a quarantine pest for several countries, including the USA, and its presence in fruit has led to interceptions and to phytosanitary requirements for export from countries where the pest occurs. Requirements were found in relation to *Citrus* or macadamia, and not to other host fruit (see section 5).

12.3 Environmental impact

In the first period of outbreaks in Brazil, control relied on massive amounts of pesticides, and had a negative impact on natural enemies, and presumably also other organisms present in orchards, even if this was not documented. In Guatemala, environmental impacts linked to the use of pesticides are mentioned (Primo Miranda, 2003).

12.4 Social impacts

None are mentioned. However, it could have had an impact on fruit in private gardens for personal consumption. More resources may have been necessary before the IPM strategy was developed to remove infested fruit from the ground and the trees.

12.5 Existing control strategies

Control methods are documented for *Citrus* in Brazil. In the 1980s, a strategy based on the application of insecticides above a threshold of 2-10% of infested fruits was not successful; it resulted in a reduction of natural enemies and increase of *G. aurantianum* populations (Bento et al., 2016 citing Parra *et al.*, 2004; Gómez Torres, 2005 citing others). This strategy did not work (did not affect adults, larvae were already in the fruit, was not effective against larvae in the fruit) and growers tended to apply pesticides below these thresholds and more frequently, leading to higher costs and elimination of natural enemies, hence worsening the situation (Bento et al., 2004).
An alternative control strategy was developed at the beginning of the 2000s within 4-5 years (Parra et al., 2004). Control is based on the application of microbial or chemical sprays when a threshold of males in pheromone traps is reached. The sex pheromone has been commercially available since 2001, and a kit containing a trap and a pheromone pellet costed ca. 7 USD. It was estimated that traps were used in at least 20% of the citrus-growing area in São Paulo and South of Minas Gerais (Bento et al., 2004 citing Parra et al., 2004). 1 trap covers 10 ha (3000 to 3500 plants). Traps are placed in the upper third of the canopy, inspected weekly and replaced every 30 days. Monitoring starts at the colouring of the fruits and extends until harvest. In dry seasons, control is adapted because there may be large numbers of males in traps, without any damage to the fruit (Fundecitrus, 2007). It worth mentioning that, according to Parra *et al.* (2004) (cited in Bento et al., 2016), the total volume of insecticide sprayed in the monitored areas decreased by at least 50%.

Chemical or biological insecticides can be used. Sprays are applied at dusk in the upper third of the crown to target adults when they mate and lay eggs. Strategies have been developed for the use of the different products (see Fundecitrus, 2019). *Bacillus thuringiensis* is sprayed some days after the threshold is reached to target larvae before they enter the fruit (Gómez Torres, 2005 citing others). The main active ingredients for use in IPM are mentioned as follows:
*Bacillus thuringiensis**, beta-cyfluthrin*, bifenthrin, cypermethrin*, deltamethrin*, esfenvalerate*, fenpropathrin, gamma-cyhalothrin*, lambda-cyhalothrin*, diflubenzuron*, lufenuron*, novaluron, triflumuron*, acephate, phosmet*, spinosad*, etofenprox*, tebufenozid* (Nakayama, 2018 citing AGROFIT, 2014), trichlorfon, carbosulfan, pyridaphenthion (Pereira, 2008 citing MEGAAGRO, 2008).
In the EU, the active ingredients marked with * are authorized for some uses, but it is not known if they could be used in host crops.

It is not known if similar IPM strategies are used on other crops and in other countries. In Costa Rica, control in macadamia relies mainly on cultural methods (see below). No information was found on control strategies in other countries.

Biological control

Parasitoids and predators were found attacking *G. aurantianum,* and play a role in reducing pest populations. However, no information was found on whether some natural enemies are used in the framework of biological control strategies in the field. Leite et al. (2005) mention the potential utilization of parasitoids against eggs as one of the control methods, but no information was found on which ones are used in the field. Extensive research has been carried out on the biological control of *G. aurantianum*, but no information was found if agents are available for use in the field. For example:
- *Trichogramma atopovirilia, T. pretiosum* (Hymenoptera, Trichogrammatidae) (Garcia, 1998 cited by others; Gómez Torres, 2005, Gómez Torres et al., 2008). *T. pretiosum* is commercially available in Brazil (https://www.koppert.com.br/pretiobug/), but it is not known if it is used against *G. aurantianum.*
- *Heterorhabditis indica, Steinernema carpocapsae* (Gómez Torres, 2005 citing Garcia 1998; Leite et al., 2005).
- *Hymenochaonia delicata* (Hymenoptera: Braconidae) (Parra, 2002 citing Garcia, 1998; Milano et al., 2008).
- In Guatemala. studies were conducted with *Beauveria bassiana* (field study Primo Miranda, 2003). No information was found on whether *B. bassiana* is used in commercial production.

Many other parasitoids and predators were found attacking *G. aurantianum*:
- In Brazil, Chrysopidae larvae and various ants species (Pereira, 2008 citing others)
- In Costa Rica, *Bassus macadamiae* (Hymenoptera: Braconidae) (Briceño & Sharkey, 2000), Trichogrammatidae, Braconidae, Microgastrine, *Ascogaster* sp., Ichneumonidae, *Pristomerus* sp. (Blanco-Metzler et al., 2009), and predators *Solenopsis geminata* (ant), *Doru* spp. (earwig), *Polybia* spp. (wasp). Predation of larvae whilst the macadamia nuts are on the ground significantly reduces the abundance of *G. aurantianum* (Blanco-Metzler et al., 2009). Both parasitoids and predators were shown to have an important role in the reduction of the *G. aurantianum* populations (Blanco-Metzler et al., 2007, 2009).

Cultural control
The methods below are additional to chemical control in Brazil on *Citrus*, while cultural control is effective on its own in macadamia in Costa Rica (in both cases, natural enemies have a role in controlling the pest).
- Collecting and destroying infested fruit (on the ground and on the trees) (Fundecitrus, 2019; Leandro, 2012, citing others)
- Early harvest in case of attack, to avoid the building up of populations (adults usually move from plots with mature fruits to those with fruits in the ripening stage) (Fundecitrus, 2007, 2019).
- Avoiding guava plantations and other fruit bearing hosts within a radius of 400 m of the citrus groves (Batista Pereira, 2008).
- In Trinidad, removal of *Sapindus saponaria* (a forest tree, also host) adjacent to citrus crop (White, 1999).
- In macadamia: monitoring, replacement of susceptible clones, more frequent harvest, to avoid completion of the life cycle; as well as avoiding macadamia husks on the ground in the orchards, because this traditional method of disposing husks after nut processing favours infestations (Blanco-Metzler et al., 1997).

Sterile Insect Technique
Di Piero (2016) studied irradiation methods and concluded that a dose of 300 Gy was effective and could also be used in the framework of the sterile insect technique. It is not clear if this is under development.

The economic cost of bringing the pest's populations below the economic threshold for *Citrus* in Brazil (references cited above) and macadamia in Costa Rica (H. Blanco-Metzler, pers. comm.) has been high.
Uncertainty: impact in other hosts and in other countries.

Rating of the magnitude of impact	*Very low* ☐	*Low* ☐	*Moderate* ☐	***High* X**	*Very high* ☐
Rating of uncertainty			*Low* ☐	***Moderate* X**	*High* ☐

13. Potential impact in the PRA area
Will impacts be largely the same as in the area where the pest occurs ? **Yes, in part of the EPPO region (as specified just below), as high as on *Citrus* in Brazil**

In areas where the conditions are suitable for the pest and there are host fruit all year round (see section 9.2/9.3), in *Citrus* crops the impact may be as high initially as in Brazil. This corresponds to the worst-case scenario. Impact would depend how early the pest is detected, as populations may build up fast. IPM programmes would need to be adapted to the EPPO situation. The sex pheromone is already commercially available, and a programme could be developed based on that in Brazil, including the authorization of relevant active ingredients, possible biological control agents, monitoring systems, etc. Due to low residue tolerance on fruit (for example in the EU), treatments may have consequences for the commercialization of fruit from such areas. The presence of this pest in Europe would have impact on major export markets, such as the USA for *Citrus*. Large volumes of host fruits are also traded between EPPO countries, and the presence of the pest may impact exports of host fruits within the EPPO region. The pest would affect the marketability of the fruit, as there is generally a low tolerance in the EPPO region for the presence of larvae in fruit, or for secondary infections leading to rot. *Citrus* and some other hosts may be present in a wide variety of environments (gardens, commercial orchards, etc.), which would all be affected.

The potential impact to tropical fruit and other hosts is not known. Many hosts are present in the PRA area, which may increase economic impact. Integrated strategies may need to be adapted to other crops. In addition, *G. aurantianum* has attacked new hosts in the Americas, and it may also pass onto new hosts in the EPPO region, and possibly cause damage (e.g. peach which is an uncertain host and other *Prunus* species that are not recorded as hosts and are widely cultivated in the EPPO region).

In other areas, it is not known if the conditions would be conducive to high impact. However, even transient populations that build up in an area of intensive cultivation of *Citrus* and other hosts may lead to heavy losses locally, until they die out.

The effect of the practices applied to the hosts in the EPPO region would probably have a limited effect on the pest. Fruit left on the trees or on the ground (e.g. partial harvest, abandoned orchards, street or garden trees) may favour establishment, as observed in Brazil when harvest is not economic, and mentioned as happening in the EPPO region (EPPO, 2013). Finally, the effect of cultural practices or pest management measures applied in the EPPO region is not known. There are no treatments on Lepidopteran pests of citrus in the EU. EPPO (2013) noted that two species present on *Citrus* in the EPPO region (*Ectomyelois ceratoniae* and *Cryptoblabes gnidiella*) are considered to be secondary pests and no specific treatments are usually required against these Lepidoptera. In Turkey, treatments against *Phyllocnistis citrella*, *Ectomyelois ceratoniae* and *Cryptoblabes gnidiella* are included in the *Citrus* IPM programme (N. Üstün, pers. comm., 2019-11). In peach, *Cydia molesta* may be controlled; however these control measures are unlikely to be fully effective against *G. aurantianum* because of the timing. Finally, management may not be applied for domestic production/gardens.

14. Identification of the endangered area

The endangered area is considered to be the Mediterranean coast, Southern Portugal and the Atlantic coast of Morocco, as well as part of Northern Italy, Balkans, and Black sea area, where *Citrus* is grown, if host fruits are present all year round.

There is more uncertainty for more continental and northern areas where *Citrus* or other hosts are grown, but where the climatic conditions may be less favourable for the pest.

15. Overall assessment of risk

Summary of ratings:

	Likelihood	**Uncertainty**
Entry (overall)		
Citrus fruit	Moderate-High	Moderate
Macadamia nuts	Low	Moderate
Other fruits	Very low	High
Travellers' luggage	Low	Moderate
Bare-rooted plants	Very low	Low
Plants for planting with soil or growing medium EU or others	Low Very low	Moderate Low
Establishment outdoors - Mediterranean coast (and where conditions appropriate) - rest of the EPPO region	 High Low	 Moderate Moderate
Establishment in protected conditions	Low	Moderate
Spread	Moderate	Moderate
Magnitude of impact where the pest occurs	High	Moderate
Magnitude of potential impact where conditions are appropriate and host fruits are present all year round	High	Moderate

The pathway with the highest likelihood of entry is *Citrus* fruit. Several other pathways were rated with a lower likelihood of entry: macadamia nuts, other fruit, travellers' luggage, and plants for planting with soil or growing medium. The pest may establish outdoors in part of the EPPO region, and cause high impact. The overall risk for the endangered area was considered to be high with a moderate uncertainty.

The EWG considered that phytosanitary measures should be recommended for host fruit, and recommendations were made for travellers.

Stage 3. Pest risk management

16. Phytosanitary measures

16.1 Phytosanitary measures to prevent entry

Measures were considered in details for fruit and plants for planting with soil or growing medium. The entry section (section 8) identifies *Citrus* fruit as the major entry pathway. There was a low likelihood of entry on macadamia fruit, only if they are green with husks, which is not a normal practice. Regarding other host fruits, the likelihood of entry was assessed as very low, but with a high uncertainty. The EWG proposed that measures should be recommended for *Citrus* and other host fruit (including green macadamia fruit with husks). The pest is polyphagous, and measures for fruit consequently target all *Citrus*. For other host fruit, given the lower likelihood of entry, EPPO countries may consider whether the measures should be as for *Citrus*. The PPM recommended measures for *Citrus* fruit only. As for many PRAs on fruit pests, the separation of fruit imports and production is important. Finally, measures for packaging were added to the fruit pathway.

Host plants for planting with soil or growing medium were a less likely entry pathway (low likelihood of entry), and entry on other plants for planting (e.g. bare rooted plants, cuttings) was very unlikely. The EWG studied measures for host plants for planting with soil or growing medium, but the likelihood of entry was low and the EWG did not think that they were needed. The PPM did not recommend measures for host plants for planting with soil or growing medium.

Measures for travellers are discussed below.

The PPM modified the recommended measures for *Citrus* fruit, and in particular sought closer consistency with the measures recommended for *Thaumatotibia leucotreta* (which had been used as the basis for pest risk management in the draft PRA). Detailed consideration of measures is provided in Annex 1.

Travellers' luggage

Infested fruit, and to a lesser extend plants for planting, carried in travellers' luggage were identified as a potential entry pathway. Many EPPO countries do not take requirements on travellers' luggage at present. However, as of 14th December 2019, the import of plants and fruit in the EU is subject to the same rules as commercial imports (PC and therefore inspection at import, except for fruit of *Ananas comosus, Cocos nucifera, Durio zibethinus, Musa* and *Phoenix dactylifera*). In addition, distribution of information to passengers through airlines will become compulsory. Part of the luggage will presumably be inspected to ensure compliance with the PC requirements. Detection at the point of entry (e.g. airport) will depend on the intensity and methods of sampling of passenger luggage to verify that they comply with the rules. Compliance with the rules may heavily depend on the proper information of passengers (in airports and in planes, but also entry ports) and on their understanding of the rules and their reasons. In the absence of proper information, passengers may continue bringing plant products in their luggage. For *G. aurantianum*, countries at risk of establishment could focus random checks for planes coming from countries with the greatest numbers of passengers.

Possible pathways (in order of importance)	Measures identified

Citrus fruit **See remark below the table**	Only new or cleaned packaging should be used to avoid the presence of pupae AND PFA (conditions outlined below the table and detailed in Annex 1) or Pest free place of production or pest free production site (conditions outlined below the table and in Annex 1) or Systems approach in the framework of a bilateral agreement: Visual inspection in the field (with cutting of representative samples of fallen fruit) + Treatment of the crop (based on monitoring with pheromone traps) + Visual examination at harvest and during handling/packing of the consignment, and visual inspection at export (with cutting of representative samples of fruit)

Remarks.

- *Treatments*: no treatment can be recommended for *Citrus* fruit (or other hosts). In particular, there is currently no cold treatment schedule available against this pest (unlike for the related species *T. leucotreta* – EPPO, 2013).

- *Systems approach*: The EWG discussed whether the options that were not sufficient on their own could be combined to reduce the risk to an acceptable level. Consequently, the combination in the table above was proposed as a systems approach. The EWG believed that it would reduce fruit infestation, but would not guarantee absence of the pest. In any case, visual inspection and sampling of fruit should be done at a high level, and an appropriate treatment programme of the crop should be in place. The sampling procedures for fruit should be able to detect low infestation of early stage larvae (generally one larva per fruit on *Citrus* fruit, small size of early larval instars, small entry holes; e.g. increase the number of cut fruit and the number of cuts per fruit). As for *T. leucotreta* (EPPO, 2013), there should be cull sanitation analysis in the field (i.e. cutting fallen fruits). The PPM noted that this systems approach is similar to that recommended for *T. leucotreta*, and maintained it as a possible option in the framework of a bilateral agreement.

- *PFA*. Measures required (details in Annex 1):

- provision of surveillance data (based on monitoring with pheromone traps and fruit sampling) to demonstrate absence of the pest, and of information on how pest freedom is maintained.
- intensive surveys using pheromone traps during a sufficient period at sites favourable for the pest, in host crops and in the natural environment and non-commercial conditions (e.g. gardens, urban trees)
- measures to prevent that infested plants or fruit, or growing medium or packaging, are moved into the PFA.
- establishment of a buffer zone around the PFA (the distance was not determined)
- no signs of the pest found at least in the past 2 years, depending on the intensity of surveys.
- official inspection of consignments immediately prior to export.

- *Pest-free production site/pest-free place of production*. Measures required:

- absence of any detection in pheromone traps in places of production/production site and the vicinity during a suitable period, and at least since the beginning of the last complete cycle of vegetation
- monitoring of traps should be done on a weekly basis and traps should be regularly serviced.
- sanitation with the removal of fallen fruits and fruits that are not harvested should be mandatory.
- in addition, examination to check absence of signs of the pest on the fruits before harvest at the place of production should take place under the authority of the NPPO.
- absence of signs of infestation on fruit at harvest.

The establishment of a buffer zone could be considered in areas of continuous presence of hosts or depending on pest prevalence in the area. The presence of hosts in the natural environment should be considered. Trapping using pheromone traps should be used in the buffer zone, including in the natural environment.

Depending on the pest prevalence in the area where the place of production is located, preventive control measures may also be recommended (in particular if the pest is trapped in the buffer zone).

16.2 Eradication and containment

G. aurantianum is a poor flyer with a high reproduction rate. It may remain locally, and lay eggs on many fruits, and build up a population before it is noticed. It may be difficult to detect the pest before it has spread to other places in the EPPO region through human-assisted pathways.

Early detection would therefore be essential, but may be difficult as the adult is inconspicuous (size, colour) and has a crepuscular behaviour, and that signs of infestation by larvae may not be noticed at early stages of infestation. Damage may be confused with other pests, such as Tephritidae at early stages of infestation. The fact that identification requires a specialist of Tortricidae may also complicate early detection in EPPO countries; there have been misidentifications (see section 1). Correct identification may be delayed by misidentification with species already attacking the crop, or pests of quarantine concern (such as *T. leucotreta*).

Few Lepidopteran pests are present in *Citrus* crops and controlled in the EPPO region (see section 13). Control measures applied against other pests are likely to be ineffective.

Monitoring using pheromone traps is effective, but may not be feasible as long as the pest is not present in the region. In some EPPO countries, pheromones would need to be authorized for use. However, informing growers (*Citrus* and other hosts grown in the PRA area) of egg and larvae scouting procedures, of the specific symptoms of larval infestation and location, and of differences with fruit flies or other pests, may help detecting the pest early. The pest could be included in guides such as (CARM (2015). Any NPPO surveys on *Citrus* or other hosts may include the pest.

Eradication would be more feasible indoors (which is not the normal cultivation practice for hosts in the EPPO region), and in conditions where the plants are subject to more controls, like nurseries. Eradication may be difficult in orchards – where the pest would be favoured by a high abundance of fruit – and in gardens or urban areas where it may not be detected before it has spread to neighbouring areas. In addition, the pest has a wide host range. Eradication may be possible in areas where conditions are not favourable to building up of populations (i.e. mild temperatures, dryer areas).

G. aurantianum is sensitive to low relative humidity, and in part of the EPPO region, infestations may remain located to the limited area where conditions are suitable (e.g. under irrigation). This may be favourable to containment and eradication.

Containment may be more feasible due to the low dispersal capacity of adults and trapping possibilities, but would be complicated where there are many different hosts in different environments (including gardens, cities, etc.). In addition, abandoned or poorly-managed orchards would favour population build-up. Containment may also require the extensive application of chemical treatments (at least until biological control methods or sterile insect techniques are available for the relevant conditions).

It would be useful to develop contingency plans in advance of the introduction of the pest.

Eradication would require:

- intensive monitoring to delimitate outbreaks, using pheromone traps, including in non-agricultural environments
- demarcation of infested zones and buffer zones,
- application of control methods, incl. treatments, cultural controls (see section 12), measures for cleaning of machinery used in different plots,
- regulatory measures to prevent spread by human assistance (e.g. prohibition of the movement of host plant material from the demarcated area),
- training of growers for detecting the pest and public awareness (incl. regarding pests in fruit for consumption) .
- Trace -back and trace-forward studies to identify possible other areas infested by the pest.

The EWG noted that there is no information available to determine the size of the demarcated area. The distance for sex pheromone traps which has been defined as being effective for trapping in Brazil (350 m) does not reflect the flight capacity of the pest. In Brazil, it is recommended that plantations of guava and other hosts should be avoided in a radius of 400 m around *Citrus* groves (Pereira, 2008). It is not clear how this distance was determined and whether it could be used in the EPPO region to establish buffer zones. Local conditions should be considered (i.e. strong winds, prevalent in part of the endangered area).

17. Uncertainty

Main sources of uncertainty within the risk assessment are:

- host range (especially host status of Table 7B hosts, and whether other species would be attacked in the EPPO region) and whether some hosts in Table 7A are only occasional hosts
- why the pest does not attack the same hosts in different countries (i.e. never detected on *Citrus* in Costa Rica) and reasons for the variations in damage between countries
- possible presence in South American countries where it has not been recorded to date
- flight capacity
- duration of life cycle on some hosts (for the purpose of control and eradication)
- trade volumes of some commodities
- whether the natural enemies present in the EPPO region would control the pest
- current situation of the pest in countries for which no information is available, and damage on certain hosts
- for some countries where information is missing, impact and control methods applied.
- if active ingredients currently available for *Citrus* or other hosts in the EPPO region are effective against this pest
- whether control strategy developed in *Citrus* in Brazil is used in cocoa.

18. Remarks

- A schedule for cold treatment of *Citrus* fruit, and possibly other hosts, to kill *G. aurantianum,* is needed, as well as other types of treatments for fruit that cannot be subject to cold treatment.
- Additional studies (incl. morphological and molecular) are needed to determine if *G. aurantianum* is a complex of species.
- Studies on flight capacity would be useful, especially in relation to containment and eradication.
- Studies on elements for which biological information is lacking (see uncertainties).

- NPPOs of the EPPO region may consider including the pest in surveys, mainly in *Citrus* crops.
- Data would be useful on whether host fruit would be available all year-round in EPPO countries other than Spain and Turkey.

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ANNEX 1. Consideration of pest risk management options

The table below summarizes the consideration of possible measures for *Citrus* (based on EPPO Standard PM 5/3). When a measure is considered appropriate, it is noted "yes", or "yes, in combination" if it should be combined with other measures in a systems approach[2]. "No" indicates that a measure is not considered appropriate. A short justification is included. Elements that are common to several pathways are in bold. This table combines the recommendations of the EWG with later adjustments made by the PPM.

Experience from other countries: In the USA for *Citrus* fruit (USDA, 2003 and 2012), a PC is required with an Additional Declaration of freedom from *G. aurantianum*, and inspection of the fruit at the port of entry is considered sufficient to assure that sufficient phytosanitary security has been provided. USA do not require treatment of fruit consignments. The PRAs justify these requirements by the fact that *G. aurantianum* has never been intercepted in commercial *Citrus* fruit consignments in the USA, which is attributed to the fact that it must be excluded by harvest and post-harvest processes. It should be noted that fruit of *Citrus* is permitted import from part of the distribution, but not from Brazil where the main damage on *Citrus* are recorded.

Option	***Citrus* fruit**
Existing measures in EPPO countries	Partly, see section 8. **But not sufficient to prevent entry of the pest**
Options at the place of production	
Visual inspection	Yes, in combination * (for measures marked with *, see after the table) The presence of the pest at the place of production may not be detected, especially at early stages of infestation. Pheromone traps may be used in combination with other measures.
Testing	Not relevant.
Treatment of crop	Yes, in combination*. **Not reliable to guarantee pest freedom, but control strategies exist that reduce pest populations for *Citrus* in Brazil. Insecticide treatments are not completely effective against larvae inside the fruit.** **This would require the use of pheromone traps. Combined with others, this could provide a sufficient level of protection. A sterile insect programme, or a mating disruption programme, associated with the use of pheromone traps may be effective but have not been developed to date**
Resistant cultivars	No. **Not available.** Some clones of macadamia are less susceptible, but there is no complete resistance.
Growing the crop in glasshouses/screenhouses	No. This would require complete physical isolation (following EPPO Standard PM 5/8 *Guidelines on the phytosanitary measure 'Plants grown under complete physical isolation*'; i.e. including additional measures to guarantee pest freedom). The EWG considered this would be an option, although recognizing that complete physical protection is difficult to implement in commercial fruit production. Considering that complete physical isolation is not feasible for commercial *Citrus* production, the PPM decided to not retain this option.

[2] 'The integration of different risk management measures, at least two of which act independently, and which cumulatively achieve the appropriate level of protection against regulated pests' (ISPM 5).

Specified age of plant, growth stage or time of year of harvest	No. *G. aurantianum* may be associated with fruit at any time of the year, and at various stages of development.
Produced in a certification scheme	No. **Not relevant for an insect.**
Possibility for pest-free production site, place of production, area?	Yes (see detailed consideration for pest-free production site, pest free place of production and pest-free area below). The pest has a low rate of dispersal, with an uncertainty
Pest-free production site	No under complete physical isolation. Not feasible (see above) Yes without complete physical isolation. The measures required to determine a pest-free production site or pest-free place of production for *G. aurantianum* would imply: • absence of any detection in pheromone traps in places of production/production site and the vicinity during a suitable period, and at least since the beginning of the last complete cycle of vegetation. • monitoring of traps should be done on a weekly basis and traps should be regularly serviced. • sanitation with the removal of fallen fruits and fruits that are not harvested should be mandatory. • in addition, examination to check absence of signs of the pest on the fruits before harvest at the place of production should take place under the authority of the NPPO. • absence of signs of infestation on fruit at harvest. The establishment of a buffer zone could be considered in areas of continuous presence of hosts or depending on pest prevalence in the area. The presence of hosts in the natural environment should be considered. Trapping using pheromone traps should be used in the buffer zone, including in the natural environment. Depending on the pest prevalence in the area where the place of production is located, preventive control measures may also be recommended (in particular if the pest is trapped in the buffer zone). The EWG considered that the conditions above are unlikely to be feasible, except in situations of low pest density, and would be difficult to guarantee in countries where the pest occurs. The pest has a low dispersal capacity, but it may move into adjacent sites, even at low pest density. Where it is present, it is also present in the natural environment, and has a wide host range. Consequently, the EWG did not retain pest free production site as a possible measure. However, the PPM noted that this option has been recommended for similar pests. The PPM also noted that this pest has a low dispersal capacity and that suitable detection methods exist (pheromone traps are used in Brazil to monitor the pest in citrus orchards and to decide on treatments). The PPM therefore finally retained pest free production site as a possible measure.
Pest-free place of production	No for complete physical isolation (see above). Yes without complete physical isolation. The EWG noted that pest-free places of production without complete physical isolation would not be possible, based on the same arguments as for pest-free production sites (see above). However, the PPM noted that this option has

	been recommended for similar pests and should be retained (see above).
Pest free area	Yes. **PFA is a possible measure as described in ISPM 4.** **There are potentially areas free from the pest at least in Argentina (where the pest is recorded only in the North). This is not known for other countries.** **It would be difficult for the 4 South American countries where the pest has <u>not</u> been reported to date to declare pest freedom at country level. This may be possible for Chile due to geographical isolation, but others are situated between countries where the pest occurs.** **In all cases, the feasibility of the establishment of PFAs in any country should be carefully evaluated.** **Declaration of PFA should be based on intensive surveys using pheromone traps during a sufficient period at sites favourable for the pest, in host crops and in the natural environment and non-commercial conditions (e.g. gardens, urban trees).** **In order to declare a PFA within a country, the exporting country should provide surveillance data (based on monitoring with pheromone traps and fruit sampling) to demonstrate that the pest is absent from all or part of its territory and information on how pest freedom is maintained.** **If the pest is present in part of the country, specific surveys should be conducted to delimitate and to maintain the PFA.** **Measures should be in place to prevent that infested plants or fruit, or growing medium or packaging, are moved to the PFA. This may be difficult to implement due to the large number of host plants. To provide a buffer against the introduction of *G. aurantianum*, the PFA should be distant from any infestation. (The EWG did not discuss a distance). There should be official inspections for the presence of *G. aurantianum*.** **No signs of the pest should have been found at least in the past 2 years (similar to other Lepidoptera species with several generations per year), depending on the intensity of surveys. Immediately prior to export, consignments should be subjected to an official inspection.**
Options after harvest, at pre-clearance or during transport	
Visual inspection	Yes in combination* Some infested fruit may be sorted out at harvest and post-harvest. This is suggested by USDA (2003) to be one of the reasons why the pest is not intercepted more in fruit consignments. However, not every single individual may be detected, especially at early stages of infestation. USA and EU interceptions on fruit indicate that there is a risk of not detecting low infestation levels or early infestation prior to dispatch. *G. aurantianum* would be difficult to detect in large consignments of fruits, as larvae are internal feeders, eggs are small and symptoms caused by the feeding of larvae are not visible in early stages of infestation (MAPA, 2018). Targeted inspection (i.e. cutting the fruit open) would increase the probability of detection, but require large samples.
Testing	No. **Not relevant.**
Treatment of the consignment	No. No information was found on effective quarantine treatments that are currently applied against *G. aurantianum.* *Cold treatment.* In the USA treatment manual, the cold treatment T107-e is authorized for peach and *Citrus* against *T. leucotreta* and several fruit flies (-0.55 ºC for 22 days). A number of cold treatments are available for various fruit, but they target fruit flies. It is not

	known if such measures are effective against *G. aurantianum*. The use of cold treatment to impede the spread of *G. aurantianum* in oranges 'is said to be inadequate' in an older PRA (USDA, 2003 citing Faria et al., 1998). *Ionizing radiation/gamma irradiation* may be possible, but no approved protocol is available to date to kill larvae in fruit. Faria (1997) tested gamma radiation on oranges for use in quarantine situations against *G. aurantianum*: doses over 200 Gy affected the emergence of adults from pupae. Arthur et al. (2016) noted that an ionizing radiation treatment of 400 Gy against all insect species has been approved for commodities entering the USA, except commodities potentially infested with pupae and/or adults of Lepidoptera. They found that irradiation of *G. aurantianum* pupae with 300 Gy in controlled atmosphere with 100% oxygen completely prevented emergence of adults (irradiation in air of pupae with 300 Gy resulted in 5% egg hatch, but 100% of the larvae died as 1st or 2nd instar). They concluded that further work is needed to determine if irradiation of infested produce in oxygen gas as a commercial operation is practical and profitable. Di Piero (2016) studied the lethal and sterilising doses for gamma irradiation for all life stages, and concluded that a dose of 400 Gy could be used. It is not clear if used in practice. Fumigation with methyl bromide is not recommended (phased out in 2015)
Pest only on certain parts of plant/plant product, which can be removed	No. The pest is in the fruit itself.
Prevention of infestation by packing/handling method	Yes, in combination* (additional to relevant measures) Only new packaging or cleaned or disinfected packaging should be used to avoid the presence of pupae. After import, packaging should be destroyed or safely disposed of. At packing, damaged or discoloured fruits may be discarded, but recently infested fruit would not present signs of infestation. It is very unlikely that *Citrus* fruit becomes infested after harvest or in storage (i.e. that females lay eggs in boxes/crates of harvested fruit). There is no evidence or knowledge of this in Brazil (J. Parra, University of São Paulo, Brazil, pers. comm., 2020-04). In addition, adults are mostly active at night and picking operations are conducted in the day. This is similar to T. leucotreta (EPPO, 2013).
Limited distribution in time and/or space or limited use	No Difficult to control. For fruit, consignments may be imported for immediate processing or consumption where *G. aurantianum* cannot survive outdoors. In any case, no handling or packing should be done in or in close proximity of a place producing host plants (separation of trade and production flows). However, it is difficult to guarantee that the consignment is used in the same area, at least within the EU. Immediate processing of the fruit and destruction of the waste (e.g. burning, deep burial) is possible, but it is not practical and difficult to control in practice. A similar option was retained for fruits intended for processing in the PRA for *T. leucotreta*. However, recognizing the difficulties to implement such measure in practice, and uncertainties about the potential area of establishment of *G. aurantianum* in the EPPO region, this option was not retained here.
Post-entry quarantine	No. Not relevant for fruit as they are perishable and imported in large volumes.

Only surveillance and eradication in the importing country	No. Surveillance in the importing country could be put in place, but the pest may be detected after it has already established and spread to other locations. In the part of the EPPO region where the pest cannot establish outdoors, infested consignments could in theory be imported. This would require the separation of trade and production flows (separate facilities for imported consignments and for growing hosts indoors. Hosts would mostly not be grown indoors for fruit production, but they may be grown for other purposes (e.g. ornamental, nurseries)) and a good surveillance system. Eradication is considered possible at a local scale (see under 16). This would be possible only as long as the trade volumes are very low. This may be possible in individual EPPO countries, but may not be feasible overall.

*The EWG considered whether the measures identified above as 'Yes in combination' (summarized in the table below) could be combined to provide an appropriate level of protection. The combinations of measures identified are provided in section 16.

'Yes in combination' measures	***Citrus* fruit**
Visual inspection at the place of production	X
Treatment of the crop	X
Specified age of plant, growth stage or time of year of harvest	
Visual inspection after harvest, at pre-clearance or during transport	X
Treatment of the consignment	
Pest only on certain parts of plant/plant product, which can be removed	

ANNEX 2. Pictures of life stages and damage of *Gymnandrosoma aurantianum*
All courtesy of H. Blanco Metzler, Universidad de Costa Rica.

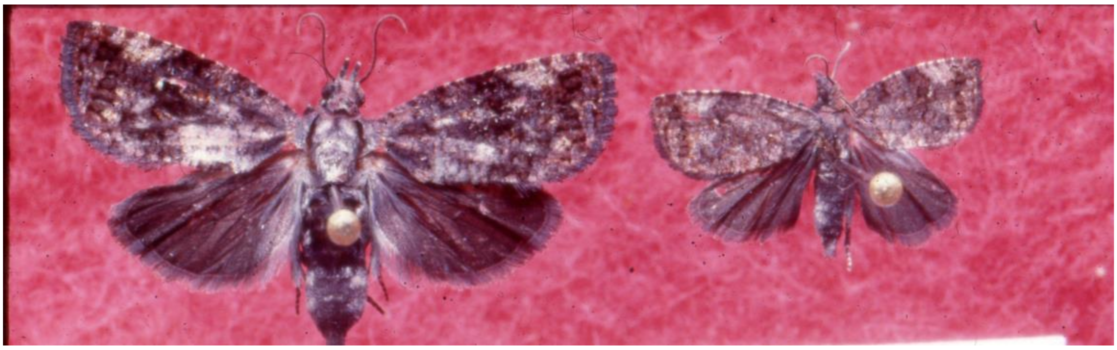


Fig. 1. Female (left), male (right)

Fig 2. Eggs (measuring 1.09-1.34 mm)

Fig. 3 Different larval instars (note: no scale is given on the photo, but larvae are reported in the literature to measure 5 mm at the neonatal stage and 15-19 mm when nature)

Fig. 4. Oviposition site and damage on macadamia nut

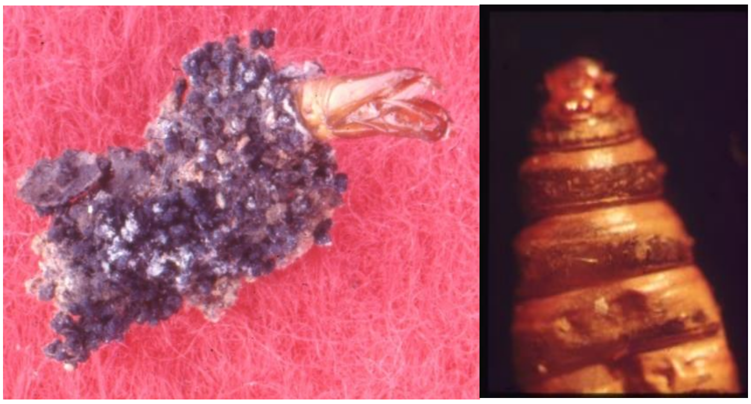


Fig 5. Pupae with the body extruding from the nut (husk removed), and pupa head

ANNEX 3. Fruit imports by EPPO countries (FAOStat)
In tonnes. 0 indicates quantities below 1 t

Grapefruit incl. pomelos

Import by	from	2016
Bosnia and Herzegovina	Argentina	1
Greece	Argentina	62
Netherlands	Argentina	312
Norway	Argentina	0
Russian Federation	Argentina	262
Kazakhstan	Brazil	0
Norway	Brazil	1
Switzerland	Brazil	2
Italy	Costa Rica	21
Norway	Costa Rica	0
Switzerland	Costa Rica	22
France	Cuba	8
France	Dominica	81
Germany	El Salvador	2
France	Honduras	42
Belarus	Mexico	119
Belgium	Mexico	1822
France	Mexico	4777

Import by	from	2016
Germany	Mexico	766
Italy	Mexico	427
Kazakhstan	Mexico	3
Netherlands	Mexico	5488
Norway	Mexico	11
Republic of Moldova	Mexico	3
Russian Federation	Mexico	606
Spain	Mexico	20
Switzerland	Mexico	137
United Kingdom	Mexico	383
France	Peru	35
Netherlands	Peru	152
Norway	Peru	1
Spain	Peru	61
United Kingdom	Peru	40
France	Suriname	1
Netherlands	Suriname	1
total		**15669**

Lemons and limes

Import by	From	2016
Albania	Argentina	831
Austria	Argentina	0
Belarus	Argentina	879
Belgium	Argentina	2638
Bosnia and Herz.	Argentina	872
Bulgaria	Argentina	852
Croatia	Argentina	285
Cyprus	Argentina	621
Denmark	Argentina	638
Finland	Argentina	326
France	Argentina	5891
Georgia	Argentina	50
Germany	Argentina	1540
Greece	Argentina	7692
Ireland	Argentina	1081
Italy	Argentina	31993
Jordan	Argentina	603
Kazakhstan	Argentina	472
Latvia	Argentina	441
Lithuania	Argentina	735
Montenegro	Argentina	704
Netherlands	Argentina	64848
Norway	Argentina	1530
Poland	Argentina	262
Portugal	Argentina	1211
Rep. of Moldova	Argentina	580
Romania	Argentina	3081
Russian Federation	Argentina	38738
Slovakia	Argentina	19

Import by	From	2016
Slovenia	Argentina	1801
Spain	Argentina	62008
Sweden	Argentina	330
Switzerland	Argentina	1058
United Kingdom	Argentina	8428
Belarus	Bolivia	1
Italy	Bolivia	549
Kazakhstan	Bolivia	32
Netherlands	Bolivia	1524
Norway	Bolivia	1
Russian Federation	Bolivia	207
Switzerland	Bolivia	4
United Kingdom	Bolivia	881
Belarus	Brazil	35
Belgium	Brazil	446
Bosnia and Herz.	Brazil	5
France	Brazil	281
Germany	Brazil	2677
Italy	Brazil	323
Kazakhstan	Brazil	10
Luxembourg	Brazil	121
Montenegro	Brazil	9
Morocco	Brazil	0
Netherlands	Brazil	59559
Norway	Brazil	1809
Portugal	Brazil	978
Rep. of Moldova	Brazil	19
Russian Federation	Brazil	1091
Spain	Brazil	1419

Import by	From	2016
Switzerland	Brazil	2481
Turkey	Brazil	384
United Kingdom	Brazil	14053
France	Colombia	1376
Germany	Colombia	294
Italy	Colombia	341
Netherlands	Colombia	558
Norway	Colombia	5
Portugal	Colombia	133
Rep. of Moldova	Colombia	0
Spain	Colombia	488
Switzerland	Colombia	21
United Kingdom	Colombia	65
Netherlands	Costa Rica	48
Russian Federation	Costa Rica	0
Switzerland	Costa Rica	0
France	Cuba	13
Italy	Cuba	2
Netherlands	Cuba	2
Spain	Cuba	14
Switzerland	Cuba	0
Belgium	Dominican Rep.	671
France	Dominican Rep.	190
Germany	Dominican Rep.	120
Netherlands	Dominican Rep.	36
Norway	Dominican Rep.	0
Spain	Dominican Rep.	1
Switzerland	Dominican Rep.	0
United Kingdom	Dominican Rep.	98
France	Ecuador	46
Italy	Ecuador	49
Switzerland	Ecuador	6
Germany	El Salvador	1
Belarus	Guatemala	2
Bosnia and Herz.	Guatemala	0
France	Guatemala	5
Israel	Guatemala	5
Kazakhstan	Guatemala	1
Netherlands	Guatemala	1136
Norway	Guatemala	6
Rep. of Moldova	Guatemala	1
Russian Federation	Guatemala	7
Switzerland	Guatemala	8
United Kingdom	Guatemala	396
France	Honduras	907
Belarus	Mexico	50

Import by	From	2016
Belgium	Mexico	1136
Bosnia and Herz.	Mexico	14
France	Mexico	1345
Germany	Mexico	160
Italy	Mexico	885
Kazakhstan	Mexico	20
Luxembourg	Mexico	194
Montenegro	Mexico	23
Morocco	Mexico	0
Netherlands	Mexico	36643
Norway	Mexico	531
Rep. of Moldova	Mexico	23
Russian Federation	Mexico	2277
Spain	Mexico	616
Switzerland	Mexico	599
Turkey	Mexico	35
United Kingdom	Mexico	9369
Belgium	Peru	50
Germany	Peru	23
Netherlands	Peru	29
Norway	Peru	8
Sweden	Peru	0
Switzerland	Peru	4
United Kingdom	Peru	553
Bosnia and Herz.	Uruguay	124
Greece	Uruguay	639
Italy	Uruguay	1976
Netherlands	Uruguay	3528
Norway	Uruguay	14
Portugal	Uruguay	862
Russian Federation	Uruguay	1295
Serbia	Uruguay	0
Slovenia	Uruguay	49
Spain	Uruguay	491
Sweden	Uruguay	68
Switzerland	Uruguay	42
Ukraine	Uruguay	289
United Kingdom	Uruguay	336
Netherlands	Venezuela	4
Portugal	Venezuela	6
Spain	Venezuela	65
Total		**403364**

Oranges

Import by	From	2016
Belarus	Argentina	510
Belgium	Argentina	596
Bosnia and Herz.	Argentina	26
Denmark	Argentina	168

Import by	From	2016
France	Argentina	195
Ireland	Argentina	87
Italy	Argentina	3748
Kazakhstan	Argentina	38

Import by	From	2016
Lithuania	Argentina	72
Montenegro	Argentina	6
Netherlands	Argentina	10170
Norway	Argentina	62
Portugal	Argentina	954
Rep. of Moldova	Argentina	70
Russian Federation	Argentina	5306
Spain	Argentina	32758
Switzerland	Argentina	103
United Kingdom	Argentina	381
France	Belize	223
Netherlands	Belize	111
Belgium	Brazil	98
Bosnia and Herz.	Brazil	21
Denmark	Brazil	297
France	Brazil	1769
Germany	Brazil	5
Italy	Brazil	560
Montenegro	Brazil	266
Netherlands	Brazil	2324
Norway	Brazil	20
Portugal	Brazil	8344
Russian Federation	Brazil	736
Slovenia	Brazil	83
Spain	Brazil	4080
Sweden	Brazil	1061
Switzerland	Brazil	59
United Kingdom	Brazil	4437
France	Colombia	1174
France	Costa Rica	0
Italy	Costa Rica	449
Russian Federation	Costa Rica	3
Switzerland	Costa Rica	0
France	Cuba	677
France	Dominica	5
France	Dominican Rep.	100
Netherlands	Dominican Rep.	0
Switzerland	Dominican Rep.	0
Bosnia and Herz.	Ecuador	22

Import by	From	2016
Norway	Ecuador	2
Sweden	Ecuador	0
Switzerland	Ecuador	1
Germany	Haiti	21
France	Honduras	2866
Ireland	Mexico	195
Netherlands	Mexico	1930
Sweden	Mexico	119
Switzerland	Mexico	50
United Kingdom	Mexico	5507
France	Peru	166
Netherlands	Peru	3180
Switzerland	Peru	43
United Kingdom	Peru	6887
Netherlands	Suriname	0
Belgium	Uruguay	98
Bosnia and Herz.	Uruguay	35
Denmark	Uruguay	167
France	Uruguay	142
Germany	Uruguay	266
Ireland	Uruguay	66
Italy	Uruguay	3889
Kazakhstan	Uruguay	25
Malta	Uruguay	97
Netherlands	Uruguay	8701
Norway	Uruguay	388
Portugal	Uruguay	75
Russian Federation	Uruguay	9405
Serbia	Uruguay	19
Slovenia	Uruguay	25
Spain	Uruguay	10672
Sweden	Uruguay	1247
Switzerland	Uruguay	335
Ukraine	Uruguay	445
United Kingdom	Uruguay	2334
		141572

Tangerines, mandarins, clementines, satsumas

Import by	From	2016
Belarus	Argentina	35
Belgium	Argentina	70
Italy	Argentina	3
Kazakhstan	Argentina	186
Lithuania	Argentina	116
Netherlands	Argentina	1799
Norway	Argentina	30
Portugal	Argentina	442
Republic of Moldova	Argentina	38
Russian Federation	Argentina	24280
Sweden	Argentina	95

Import by	From	2016
Switzerland	Argentina	4
United Kingdom	Argentina	1389
Switzerland	Brazil	0
France	Colombia	75
Netherlands	Costa Rica	24
France	Cuba	0
Switzerland	Ecuador	0
Germany	El Salvador	2
France	Honduras	12
Norway	Mexico	8
Republic of Moldova	Mexico	1

Import by	From	2016
United Kingdom	Mexico	22
Belarus	Peru	58
Denmark	Peru	46
Finland	Peru	824
France	Peru	402
Germany	Peru	373
Ireland	Peru	3003
Italy	Peru	275
Kazakhstan	Peru	15
Netherlands	Peru	15736
Norway	Peru	875
Portugal	Peru	321
Republic of Moldova	Peru	19
Russian Federation	Peru	3625
Spain	Peru	287
Sweden	Peru	131
Switzerland	Peru	48
United Kingdom	Peru	26443

Import by	From	2016
Belarus	Uruguay	3
Finland	Uruguay	99
Germany	Uruguay	23
Ireland	Uruguay	474
Italy	Uruguay	508
Kazakhstan	Uruguay	2
Netherlands	Uruguay	2240
Norway	Uruguay	1
Portugal	Uruguay	630
Russian Federation	Uruguay	6782
Spain	Uruguay	727
Sweden	Uruguay	50
Switzerland	Uruguay	95
Ukraine	Uruguay	73
United Kingdom	Uruguay	1203
		94022

ANNEX 4. Details on the presence of host plants in the EPPO region

Citrus. The Euro-Mediterranean citrus industry includes approximately 12% of the world's citrus growing area and produces approximately 20% of the world's citrus fruit (citing Siverio *et al.*, 2017). Around 70% of the Euro-Mediterranean citrus fruit production is concentrated in four countries: Spain (27%), Italy (16%), Egypt (15%) and Turkey (10%) (Siverio *et al.*, 2017) (cited from the EPPO PRA on *Naupactus xanthographus*). In relation to production areas for the hosts of *G. aurantianum* in the EPPO region (from FAO Stat, detailed data is provided in Annex 3):

- Oranges (covering *C. sinensis* and *C. aurantium*) are the most widely cultivated citrus. In 2017, there were about 450000 ha oranges harvested in 20 EPPO countries (see Annex 3), mostly in the Mediterranean area, but also Central Asia to Georgia and Russia. The largest harvested areas were in Spain (ca. 140000 ha), Italy (ca. 80000), Morocco, Turkey and Algeria (ca. 50000 ha each). In Turkey in 2018, oranges were cultivated on ca. 50800 ha and produced 1.9 million tons oranges (https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr). C. *aurantium* (sour orange) is also cultivated, and is also a street tree in the Mediterranean area.
- 'Tangerines, mandarins, clementines, satsumas' were cultivated on over 320000 ha in 20 countries in the Mediterranean area and Central Asia, with over 220000 ha in Spain, Morocco and Turkey. This category would cover *C. reticulata* as well as all hybrids and varieties that are sometimes called with a different name, such as *C. nobilis* and *C. clementina* (widely-grown species in Europe; EFSA, 2017) or *C. deliciosa*. These are considered as synonyms of *C. reticulata* in some sources.
- 'Lemons and limes' were recorded in the Mediterranean area and Central Asia (to Georgia) with ca. 120000 ha in 2017, with over 100000 ha in Spain, Turkey and Italy. The production area probably relates mostly to *C. limon* lemon. *C. aurantifolia* is cultivated on a limited area at least in Spain. Another lime, *C. latifolia* (Tahiti lime) is cultivated in Europe (EFSA, 2017).
- 'Grapefruit (incl. *C. maxima* and pomelos *C. x paradisi*)' were cultivated on only about 16000 ha, with over 60% in Tunisia and Turkey as well as ca. 2000 ha in Spain (*C x paradisi*) and 1600 ha in Israel. In 2018 in Turkey, there were 5182 ha (250 000 t) (https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr). In the EPPO region, *C.* x *paradisi* is probably more widely cultivated than *C. maxima*.

Punica granatum originates from Central Asia, where there are wild pomegranates (Holland et al., 2009). It is also widely planted around the Mediterranean Basin and in the Middle East. Commercial orchards are reported in the Mediterranean basin and Central Asia, in the following EPPO areas/countries: North Africa, Israel, Turkey, Greece, Cyprus, Italy, France, Spain, Portugal, Kazakhstan, Tajikistan, Kirgizstan, Armenia, Georgia (Holland et al., 2009), Jordan (Melgarejo and Valero, 2012 cited in Hmid, 2013). In Morocco, there were 8200 ha producing 76300 t in 2012 (Hmid, 2013, citing others). Turkey is a major producer in the EPPO region, as well as Spain and Israel (Hmid, 2013, citing Quiroz, 2009). In Turkey in 2018, there were 29149 ha (537847 t). In most growing areas where pomegranates are grown commercially, some sort of irrigation is required.

***Prunus persica* (uncertain host).** In 2017, 'peach and nectarine' (incl. *P. persica* and *P. persica* var. *nucipersica*) were cultivated commercially in 36 EPPO countries on over 370000 ha, north to Germany and Poland, and East to Central Asia (FAOStat, see Annex 3). In terms of area, the top 5 EPPO countries were Spain, Italy, Turkey, Greece and Algeria (with ca. 84000, 67000, 46000, 41000 and 21000 ha). In 2013, Italy and Spain were the 2nd and 3rd producers worldwide (1.402000 t and 1.330000 t) and Greece, Turkey, France, Algeria, Tunisia and Uzbekistan were amongst the 20 biggest producers worldwide (from the PRA on *Candidatus* 'Phytoplasma phoenicium'). Central Asia is the centre of origin and of diversity for significant fruit trees, and in particular has wild populations of apricot (Bioversity International, 2017 cited in EPPO PRA on *Candidatus* Phytoplasma phoenicium).

Tropical host fruits

Annona cherimola is grown commercially in some countries of the Mediterranean Basin. Spain is considered the most important producer worldwide (CABI, 2019) with approximately 3102 ha producing 44305 t in 2016 (MAPA, 2018) in the Almuñécar and Motril valleys (in Granada province, MAPA 2018 - cited in the EPPO PRA on *Naupactus xanthographus*). It is also introduced in the Canary Islands (CABI, 2019 cited in the EPPO PRA on *Naupactus xanthographus*). In Israel, (Gazit et al., 1982) and (Drory, 2013) refer to the cropping of *Annona cherimola* and of *A. squamosal* x *A. cherimola* (also a host). In Israel, fruit of *A. cherimola* x *A. squamosa* appear in winter (Drory, 2013), and in the 1990s, Israel produced 500 t per year (Janick & Paull, 2008). In Morocco, *A. cherimola* was originally used in gardens but commercial cultivation started in the 1980s. As of 2018, there were 18 ha in production (out of 57 ha planted) producing 180 t (Agrimaroc, 2018). In Italy, *A. cherimola* is cultivated on a small scale in Calabria (since the end of the 1800s) and Sicilia, often in association with *Citrus* (fruiting in the autumn) (Laforchettasullatlante, 2016). *A. squamosa* is mentioned as 'introduced' in Cyprus, Malta and Greece in CABI invasive species compendium.

Averrhoa carambola is cultivated in Andalusia (Peláez, 2017).

Eriobotrya japonica was first introduced into the EPPO region as an ornamental species and then later for fruit production (Caballero & Fernandez, 2003). In 2016, in Spain, there were 2 461 ha (27 272 t) in regular production (MAPA, 2018). In Turkey in 2018, there were 137 ha (4695 t) (https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr), Caballero and Fernandez (2003) also details production in Italy (663 ha), Morocco (385 ha) and Greece (300 ha). It is also recorded as cultivated commercially in Cyprus and Tunisia (EPPO PRA on *Apriona*, citing others) (all from EPPO PRA on *Naupactus xanthographus*, citing others).

Macadamia integrifolia is present in Andalusia (Peláez, 2017). It is reported to have been planted commercially in Israel (Ondabu et al., 2007); however, this may relate to a past situation as there were no longer macadamia crops in Israel in 2003 according to the NPPO (gd.eppo.int, distribution of *Thaumatotibia leucotreta* in Israel).

Psidium guajava is grown commercially in Spain (Malaga, Granada, Canary Islands) and is also recorded in Greece and Portugal (incl. Madeira) (CABI, 2019). No details are available on the conditions (outdoors or indoors).

***Litchi chinensis* (uncertain host)** is cultivated commercially in Andalusia (Peláez, 2017, Rivas, 1990) and is also mentioned in Morocco (MADER, 2003).

***Mangifera indica* (uncertain host)** in the EPPO region is cultivated mainly in Spain and Israel, with also some production in Sicily (harvested end of summer to mid-November depending on cultivars) (Montefalcone, 2010). In Spain, it is cultivated in Andalusia and the Canary Islands (D'Asaro et al., 2014). In Israel, *M. indica* has been planted for agricultural purposes since the 1930s (Drory, 2013). FAOStat records ca. 1800 ha in production in Israel in 2017 for 'mangoes, mangosteen and guavas'. There was a limited production in Morocco in the field at the end of the 1990s (10 ha in 1998/1999 – MADER, 2003), but FAOStat records only 2 ha in production in Morocco in 2017 for the category 'mangoes, mangosteen and guavas'.

***Persea americana* (uncertain host).** Within Europe, Spain has a commercial production and is the largest producer of avocados (92 936 tonnes 2017; 11 455 ha (2016 data; MAPA, 2018) mainly along the coast of Malaga and Granada. In addition, avocado production for 2017 (in tonnes) was as follows countries: Bosnia and Herzegovina (1 053), Cyprus (885), France (2 115), Greece (1 515), Israel (110 000), Tunisia (328), Turkey (2 765) (FAO, 2018) (from the EPPO PRA on *Naupactus xanthographus*). In Turkey, avocadoes are grown in Antalya and other Mediterranean parts of Turkey (N. Üstün, pers. comm.).

Other hosts or uncertain hosts may be planted for domestic fruit production or ornamentals, or grown in botanical gardens outdoors where conditions are appropriate (see table 7).

ANNEX 5. Production areas in EPPO countries.
In ha. FAO Stat (from either official data, or FAO data based on imputation methodology, FAO estimate or unofficial figures)

Oranges

area harvested ha	**2015**	**2017**
Albania	223	220
Algeria	43328	49942
Azerbaijan	138	233
Bosnia and Herzegovina	256	269
Croatia	32	24
Cyprus	1216	1298
France	812	1305
Georgia	898	447
Greece	31263	29600
Israel	4217	4260
Italy	86840	83740
Jordan	2663	2425
Malta	76	57
Montenegro	925	940
Morocco	54390	56638
Portugal	16722	16977
Russian Federation	25	26
Spain	147420	140505
Tunisia	12876	11023
Turkey	54298	51340
Total	**458618**	**451269**

Lemons and lime

area harvested ha	**2015**	**2017**
Albania	430	610
Algeria	3790	4234
Azerbaijan	390	434
Bosnia and Herzegovina	2	1
Croatia	30	22
Cyprus	593	468
France	938	956
Georgia	898	413
Greece	4186	4000
Israel	2079	2370
Italy	25466	25115
Jordan	1596	2090
Kyrgyzstan	2	2
Malta	29	25
Morocco	2827	3077
Portugal	967	997
Spain	38484	42507
Tunisia	3370	3890
Turkey	28570	32428
Uzbekistan	130	102
Total	**114777**	**123741**

Grapefruit

Area harvested ha	**2015**	**2017**
Algeria	91	88
Cyprus	429	472
France	369	346
Greece	186	160
Israel	3819	1621
Italy	269	271
Jordan	434	384
Malta	1	1
Morocco	42	59
Portugal	20	22
Spain	1976	2066
Tunisia	4641	4796
Turkey	6348	5359
Uzbekistan	146	146
Total	**18771**	**15791**

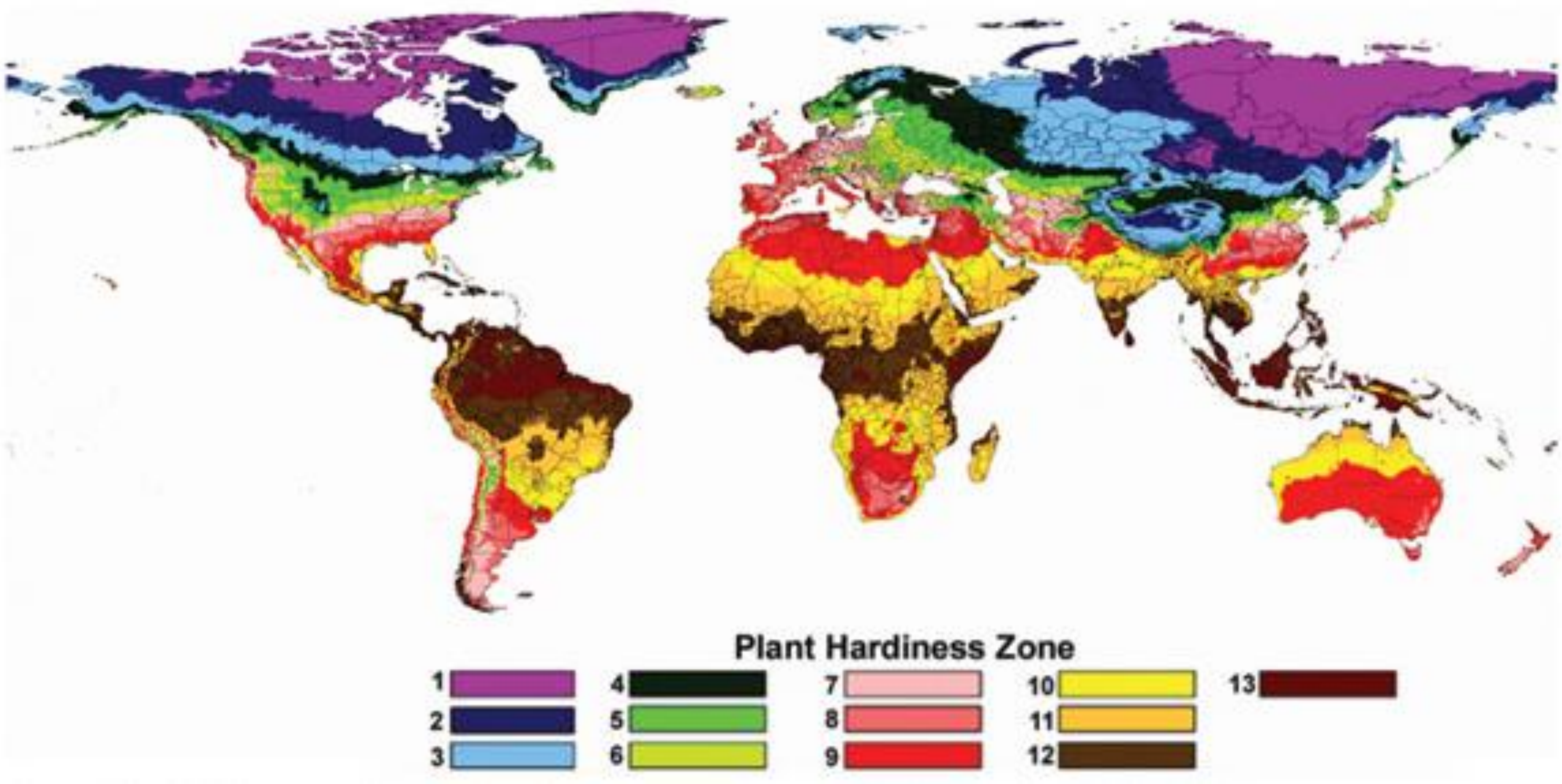
Tangerines, mandarins, clementines, satsumas

area harvested ha	**2015**	**2017**
Albania	628	766
Algeria	12734	14414
Azerbaijan	1221	1591
Bosnia and Herzegovina	8	1
Croatia	2150	2017
Cyprus	602	1243
France	2223	2220
Georgia	20340	16498
Greece	7930	8700
Israel	10186	9520
Italy	35921	35455
Jordan	1576	1416
Malta	6	5
Montenegro	120	130
Morocco	59362	63761
Portugal	2500	2511
Spain	195003	107515
Tunisia	8639	7094
Turkey	43506	50699
Uzbekistan	130	122
Total	**404785**	**325678**

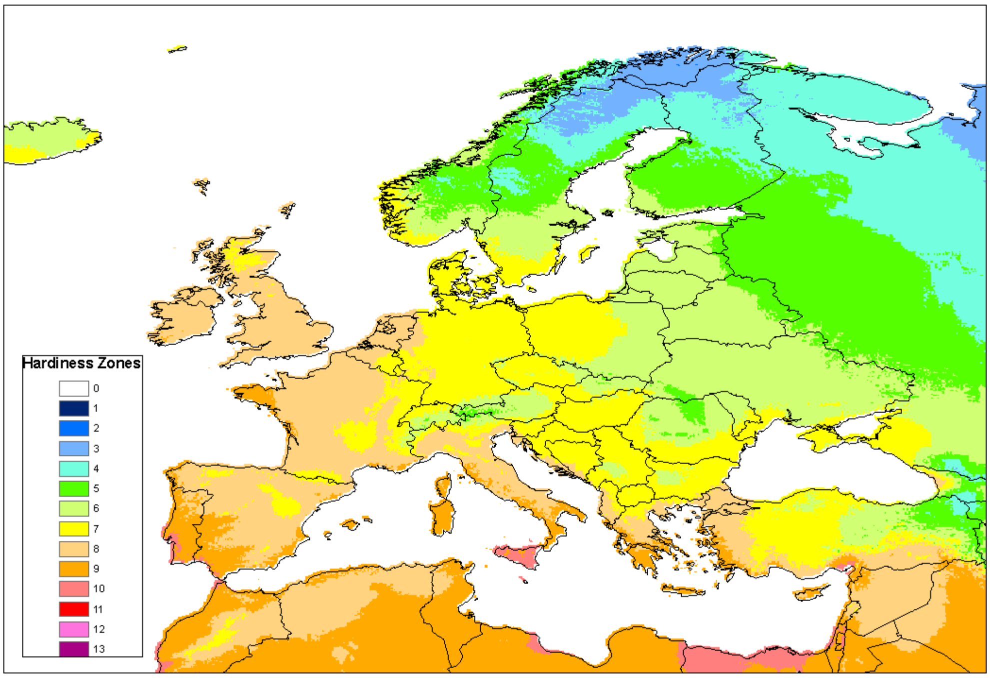
Peach and nectarine

EPPO country	2015	2017
Albania	1124	1191
Algeria	18262	21424
Austria	165	164
Azerbaijan	4077	4514
Bosnia and Herzegovina	2013	1183
Bulgaria	3711	3893
Croatia	1267	959
Cyprus	462	422
Czechia	481	366
France	9841	8810
Georgia	4604	6428
Germany	84	79
Greece	38648	41000
Hungary	5705	5711
Israel	3480	6420
Italy	72153	67021
Jordan	1945	3609
Kazakhstan	390	539
Kyrgyzstan	2500	2375
Malta	61	50
Montenegro	93	81
Morocco	7290	10929
Poland	2426	2262
Portugal	3750	3902
Republic of Moldova	7599	4722
Romania	1750	1770
Russian Federation	5600	5128
Serbia	7501	7132
Slovakia	402	323
Slovenia	317	282
Spain	86506	84219
Switzerland	10	10
Tunisia	15850	13177
Turkey	44504	46299
Ukraine	3500	3300
Uzbekistan	20372	16835

ANNEX 6. Plant hardiness zone maps
(as updated by Magarey et al., 2008)

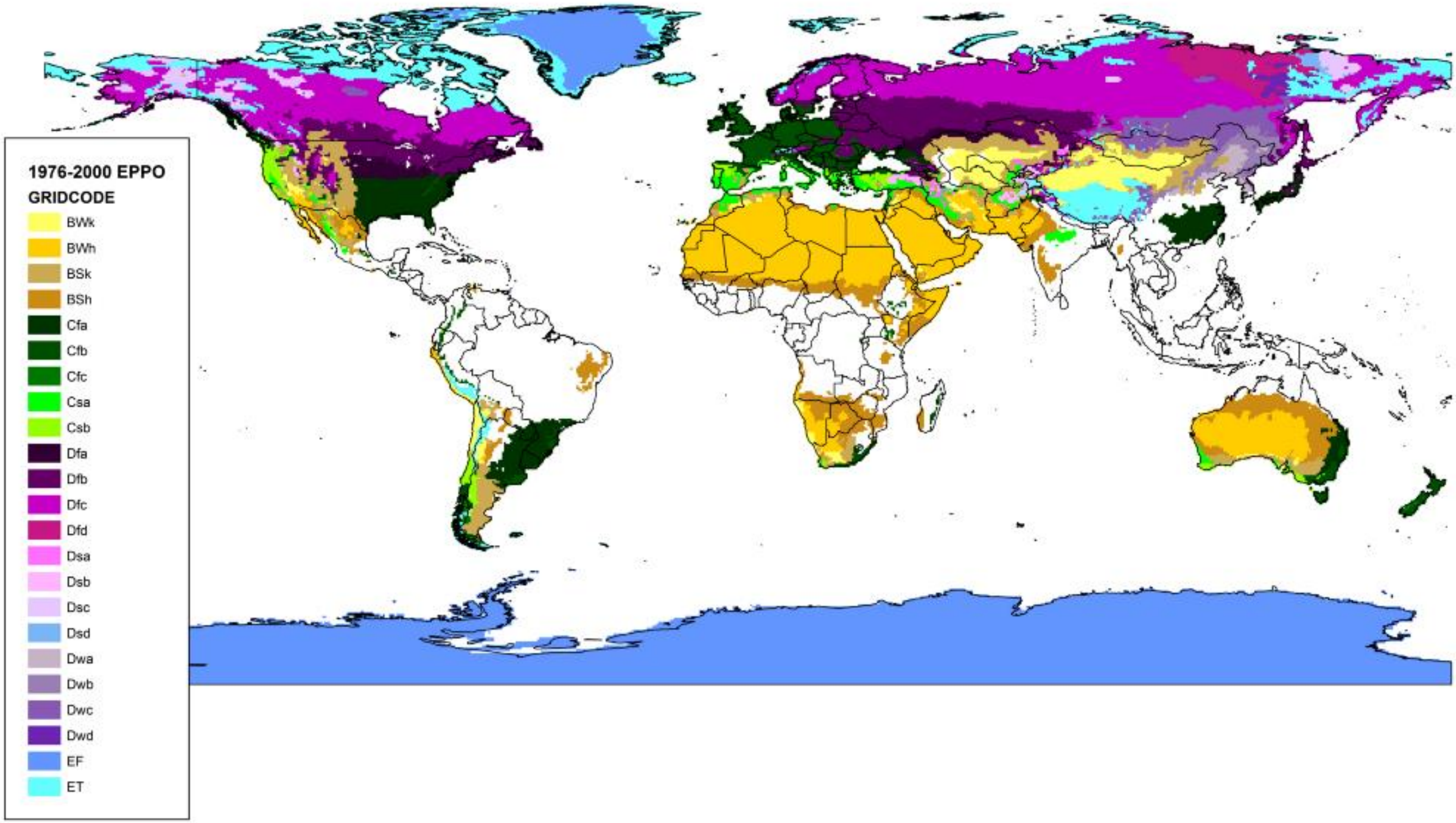


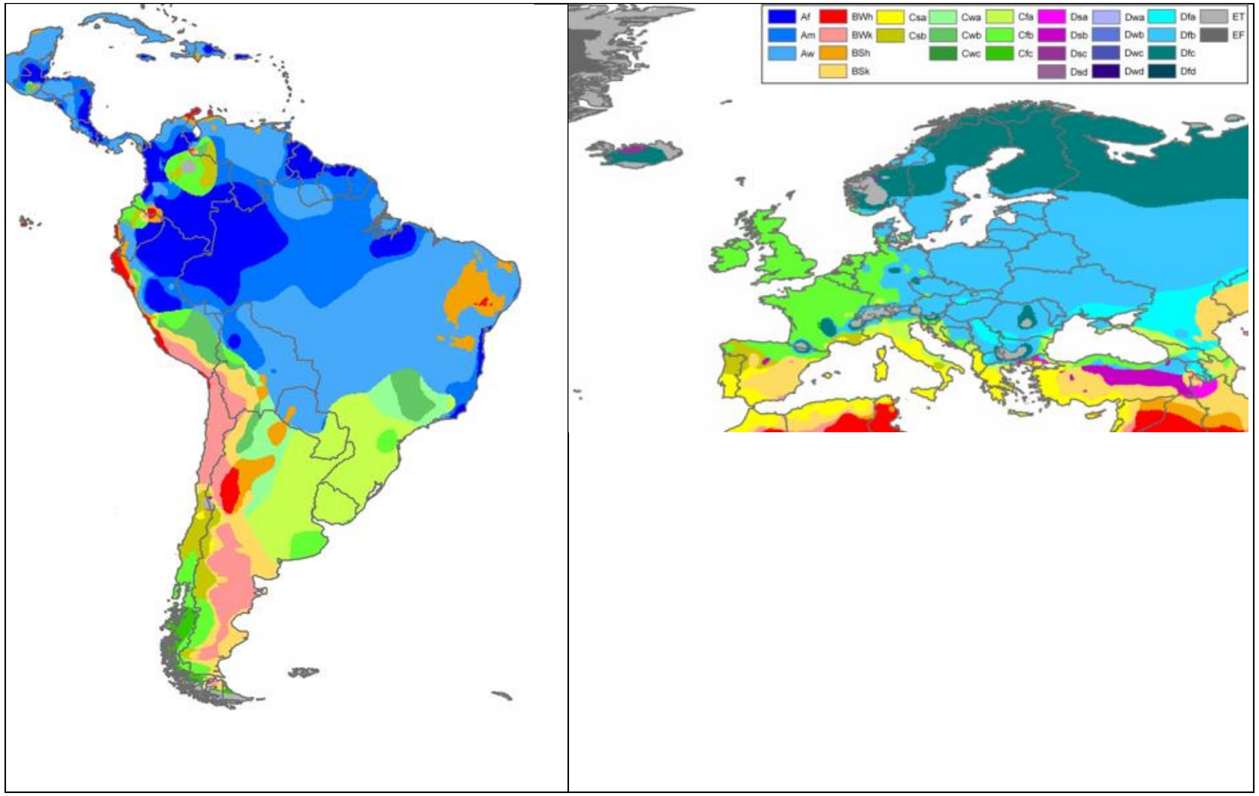
Hardiness zones in Europe (prepared in the framework of the EU project PRATIQUE, based on Magarey *et al.*, 2008)



ANNEX 7. Kőppen-Geiger Climate classification maps

Köppen-Geiger climate classification showing only climates that occur in the EPPO region (based on Rubel and Kottek (2010), adapted by Richard Baker, Fera, UK, August 2013 – EPPO Study on tomato fruit)

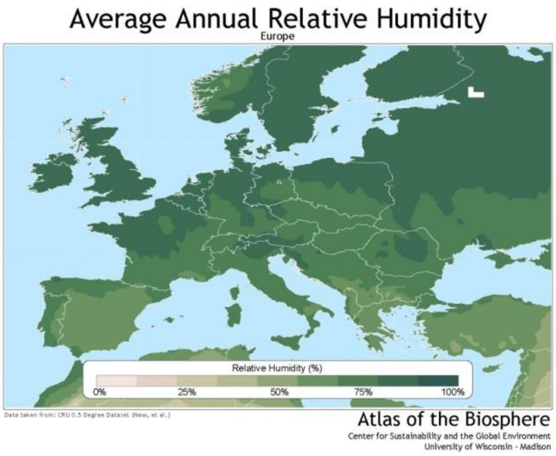




Köppen-Geiger climate zones in South America and Europe (from EPPO PRA on *Neoleucinodes elegantalis*)

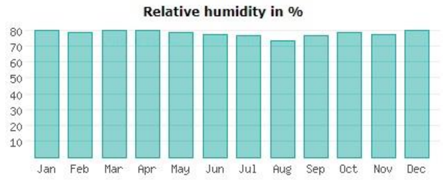
ANNEX 8. Data on relative humidity in the EPPO region and in South America

<u>1. Average annual relative humidity in the EPPO region and in South America</u>. University of East Anglia, 2020

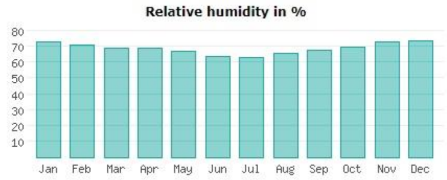


<u>2. Monthly average humidity in some major *Citrus* and hosts growing areas in EPPO countries and in São Paulo (Brazil)</u>. Data extracted from https://www.worlddata.info/, giving average monthly values for per region for the last 20 years

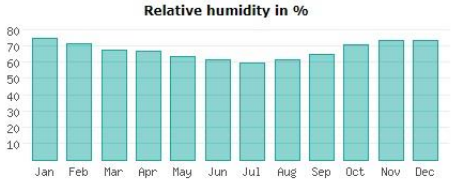
São Paulo (BR)



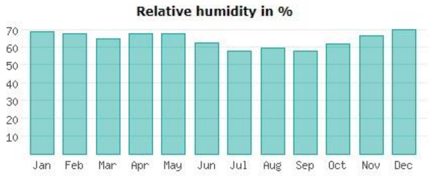
Sicilia (IT)



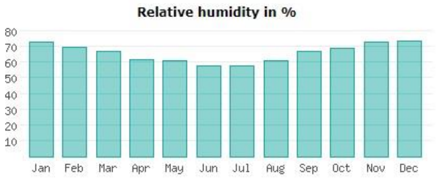
Andalusia (ES)



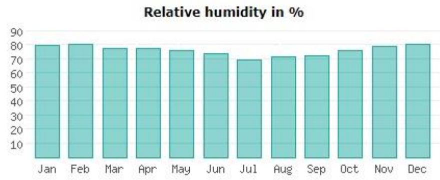
Antalya (TR)



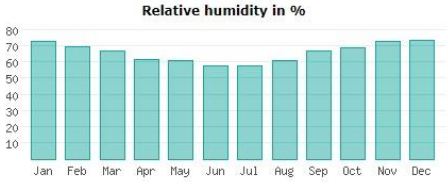
Valencia (ES)



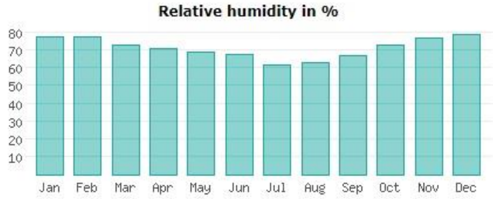
Tanger-Tetouan-Al Hoceima (MA)



Murcia (ES)



Faro region (PT)



3. Daily values over the year for some locations in the EPPO region. 2019. Data extracted from https://www.weatheronline.co.uk, Archives)