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Commodity risk assessment of *Momordica charantia* fruits from Thailand

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Abstract

The European Commission requested the EFSA Panel on Plant Health to prepare and deliver risk assessments for commodities listed in Commission Implementing Regulation (EU) 2018/2019 as 'High risk plants, plant products and other objects'. *Momordica* fruits originating from countries where *Thrips palmi* is known to occur qualify as high-risk plants. This Scientific Opinion covers the introduction risk for *T. palmi* posed by fruits of *Momordica charantia* L. imported from Thailand, taking into account the available scientific information, including the technical information provided by the Department of Agriculture of Thailand. The risk mitigation measures proposed in the technical dossier from Thailand were evaluated taking into account the possible limiting factors. An expert judgement is given on the likelihood of pest freedom taking into consideration the potential pest pressure in the field, the risk mitigation measures acting on the pest in the field and in the packing house, including uncertainties associated with the assessment. For *T. palmi* on *M. charantia* fruits from Thailand, an expert judgement is given on the likelihood of pest freedom following the evaluation of the risk mitigation measures acting on *T. palmi*, including any uncertainties. The Expert Knowledge Elicitation indicated, with 95% certainty that between 9,496 and 10,000 *M. charantia* fruits/10,000 will be free from *T. palmi*.

Keywords: European Union, plant health, plant pest, quarantine, *Thrips palmi*, bitter gourd, bitter melon, melon thrips

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Table of contents

1. Introduction

1.1. Background and Terms of Reference as provided by European Commission

1.1.1. Background

The new Plant Health Regulation (EU) 2016/2031,[1] on the protective measures against pests of plants, has been applied from December 2019. Provisions within the above Regulation are in place for the listing of 'high risk plants, plant products and other objects' (Article 42) on the basis of a preliminary assessment, and to be followed by a commodity risk assessment. A list of 'high risk plants, plant products and other objects' has been published in Regulation (EU) 2018/2019.[2] Scientific opinions are therefore needed to support the European Commission and the Member States in the work connected to Article 42 of Regulation (EU) 2016/2031, as stipulated in the terms of reference.

1.1.2. Terms of reference

EFSA is expected to prepare and deliver risk assessments for commodities listed in the relevant Implementing Act as "High risk plants, plant products and other objects". Article 42, paragraphs 4 and 5, establishes that a risk assessment is needed as a follow-up to evaluate whether the commodities will remain prohibited, removed from the list and additional measures will be applied or removed from the list without any additional measures. This task is expected to be on-going, with a regular flow of dossiers being sent by the applicant required for the risk assessment.

In view of the above and in accordance with Article 29 of Regulation (EC) No. 178/2002, the Commission asks EFSA to provide a scientific opinion in the field of plant health for *Momordica charantia* fruits from Thailand taking into account the available scientific information, including the technical dossier provided by Thailand.

1.2. Interpretation of the Terms of Reference

The EFSA Panel on Plant Health (hereafter referred to as 'the Panel') was requested to conduct a commodity risk assessment of *Momordica charantia* fruits from Thailand following the Guidance on commodity risk assessment for the evaluation of high-risk plant dossiers (EFSA PLH Panel, 2019).

As stated in the EU implementing regulation 2018/2019, fruits of *Momordica* L. are known to host and provide a significant pathway for the introduction and establishment of the pest *Thrips palmi* Karny, which is known to have the potential to have a major impact on plant species which are of a major economic, social or environmental importance to the Union territory. However, this pest does not occur in all third countries nor in all areas within a third country where it is known to occur. Certain third countries also have effective mitigation measures in place for that pest. In view of this, fruits of *Momordica* L. that originate in third countries or parts thereof where *T. palmi* is known to occur and which lack effective mitigation measures for *T. palmi,* qualify as high-risk plants, within the meaning of Article 42(1) of Regulation (EU) 2016/2031, and therefore, the introduction into the Union of those plants should be provisionally prohibited. Where demand for the importation of these plant products is identified, a risk assessment will be carried out in accordance with an implementing act to be adopted pursuant to Article 42(6) of Regulation (EU) 2016/2031.

Based on the information provided in the dossier, the panel will make an assessment to evaluate if the mitigation measures against *T. palmi* on *M. charantia* fruits from Thailand are effective to substantiate pest freedom. When necessary, additional information was requested to the applicant.

Risk management decisions are not within EFSA's remit. Therefore, the Panel provided a rating based on expert judgement regarding the likelihood of pest freedom for *T. palmi* given the risk mitigation measures proposed by the applicant.

[1] Regulation (EU) 2016/2031 of the European Parliament of the Council of 26 October 2016 on protective measures against pests of plants, amending Regulations (EU) 228/2013, (EU) 652/2014 and (EU) 1143/2014 of the European Parliament and of the Council and repealing Council Directives 69/464/EEC, 74/647/EEC, 93/85/EEC, 98/57/EC, 2000/29/EC, 2006/91/EC and 2007/33/EC. OJ L 317, 23.11.2016, pp. 4–104.

[2] Commission Implementing Regulation (EU) 2018/2019 of 18 December 2018 establishing a provisional list of high risk plants, plant products or other objects, within the meaning of Article 42 of Regulation (EU) 2016/2031 and a list of plants for which phytosanitary certificates are not required for introduction into the Union, within the meaning of Article 73 of that Regulation C/2018/8877. OJ L 323, 19.12.2018, pp. 10–15.

2. Data and methodologies

2.1. Data provided by the Department of Agriculture of Thailand

The Panel considered all the data and information (hereafter called 'the Dossier') provided by Department of Agriculture of Thailand on 9 of December of 2019, including the additional information provided by the DOA of Thailand on 10 of July of 2020 after EFSA's request. The Dossier is managed by EFSA.

The structure and overview of the Dossier is shown in Table 1. The number of the relevant section is indicated in the opinion when referring to a specific part of the Dossier.

Table 1: Structure and overview of the Dossier and the additional information submitted by the NPPO of Thailand

Dossier section	Overview of contents	Filename
1	Main document-dossier	20191122 INFORMATION OF HIGH RISK PLANT-Momordica charantia-final.pdf
2	Point by point reply to requested additional information by EFSA	*Additional information related to the contents of Momordica charantia dossier (EFSA-Q-2019-00791) from Thailand.pdf*
2.1	Letter to EFSA	AC 0914-3465.pdf

2.2. Literature searches performed by EFSA

A literature search was undertaken by EFSA to assess the state of the art regarding 1) the level of pest pressure in the applicant country; 2) efficacy of pre- and post-harvest measures applied to control *T. palmi*; 3) efficacy of insecticides to control *T. palmi*. The searches were run on 29/6/2020 (Appendix B). No language, date or document type restrictions were applied in the search strategy. Additional searches, limited to retrieve documents, were run when developing the opinion. The available scientific information, including previous EFSA opinions on the relevant pest (see pest data sheets in Appendix A) and the relevant literature and legislation (e.g. Regulation (EU) 2016/2031; Commission Implementing Regulations (EU) 2018/2019; (EU) 2018/2018 and (EU) 2019/2072) were taken into account.

2.3. Methodology

When developing the opinion, the Panel followed the EFSA Guidance on commodity risk assessment for the evaluation of high-risk plant dossiers (EFSA PLH Panel, 2019). Therefore, the proposed risk mitigation measures for *T. palmi* were evaluated in terms of efficacy or compliance with EU requirements as explained in Section 1.2. A conclusion on the likelihood of the commodity being free from *T. palmi* was determined and uncertainties identified using expert judgements. Pest freedom was assessed by estimating the number of infested fruits out of 10,000 exported fruits.

2.3.1. Listing and evaluation of risk mitigation measures

All currently used risk mitigation measures in the country of export were listed and evaluated.

The risk mitigation measures adopted in the production places and packing houses as communicated by SENASA were evaluated with Expert Knowledge Elicitation (EKE) according to the Guidance on uncertainty analysis in scientific assessment (EFSA Scientific Committee, 2018).

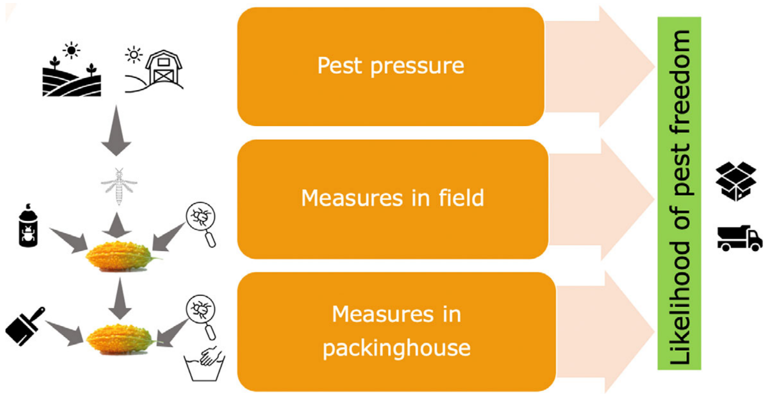

Figure 1: Conceptual framework to assess the likelihood of pest freedom for *Thrips palmi* in *Momordica charantia* fruits

Estimates of pest pressure of *T. palmi* in the production places and the effect of the mitigation measures taken in the field during production and the postharvest mitigation measures taken in the packing house were summarised in a pest data sheet (see Appendix A).

To estimate the pest freedom of the commodity a three-step approach was adopted following EFSA guidance (Annex B.8 of EFSA Scientific Committee, 2018). Therefore, three independent elicitations were conducted, i.e. one to estimate pest pressure in the field; one to estimate the efficacy of mitigation measures applied in the field; and a final one to estimate the efficacy of postharvest mitigation measures applied in the packing house. Combining these three estimations, the level of pest-freedom for *T. palmi* on *M. charantia* fruits from Thailand was determined (see Section 2.3.2). The final result indicates how many fruits out of 10,000 will be infested with *T. palmi* when arriving in the EU.

The uncertainties associated to the EKE were taken into account and quantified in the probability distribution applying the semi-formal method described in Section 3.5.2 of the EFSA-PLH Guidance on quantitative pest risk assessment (EFSA PLH Panel, 2018). Finally, the results were reported in terms of the likelihood of pest freedom. The lower 5% percentile of the uncertainty distribution reflects the opinion that pest freedom is with 95% certainty above this limit.

2.3.2. Conceptual model for risk of entry

The risk of entry of *T. palmi* via import of *M. charantia* fruits from Thailand was estimated in three steps using a formal conceptual model? In this model the estimated pest pressure is used as starting point and corrected by the independent effects of measures in the field and in the packing house. The result of this model is the level of infestation at import calculated as follows:

$$\text{Import risk: } r_{\text{import}} = p_{\text{pressure}} \times p_{\text{field}}/10,000 \times p_{\text{packing}}/10,000$$

$$\text{Pestfreedom: } PF_{\text{import}} = 10,000 - r_{\text{import}}$$

All values are expressed in numbers of fruits out of 10,000 (Table 2).

Table 2: Parameters for three-step conceptual model to estimate the likelihood of pest-freedom in *Momordica charantia* fruits

Parameter	Unit	Description
r_{import}	[No out of 10,000 fruits]	The number (out of 10,000) *M. charantia* fruits imported to the European Union (EU) from Thailand, which will be infested with *Thrips palmi* when arriving the EU
p_{pressure}	[No out of 10,000 fruits]	The number (out of 10,000) *M. charantia* fruits harvested on production sites in Thailand, which will be infested with *Thrips palmi* without application of specific measures against the pest (pest pressure under general agricultural practice)

Parameter	Unit	Description
p_{field}	[No out of 10,000 fruits]	The number of *M. charantia* fruits (out of 10,000 infested fruits) that remain infested after applying measures on production sites
$p_{packing}$	[No out of 10,000 fruits]	The number of *M. charantia* fruits (out of 10,000 infested fruits) that remain infested after applying measures at the packing house
PF_{import}	[No out of 10,000 fruits]	The number (out of 10,000) *M. charantia* fruits imported to the EU from Thailand, which will be pest free of *Thrips palmi* when arriving the EU

The input parameters $p_{pressure}$, p_{field} and $p_{packing}$ are determined by separate EKE. The uncertainties associated to the EKE were taken into account and quantified in the probability distribution applying the semi-formal method described in Section 3.5.2 of the EFSA-PLH Guidance on quantitative pest risk assessment (EFSA PLH Panel, 2018).

The model results r_{import} and PF_{import} were calculated using Monte Carlo simulation. A final distribution is fitted to the simulation results.

Finally, the results were reported in terms of the likelihood of pest freedom. The lower 5% percentile of the uncertainty distribution reflects the opinion that pest freedom is with 95% certainty above this limit.

3. *Thrips palmi*

3.1. Biology of the pest

Thrips palmi Karny (Thysanoptera: Thripidae), commonly known as melon thrips, oriental thrips and southern yellow thrips, was first described in 1925 from Sumatra and Java (Indonesia) (Karny, 1925). The species previously had the common name 'palm thrips'; however, no palm species are known to host this pest and the origin of this name is in honour of Dr B.T. Palm, a well-known specialist of this group.

At 25°C, the life cycle from egg to egg lasts 17.5 days (OEPP/EPPO, 1989). The life cycle differs little from that of most phytophagous Thripidae (Figure 1). The adults emerge from the pupa in the soil, and consequently, move to the leaves, flowers and fruits of the plant, where they lay their eggs in an incision made with the ovipositor. They preferably lay their eggs in young growing tissue of leaves, and also the flowers and fruit of a wide range of host plants, especially Cucurbitaceae, Solanaceae and Leguminosae. The two larval stages (LI and LII) and male and female adults feed on the maturing leaves, stems, flowers and flower petals and surfaces of fruits. They suck the contents of tissue cells with their specialised mouthparts, leaving them empty, causing silvery scars or leaf bronzing. The second-stage larva drops from the plant to the soil (or packing cases or growing medium) and completes its cycle by pupating (pupa I and pupa II) in the substrate (EPPO, 2018a,b).

The life cycle and population dynamics of *T. palmi* in Japan have been reviewed by Kawai (1990).

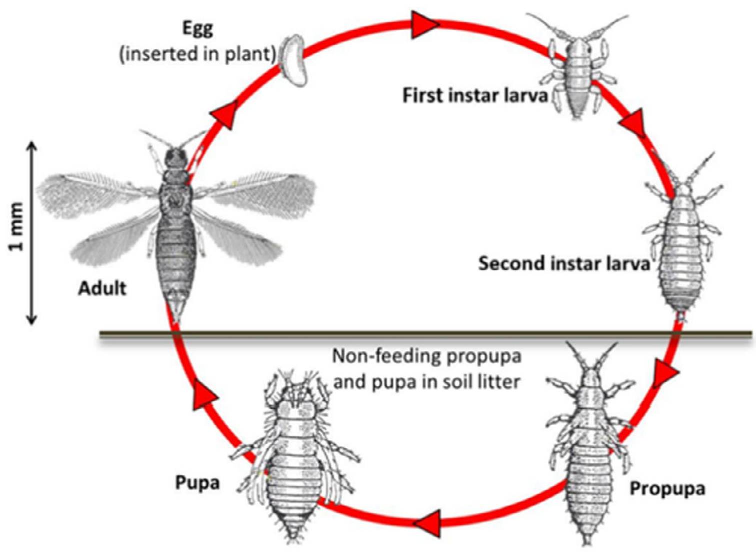

Figure 2: Life cycle of Thripidae (e.g. *Thrips palmi*)

Thrips palmi is primarily a subtropical and tropical species. Tsumuki et al. (1987) analysed the cold hardiness of *T. palmi* in Japan and concluded that it could not survive outdoor winter conditions in southern Honshu Island.

Sakimura et al. (1986a,b) set the outdoor northern limit to 34°N, which corresponds to the very south of Honshu. However, Nagai and Tsumuki (1990) reported no reduction of adult populations at temperatures as low as from −3 to −7°C on weeds in an unheated glasshouse between mid-January and mid-February in Japan. Developmental time decreased with increasing temperature up to 32.5°C in all stages. The total developmental time was longest at 12.5°C (64.2 days) and shortest at 32.5°C (9.2 days), 12.7 days at 25°C (Park et al., 2010). The mean developmental time for the egg stage varied between 24 days at 12.5°C, 6–7 days at 25°C, 4–5 days at 30°C and 3.3 days at 32.5°C (Park et al., 2010). Developmental times varied however between different lab assays, host plants, photoperiod, etc. by a few days between different experiments in particular larval development at lower temperatures. The lower developmental threshold was 10.6, 10.6, 9.1, and 10.7°C for egg, larva, prepupa, and pupa, respectively. The thermal constant required to complete the respective stage was 71.7, 59.2, 18.1, and 36.8 degree-days (DD). The lower threshold temperature and thermal requirements varied a bit between different studies ranging from 10.1°C and 194 DD (McDonald et al., 1999) and 10.6°C and 183.3 DD for egg to adult development (Park et al., 2010) to 11.3°C and 196 DD (Yadav and Chang, 2014) and 11.6°C and 189.1 DD (Kawai, 1985).

Parthenogenesis (arrhenotoky) in *T. palmi* has been reported by Yoshihara and Kawai (1982). The oviposition behaviour of the species was observed in Taiwan (Wang et al., 1989); a preoviposition period of 1–3 days for virgin females and 1–5 days for mated ones was recorded. Virgin females laid 3–164 eggs (1.0–7.9 eggs per day) during their lifespan, while mated females laid 3–204 eggs (0.8–7.3 eggs per day). At 25°C, the net reproductive rate (28.0), female fecundity (59.6 eggs/female) and daily oviposition rate (3.8 eggs/day) reached the maximum level (Kawai, 1985). At the optimum temperature for population growth (25–30°C), the number of generations was estimated in 25–26/year (Huang and Chen, 2004). Significant differences in population growth among crops were highlighted (Kawai, 1986). The survival rates of the larval and pupal stages fed on cucumber, kidney bean, eggplant and balsam pear were high, whereas the survival rates of those fed on okra and chrysanthemum were low. The larvae fed on tomato and strawberry were unable to pupate. Duration of the larval and pupal stages fed on chrysanthemum and okra was longer than the duration of those fed on other crops. The longevity of the adults fed on cucumber, pumpkin, eggplant and kidney bean was increased, whereas the longevity of those fed on chrysanthemum, tomato and strawberry was decreased. The fecundity of adult females (no. eggs/female) fed on cucumber was maximum (60), while the fecundity of those fed on melon, eggplant and pumpkin amounted to 20. The differences in the generation time were not significant among crops, unlike the differences in the net reproductive rate. The intrinsic rate of natural increase of *T. palmi* fed on cucumber was maximum and the value was 0.134, while that of *T. palmi* fed on melon, eggplant and pumpkin ranged from 0.08 to 0.11 (Kawai, 1986).

3.2. Symptoms

3.2.1. General symptoms

On plant material, at inspection, silvery feeding scars on the leaf surface, especially alongside the midrib and veins, can be seen (Cannon et al., 2007). Heavily infested plants are characterised by a silvered or bronzed appearance of the leaves, stunted leaves and terminal shoots. At high densities, feeding by *T. palmi* may cause damage to fruits (Kawai, 1986) as well, such as scarring, discoloration and deformation in developed fruits or fruit abortion in an early stage. Cucumber, eggplant and pepper fruit are damaged when thrips feed in the blossoms. Symptoms may be found on all parts of a wide range of plant species (Sakimura et al., 1986a,b). Although *T. palmi* feeds on *Momordica* sp., no specific information of symptoms and damage caused to fruits of *M. charantia* is available.

3.2.2. Pest density of *Thrips palmi* in fruits

Despite its wide host range, including fruits and vegetables, the information about the actual pest density levels of *T. palmi* itself in various crops is limited. Most relevant papers measure the economic injury level (EIL) and the economic threshold (ET), which are calculated by the damage caused by the pest correlated with pest density. Yet, no information has been found of EILs and ETs calculated for *T. palmi* infestations in *M. charantia* under greenhouse or semi-field conditions in particular.

Rosenheim et al. (1990) recorded that in cucumber, densities of *T. palmi* (number per unit area of plant substrate) were greatest on foliage, and lowest on fruits, with an average ratio of 0.55 per female flower and 0.19 per fruit compared to foliage. During the early stage of development, fruits physically support the female flowers, but as the densities of *T. palmi* in flowers is low, the opportunities for them to incidentally feed upon and scar young fruit are low as well, this in contrast to *Frankliniella occidentalis*.

At high densities, *T. palmi* feeding may cause damage to fruits (Kawai, 1986; Welter et al., 1990). No records, however, are available specifically for *M. charantia*, and data available in literature for cucumber likely better reflect the incidence on *M. charantia* than those on Solanaceous crops like eggplant or sweet pepper. Kawai (1985) estimated EILs for cucumber the tolerable density of adults – at a constant high density - at 4.4 per leaf for uninjured fruit yield and at 5.3 adults per leaf for the total fruit yield (at a level of yield loss of 5%) and 8.8 adults per leaf (at a level of yield loss of 10%). In addition, Kawai (1990) reported EIL's of 0.08 adults per leaf for eggplant and 0.11 adults per flower for sweet pepper. In other studies, in Japan, EILs were estimated at densities of 1–10 adults per cucumber leaf or 2–3 adults or larvae per pepper flower in south Florida, USA, (Capinera, 2020). In case of high infestations in eggplant, less fruits are produced and of smaller size (Yadav and Chang, 2014). They recommended as an action threshold 1.05–1.50 thrips per flower or 4.91–10.17 adults per sticky trap over a 4-day period. Welter et al. (1990) calculated an action threshold of 94 thrips/ cucumber leaf early in the growing season, showing that an EIL for fruits is relatively high for *T. palmi*. EILs are quite variable and differ per crop, per country, and timing in the season and ETs depend on variable and dynamic economic factors such as costs for control, labour, yield, market price, etc. (Pedigo et al., 1986). Yadav and Chang (2014) indicated that the percentage of fruit damage correlates with the population dynamics of the thrips. Besides, thrips-related fruit damage in eggplants can best be evaluated in terms of the damaged fruit percentage, not in terms of yield loss.

3.3. Confusion with other pests

Thrips palmi identification is hampered by its small size and great similarity with other yellow species of thrips. Indeed, *T. palmi* can be mistaken for common thrips species with similar characteristics, e.g. *T. flavus* Schrank and *T. tabaci* Lindeman distributed worldwide, *T. alatus* Bhatti and *T. pallidulus* Bagnall in the Oriental region, *T. nigropilosus* Uzel and *T. alni* Uzel in the Palaearctic region and *T. urticae* Fabricius in Europe. For the distinction between look-alike species, microscopic examination by a seasoned expert of the morphological characteristics is required, or by molecular analysis (EPPO, 2018a,b).

3.4. Effectiveness of control options worldwide

A variety of chemical, cultural, biological and physical measures is used by growers across the world to manage *T. palmi* (Morse and Hoddle, 2006; Cannon et al., 2007), to prevent or maintain populations at a very low-density level. Management measures include the use of systemic and contact insecticides, insecticidal soaps, essential oils/plants extracts, soil treatments, the use of resident or introduced natural enemies, exclusion of the crops by physical barriers such as windbreaks, screenhouses, row covers, bagging of fruits, covering the soil with organic or plastic mulch or film, the removal of alternative weed hosts, trap crops (Salas, 2004), alternation of susceptible crops (Young and Zhang, 1998; Maltby and Walsh, 2005) and the use of less susceptible cultivars. Each of them separately has an effect, to restrict the entry and colonisation of the crop, to limit or suppress population growth (Kawai, 1990; Matsui et al., 1995).

Other techniques are used to monitor the number of thrips in order to establish the level and distribution of thrips infestation in a crop, such as the use of sticky traps, alone or with lures or pheromones, water pan traps, sampling of leaves and leaf beating. Monitoring results can be used to establish the distribution in a crop, to establish economic threshold levels and to facilitate the decision-making for which and when measures need to be taken to manage *T. palmi* infestations (Sánchez et al., 2011; Nakamura et al., 2014; Shibao and Tanaka, 2014; Thongjua et al., 2015; Dong and Hsiu, 2019).

3.5. Detection and monitoring

3.5.1. Sampling

Thrips palmi adults and larvae generally are found on the foliage: adults aggregate on the young vegetative parts, sometimes in the flowers, larvae on the underside of maturing leaves, concentrated in the upper third part of the crop (Kawai, 1990; Bacci et al., 2008; Zhang et al., 2014). Which parts of the plant best reflect the relationship between the density of thrips and the resulting damage depends on the crop type: flowers in orchids (Maketon et al., 2014) and egg-plant (Yadav and Chang, 2013), leaves in cucumber (Bacci et al., 2008) and bean (Osorio and Cardona, 2003). The number of leaves or flowers sampled depends on the crop, stage of infestation, the experimental setup, etc. For cucumber, reflecting best a bitter gourd crop, the best sampling size consisted of 35 leaflets per field or 40 leaflets per ha (Osorio and Cardona, 2003), taken at random from the uppermost part of plants to establish the action threshold.

3.5.2. Monitoring with traps

Adults can be sampled with water pan traps, sticky traps and LED light traps. The use of sticky traps is common practice around the world for monitoring thrips, whereas water pan traps are uncommon and LED light traps not yet implemented at a commercial level. Blue and white have shown to be attractive colours for monitoring *T. palmi* in cucumber, eggplant and sweet pepper (Kawai, 1983; Kawai and Kitamura, 1987, 1990; Kawai, 1990; Yadav and Chang, 2013; Zhang et al., 2014) or wax gourd, respectively (Huang, 1989); for some crops, e.g. in orchids, yellow is more attractive (Culliney, 1990; Thongjua et al., 2015; Maketon et al., 2014). Besides trap colour and relation to the background colour of the crop and the environment, its efficacy in a crop also depends on placement height in the crop (upper third). In recent years, a combination of LED lights covered by transparent plates show that *T. palmi* is attracted to light at wavelengths from 500 to 525 nm (Hajime et al., 2014; Shibao and Tanaka, 2014).

3.6. Management options

3.6.1. Chemical control

Contact and systemic insecticides combined with insecticidal soaps, essential oils/plant extracts, are frequently applied for suppression of *T. palmi*, in particular during the first years after invading a new area or when the pest needs to be eradicated (MacLeod et al., 2004; Cannon et al., 2007). Then, efficacy of control can be very high (90–95%) when timely and regularly applied. However, application of insecticides alone is not an adequate tool to control *T. palmi* because the eggs (in the foliar tissue) and the pupae (in the soil) are relatively insensitive to insecticide application. Given the polyphagous nature of *T. palmi* and the short life cycle, the population density in the surrounding environment of a crop may be very high and this may require repeated insecticide applications.

In addition, *T. palmi* is able to develop insecticide resistance already after a few years requiring alternation of different active ingredients which most often do not match with integration of biological or integrated control methods. Insecticide resistance in *T. palmi* was recorded as early as 1994 (Nozawa et al., 1994). In recent years, resistance has been recorded in Asia for insecticides such as cypermetrhin (Kim et al., 2019; Ghosh et al., 2020), imidacloprid (Bao et al., 2015; Kim et al., 2019; Ghosh et al., 2020), and in particular spinosad (Bao et al., 2014, Kim et al., 2019) and spinetoram (Gao et al., 2019; Shi et al., 2020). Field populations in Korea also showed reduced mortality to emamectin benzoate, chlorfenapyr, cyantraniliprole and dinotefuran (Kim et al., 2019). Resistance varies geographically and locally (Kim et al., 2019). To slow down insecticide resistance, it is important to apply insecticides that are effective in a rotation program.

3.6.2. Mass trapping

Mass trapping with sticky traps/ribbons can reduce the numbers of *T. palmi* in some crops, such as sweet pepper and eggplant (Kawai, 1990, 2001; Murai, 2002). When these ribbons were set every 2–3 m^2 in a greenhouse, the density of *T. palmi* was reduced 10–20% comparedto that in greenhouses without ribbons (Nonaka and Nagai,1984). In strawberry it could reduce adult thrips (*F. occidentalis*) numbers per flower by 61% and fruit bronzing by 55% (Sampson and Kirk, 2013). However, in these and other studies on thrips (see Sampson and Kirk, 2013), either no assessment of crop damage was made, or it failed to prevent damage (Trdan et al., 2005 for *T. tabaci* in onion crops) and therefore no evidence is available of its economic viability. Nevertheless, mass trapping could be cost-effective at an early stage of invasion (Kawai and Kitamura, 1987, 1990), in high-value crops (Sampson and Kirk, 2013) and when part of an overall IPM program. As a part of a combination of measures it could maintain thrips numbers below the damage threshold during specific periods of preharvest, when pesticides cannot be used because of residue levels.

3.6.3. Cultural control

Several cultural practices can effectively reduce the level of infestation by *T. palmi*. Physical barriers hampering the access to the host plants can protect a crop from infestation, such as windbreaks, growing the crop in glasshouses or fine meshed screenhouses, crop covers and or row covers, bagging of fruits, covering the soil with organic or plastic mulch or silver plastic, or spraying kaolin. Additionally, intercropping, the use of trap plants and the removal of alternative weed hosts (Salas, 2004; Cannon et al., 2007) (Kawai, 2001; Salas, 2004; Ingrid et al., 2012; Shirotsuka et al., 2016; Razzak and Seal, 2017; Razzak et al., 2018) also contributes to a better crop hygiene and thus a lower infestation level. Population build up is often hampered by periods of heavy rains in the open field (Huang, 1989; Etienne et al., 1990), but overhead irrigation of the crop does not.

Cultural control measures can be part of a systems approach for the control of *T. palmi*.

3.6.3.1. Fruit bagging

Preharvest fruit bagging is an extensively used practice in many countries around the world (Faci et al., 2014; Sharma et al., 2014; Shen et al., 2014). The use is twofold, it ensures homogeneity, aesthetics and quality of the product and it protects against diseases and pests, such as fruit flies (Tephritidae) and fruit borers (Lepidoptera). In the literature, there is not so much information for the effect on the prevention of damage by thrips, indicating it is primarily for other insect pests.

Few studies have been performed on the use of fruit bagging in reducing the incidence of thrips pests: Affandi et al. (2008) found a reduction in scarring of mango fruits (caused by an unspecified species of thrips) of 32–42% in Indonesia using double-layered bags of plastic and paper. Karar et al. (2019) found that harvested fruits of mango in closed paper bags (brown paper inner black and butter – wet resistant/ greaseproof - paper) were 100% free of (unspecified) thrips in Pakistan. Martins (2018) noticed a 30–50% reduction in lesions caused by *F. brevicaulis* in Brazil, and according to de López et al. (2020) bagging alone of bananas reduced losses by 90–100% by the red rust thrips (*Chaetanaphothrips signipennis*) compared to bunches with no bags. In banana plantings, covering bunches with polyethylene bags during fruit development provides a physical barrier to insect infestations, but bags cannot fully protect the fruit when a thrips infestation is heavy (Hara et al., 2002). No records have been found in literature on the effect of pre-harvest fruit bagging of *M. charantia* fruits.

3.6.4. Biological control

Macroorganisms

Augmentative biological control by seasonal or inundative releases of natural enemies such as predatory mites, (e.g. *Neoseoiulus* spp. or *Amblyseius* spp.) or predatory bugs (e.g. *Orius* spp.) can be very effective in greenhouses or in an outdoor Mediterranean climate when other crop pests are carefully managed and applications are timely made. Other generalist predators such as lacewings (*Chrysoperla* spp.), mirid bugs (*Macrolophus* spp.) or lady bugs (Coccinellidae) can prey on *T. palmi*, but will predominantly target preys which are prevalent, and thus only partly contribute to thrips control (Van Lenteren and Loomans, 1999). Conservation biological control, relying on the natural colonisation of a crop by natural enemies already present in the environment, is often too late and too less and therefore much less effective in an early and timely control of *T. palmi*. control of thrips pests heavily relies on chemical applications however the use of insectides may have detrimental effects on biological control agents (Cuthbertson, 2014).

Microorganisms

Application of entomopathogens, such as the fungi *Akanthomyces lecanii* (previously named as *Lecanicillium lecanii* and *Verticillium lecani*), *Metarhizium anisopliae*, *M. rileyi* (synonym *Nomuraea rileyi*), *Beauveria bassiana* and *Paecilomyces fumosoroseus* can have a certain control effect on thrips whereas others like *Bacillus thuringiensis* have a limited effect (Saito, 1991, 1992; Vestergaard et al., 1995; Castineiras et al., 1996; Ekesi et al., 2000; Ekesi and Maniania, 2002; Trujillo et al., 2003; Visalakshy et al., 2004; Cuthbertson et al., 2005; North et al., 2006; Panyarisi et al., 2007; Silva et al., 2011; Shao et al., 2015; Hadiya et al., 2016). Others, such as *Purpureocillium lilacinum* (Hotaka et al., 2015) and *Isaria javanica* (Park et al., 2018) are still in a developmental phase.

Biotechnical control and semiochemicals

The effect of semiochemicals (Qing et al., 2004; Kirk, 2017) – either as a repellent or attractant - on the behaviour and trapping efficiency is still in an experimental phase. An aggregation pheromone for *T. palmi* has been identified (Akella et al., 2014), it can be used for monitoring, but implementation is still in an experimental phase (Kirk, 2017). In experimental set-ups methyl salicylate (MeSA) has shown to attract natural enemies and to reduce populations in cucumber plants (Dong and Hsiu, 2019), but has not been developed to a commercial scale.

3.6.5. Host plant resistance

A few research reports mention differences in susceptibility to foliar injury among cultivars of pepper (Nuessly and Nagata, 1995), sweet pepper (Yasuda and Momonoki, 1988; Matsui et al., 1995; Visschers et al., 2019) and bean (Cardona et al., 2002; Frei et al., 2004), but host plant resistance has shown a low or no effectiveness in the management of *T. palmi*. No records have been found which specifically refer to breeding resistance genes into *M. charantia* or other *Momordica* species.

3.6.6. Post-harvest treatments

Potassium salts of fatty acids also known as insecticidal soaps are used as insecticides, herbicides, fungicides and algaecides. Mixtures of potassium salts of fatty acids and essential oils may be used as selective acaricides (Tsolakis and Ragusa, 2008) and insecticides (Wafula et al., 2017) as an alternative to synthetic chemical pesticides enabling farmers to produce with acceptable residue levels that meet market requirements. In snap bean in Kenya (Wafula et al., 2017), potassium salts of fatty acids reduced thrips (*Frankliniella* spp. and *Megalurotrhips sjostedti*) populations up to 54%, comparable with synthetic pesticides.

Washing produce - fruits and vegetables - with chlorinated or ozonated water is used to sanitise water systems and to disinfect the surface of produce to prevent decay caused by microorganisms such as bacteria, fungi and yeasts and other pathogens at concentrations between 100 and 200 ppm active ingredient, at pH around 7 (Bornhorst et al., 2018; Ilic et al., 2018). It is not designed to kill insects, and little or no scientific evidence is available that it works as such.

4. Commodity data

4.1. Description of the commodity

The commodity to be imported are fruits of *M. charantia* also known as bitter gourd or bitter melons. *M. charantia* fruits exported to EU markets are intended for human consumption. Fruits are individually wrapped in PVC film and placed in foam box with cooling gel ice. The wrapped *M. charantia* fruits are packed into a styrofoambox. The size of the box depends on the size and number of fruits. Box dimensions of 39 × 54 × 20 cm are used to contain either 13–20 or 8–12 *M. charantia* fruits (Table 3).

Table 3: Trade volumes of *M. charantia* fruits for export to the EU

Year	2014	2015	2016	2017	2018
Export volume in metric tons (MT)	45.45	19.93	18.93	23.70	18.66

4.2. Description of the production areas

Momordica charantia production is present throughout the country in Thailand (Figure 3). All production areas of *M. charantia* in Thailand are destined for exportation. Currently, all the production of *M. charantia* is carried out in open fields.

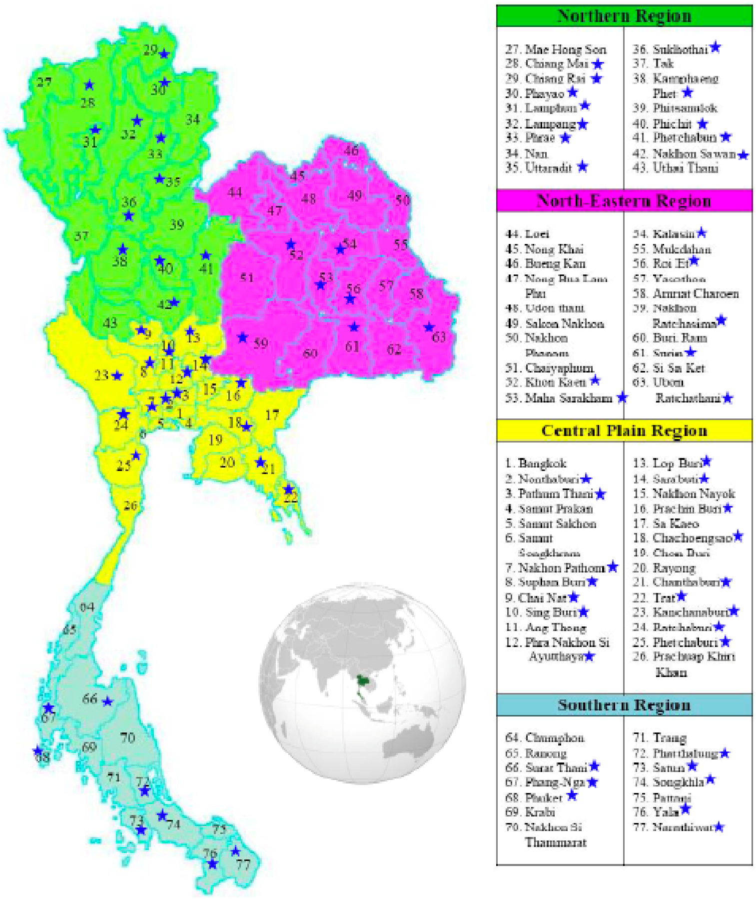

Figure 3: Location of *Momordica charantia* production sites in Thailand (globe map depicted in the picture taken from Wikipedia CC-BY-SA-3.0)

4.2.1. Source of planting material

According to the information provided in the dossier seeds are used as propagating material.

4.2.2. Production cycle

The growing cycle of *M. charantia* as described in the dossier starts with seeds soaked in water for 24 h. Then after seeds are sown and within 15–20 days, seedlings are transplanted in the field. Every 7 days, plants are fertilised with 156.25 kg of fertiliser per hectare. Flowers appear 6 weeks after sowing and harvesting starts about 2 months after sowing. Harvesting lasts about 5 weeks and the entire crop cycle lasts approximately 12 weeks. Bitter gourd production occurs throughout the year with 3–4 production cycles per year.

5. Overview of interceptions

According to Europhyt/TRACES-NT, accessed on 14 July 2020 and covering all interceptions since 1995, there are 29 interceptions reported in Europhyt/TRACES-NT (1995–2020) of *T. palmi* on *M. charantia* fruits originating from Thailand with three of them in the last 10 years.

6. Pest pressure and risk mitigation measures

The evaluation of the efficacy of the risk mitigation measures against *T. palmi* was done in a three-step approach. First an estimate was made for the pest pressure of *T. palmi* in the production environment. Second, the control effect of the pest management measures in the field was estimated. Third, the control effect of the post-harvest measures (packing house) was estimated.

The information used in the evaluation of the effectiveness of the risk mitigation measures is summarised in a pest data sheet (see Appendix A).

6.1. Pest pressure in production places

Based on monitoring data in production fields available in the dossier the Panel estimated the pest pressure in the production places under a no-intervention scenario (i.e. no mitigation measures). Moreover, the climatic conditions in Thailand (based on monthly average temperatures) are very favourable for the development of this pest.

6.2. Risk mitigation measures applied in production fields

With the information provided by DOA of Thailand (Dossier Sections 1, 2), the Panel summarised the risk mitigation measures that are currently applied in the production places (Table 4).

Table 4: Overview of currently applied risk mitigation measures for *Momordica charantia* fruits designated for export to the EU from Thailand

Risk mitigation measure	Description of applied measure
Trapping of adults	Blue sticky traps are used for monitoring and mass trapping. Depending on the cultivation method, traps are placed at every 2 or 5 meters in a row (Dossier Section 2).
Registration of exporting fields	Fields for export have to be registered and these sites are under official control.
Chemical control	Use of spinosad and emamectin benzoate is recommended by DOA when *T. palmi* population is above a threshold level of 5 thrips/shoot. According to table E1 of the dossier, these insecticides are recommended to be used during the vegetative stages of production.
Weed control	Removal of weeds before cultivation (Dossier Section 1, table E2).
Cultural control (fruit bagging)	Fruits are covered when 3–5 cm long with brown paper bags. Bags are closed on both sides.
Monitoring and inspection	DOA inspectors conduct on farm monitoring at least once a year and in case of suspicion, without prior notice, inspectors assess the control plan. Growers regularly observe pest in their farms once a week. If *T. palmi* are detected on sticky trap, growers will survey *T. palmi* in farm by random sampling. A hundred *M. charantia* shoots will be sampled and the number of thrips will be counted. If the average number of thrips is $\geq$ 5 thrips/shoot, an insecticide must be applied in accordance with DOA recommendation. During harvest the pest damaged fruits will be rejected at the farm.

6.3. Risk mitigation measures applied in the packing house

With the information provided by the DOA of Thailand (Dossier sections 1, 2), the Panel summarised the risk mitigation measures that are currently applied in the packing house.

Table 5: Overview of currently applied risk mitigation measures applied in the packing house on *Momordica charantia* fruits designated for export to the EU from Thailand

Risk mitigation measure	Description of applied measure
Inspection upon arrival to the packing house	When *M. charantia* fruits are delivered to packing houses, quality control officer will take samples to inspect the quality and pest infestation on fruits. If quality of *M. charantia* fruits is lower than standard or any pest infestation notice over standard, fruits will be refused to process in the packing house. (Dossier Section 2)
Sorting/Grading	Fruits are sorted out and graded (Dossier Section 1, Table E2).
Brushing and air blowing	Individual fruits are brushed and blown manually. (Dossier Sections 1, 2)
Manual Washing	Fruits are washed with water in backets with Peroxyacetic acid at 40–80 ppm for 1 minute (Dossier Section 1). Sodium hypochlorite may also be used.
Inspection in packing house	Samples of fruits are inspected by official quarantine inspectors at the packing site in a two-step procedure. First there is an inspection upon receiving the fruits in the packing house and one before packaging after the cleaning processing of the fruits. In both inspections a magnifier (10x) is used.

6.4. Overview of the evaluation of *Thrips palmi*

Rating of the likelihood of pest freedom	**Extremely frequently pest free** (based on the median)				
Percentile of the distribution	5%	25%	Median	75%	95%
Proportion of pest free fruits*	**9,496** out of 10,000 fruits	**9,787** out of 10,000 fruits	**9,902** out of 10,000 fruits	**9,963** out of 10,000 fruits	**9,994** out of 10,000 fruits
Proportion of infested fruits*	**6** out of 10,000 fruits	**37** out of 10,000 fruits	**98** out of 10,000 fruits	**213** out of 10,000 fruits	**504** out of 10,000 fruits
Summary of the information used for the evaluation	**Possibility that the pest could become associate with the commodity** Environmental conditions in Thailand are optimal for *T. palmi* development. *T. palmi* is widespread in Thailand and a commonly found pest on *M. charantia*. *T. palmi* is extremely polyphagous and many host plants are cultivated in Thailand such as eggplant and orchids. Adult thrips can fly and infest young *M. charantia* plants. Monitoring of *M. charantia* plants for thrips have shown to range from 1 to two individuals/shoot. **Measures taken against the pest and their efficacy** The main control measures applied in the field until harvest are soil tillage, weed control, mass trapping, chemical control, fruit bagging-, and inspection during harvesting. According to a study performed in Thailand with several insecticides against *T. palmi*, the highest efficacy observed was approximately 78% for spinosad and 81% for emamectin benzoate (Dossier section 2). Measures in the packing house include inspection before processing, brushing and air blowing, washing and pest inspections before packing. Measures in the packing house target mainly adults and larvae and have minimal effect on eggs. **Interception records** There are 29 interceptions reported in Europhyt/Traces-NT (1995–2020) of *T. palmi* on *M. charantia* fruits originating from Thailand with 3 of them in the last 10 years. **Shortcomings of current measures/procedures** Application of insecticides is limited to two active ingredients. Continuous use of these insecticides is likely to cause development of resistant populations of *T. palmi.* Most measures applied in the packing house are not likely to have an effect on eggs that may be present on fruits. **Main uncertainties** There are limited data on population dynamics of *T. palmi* on *M. charantia*. Since identification of thrips at species level is difficult in the field, it is possible that field observations of thrips refer to other species than *T. palmi* (e.g. mixtures of other thrips and *T. palmi*) Specific efficacy data for field applied measures are either limited or not available. Data on efficacy of the methods applied in the packing house in removing *T. palmi* from fruits are not available. The level of insecticide resistance against the insecticides applied in Thailand is uncertain				

*: Numbers rounded off to the nearest whole number.

6.5. Outcome of Expert Knowledge Elicitation

Table 6 and Figure 4 show the outcome of the EKE regarding pest freedom after the evaluation of the currently proposed risk mitigation measures for *T. palmi*.

Figure 4 provides an explanation of the descending distribution function describing the likelihood of pest freedom after the evaluation of the currently proposed risk mitigation measures for *M. charantia* fruits designated for export to the EU for *T. palmi.*

Table 6: Assessment of the likelihood of pest freedom following evaluation of current risk mitigation measures against *Thrips palmi* on *Momordica charantia* fruits from Thailand designated for export to the EU. In panel A, the median value for the assessed level of pest freedom for each pest is indicated by 'M', the 5% percentile is indicated by L and the 95% percentile is indicated by U. The percentiles together span the 90% uncertainty range regarding pest freedom. The pest freedom categories are defined in panel B of the table

Pest species	Sometimes pest free	More often than not pest free	Frequently pest free	Very frequently pest free	Extremely frequently pest free	Pest free with some exceptional cases	Pest free with few exceptional cases	Almost always pest free
Thrips palmi			***L***		***M***		***U***	

PANEL A

	Pest freedom category	Pest free fruits out of 10,000
	Sometimes pest free	≤ 5,000
	More often than not pest free	5,000–≤ 9,000
	Frequently pest free	9,000–≤ 9,500
	Very frequently pest free	9,500–≤ 9,900
	Extremely frequently pest free	9,900–≤ 9,950
	Pest free with some exceptional cases	9,950–≤ 9,990
	Pest free with few exceptional cases	9,990–≤ 9,995
	Almost always pest free	9,995–≤ 10,000

Legend of pest freedom categories	
L	Pest freedom category includes the elicited lower bound of the 90% uncertainty range
M	Pest freedom category includes the elicited median
U	Pest freedom category includes the elicited upper bound of the 90% uncertainty range

PANEL B

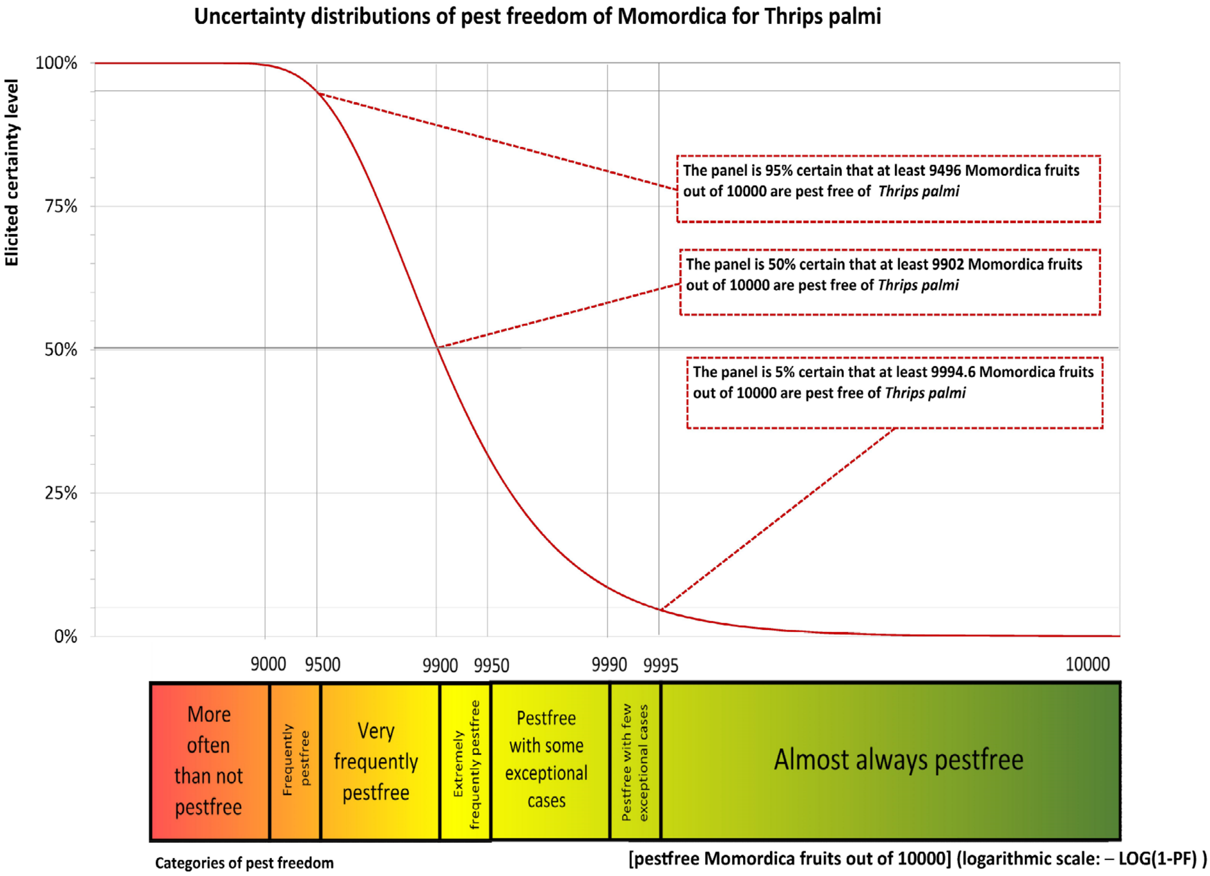

Figure 4: Explanation of the descending distribution function describing the likelihood of pest freedom from *Thrips palmi* after the evaluation of the currently proposed risk mitigation measures for fruits of *Momordica charantia* from Thailand designated for export to the EU

7. Conclusions

For *T palmi* on *M. charantia* fruits from Thailand the likelihood of pest freedom following evaluation of current risk mitigation measures was estimated as '*Extremely frequently pest free'* with the 90% uncertainty range reaching from '*frequently pest free*' to '*pest free with few exceptional cases'*. The EKE indicated, with 95% certainty, that between 9496 and 10,000 fruits per 10,000 will be free from *T. palmi*.

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Glossary

Control (of a pest)	Suppression, containment or eradication of a pest population (ISPM5, 1995, 2017)
Entry (of a pest)	Movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled (FAO, 2017)
Establishment (of a pest)	Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO, 2017)
Impact (of a pest)	The impact of the pest on the crop output and quality and on the environment in the occupied spatial units
Introduction (of a pest)	The entry of a pest resulting in its establishment (FAO, 2017)
Measures	Control (of a pest) is defined in ISPM 5 (FAO 2017) as "Suppression, containment or eradication of a pest population" (FAO, 1995). Control measures are measures that have a direct effect on pest abundance. Supporting measures are organisational measures or procedures supporting the choice of appropriate risk mitigation measures that do not directly affect pest abundance.
Pathway	Any means that allows the entry or spread of a pest (FAO, 2017)
Pest pressure	Local population density of a pest (often used in economic threshold levels in IPM)
Phytosanitary measures	Any legislation, regulation or official procedure having the purpose to prevent the introduction or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests (FAO, 2017)

Protected zone	A Protected zone is an area recognised at EU level to be free from a harmful organism, which is established in one or more other parts of the Union.
Quarantine pest	A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (FAO, 2017)
Regulated non-quarantine pest	A non-quarantine pest whose presence in plants for planting affects the intended use of those plants with an economically unacceptable impact and which is therefore regulated within the territory of the importing contracting party (FAO, 2017)
Risk mitigation measure	A measure acting on pest introduction and/or pest spread and/or the magnitude of the biological impact of the pest should the pest be present. A risk mitigation measure may become a phytosanitary measure, action or procedure according to the decision of the risk manager
Spread (of a pest)	Expansion of the geographical distribution of a pest within an area (FAO, 2017)

Abbreviations

CABI	Centre for Agriculture and Bioscience International
EIL	economic injury level
EKE	Expert Knowledge Elicitation
ET	economic threshold
EPPO	European and Mediterranean Plant Protection Organization
FAO	Food and Agriculture Organization
ISPM	International Standards for Phytosanitary Measures
MeSA	methyl salicylate
PLH	Plant Health
PRA	Pest Risk Assessment

Appendix A – Data sheets of pests selected for further evaluation via Expert Knowledge Elicitation

A.1. *Thrips palmi*

A.1.1. Organism information

Taxonomic information	Current valid scientific name: *Thrips palmi* Karny * Synonyms: *Thrips clarus* Moulton, 1928; *Thrips leucadophilus* Priesner, 1936; *hrips gossypicola* Ramakrishna & Margabandhu,1939; *Chloethrips aureus* Ananthakrishnan & Jagadish, 1967 *Thrips gracilis* Ananthakrishnan & Jagadish, 1968. Name used in the EU legislation: *Thrips palmi* Karny [THRIPL] Order: Thysanoptera Family: Thripidae Common name: oriental thrips, palm thrips, southern yellow thrips Name used in the Dossier: *Thrips palmi* * see Symptoms: confusion with other pests
Group	Insects
EPPO code	THRIPL
Regulated status	*Thrips palmi* is regulated in the European Union, and it is listed in the Union Quarantine pests: Annex II Part A - Pests not known to occur in the European Union. Commission Implementing Regulation (EU) 2019/2072. A1 list: East Africa (2001), Egypt (2018), Southern Africa (2001), Argentina (2019), Chile (2019), Paraguay (1993), Uruguay (1993), Bahrain (2003), Jordan (2013), Kazakhstan (2017), Azerbaijan (2007), Georgia (2018), Moldova (2006), Russia (2014), Turkey (2016), Ukraine (2019), EAEU (2016), EPPO (1988) A2 list: CAHFSA (1990), COSAVE (2018) Quarantine: Morocco (2018), Tunisia (2012), Mexico (2018), Israel (2009), Norway (2012), New Zealand (2000)
Pest status in Thailand	Present (EPPO, Online; CABI CPC, Online).
Pest status in the EU	Absent (EPPO, Online; CABI CPC, Online)
Host status on *Momordica charantia L.*	According to the Pest categorisation of *Thrips palmi* (EFSA, 2019), *Momordica charantia* is one of the main host plants of *Thrips palmi.*
PRA information	Pest Risk Assessments currently available: • Final group pest risk analysis for thrips and orthotospoviruses on fresh fruit, vegetable, cut-flower and foliage imports (Australian Government Department of Agriculture and Water Resources, 2017) • Pest categorisation of *Thrips palmi* (EFSA Scientific Opinion, 2019)
Interceptions (Europhyt/ Traces -NT)	There are 29 interceptions of *T. palmi* on *M. charantia* fruits originating from Thailand with 3 of them in the last 10 years.
Surveillance information	No specific information for surveillance was made available.

Country specific information

A.1.1.1. Pest pressure in the production area

Temperature ranges between 20 and 30°C which is an optimal range for multiplication of *T. palmi*.

Detailed data are not available about pest pressure of *T. palmi* in areas of Momordica production. According to a table provided by the applicant, as many as 1.4 thrips per shoot per week have been detected in a Momordica field. There is an economic threshold for insecticide application of > 5 thrips/shoot per week. Mass trapping with sticky blue traps seems to be a common practice for reducing population levels of thrips which is also an indication of high pest pressure. Farmers are advised to monitor their fields for presence of thrips in order to apply control measures but no data of this monitoring were made available. Moreover, identification of thrip species on the traps is not feasible and monitoring by farmers is about "thrips" in general.

According to the dossier, *T. palmi* is present throughout the year in Thailand in places of *M. charantia* production. Within the production cycle of *M. charantia* that lasts about 12 weeks, thrips are colonising plants soon after transplanting. In Kajita et al. (1996), it has been reported that almost all fields surveyed were found infested by *T. palmi*.

T. palmi is a highly polyphagous species and several major host plants such as eggplants are cultivated in Thailand. In a monitoring experiment without trapping ca. 1.4 thrips per shoot were reported. In another season as many as 30 thrips/shoot were recorded if pesticides are not applied.

Uncertainties:

- There are limited data on population dynamics of *T. palmi* on *M. charantia*
- Since identification of thrips at species level is difficult in the field, it is possible that field observations of thrips refer to other species than *T. palmi* (e.g. mixtures of other species of thrips and *T. palmi*)

A.1.1.2. Evaluation of measures applied in the field

The main control measures applied in the field until harvest are: (a) Soil tillage, (b) Weed control, (c) Mass trapping, (d) Application of insecticides, (e) Fruit bagging and (f) Inspection during harvesting.

There are no data available of the above methods on their efficacy against *T. palmi* and especially in field conditions in Thailand. Nevertheless, each of the above methods is expected to have an influence on population level of *T. palmi* in the field.

Since *T. palmi* is present throughout the year in Thailand and pupation takes place in the soil, soil tillage prior to a new crop establishment will mediate some mortality to pupae in the soil. Farmers are also taking measures to remove weeds from the field and therefore reduce the available host plant for *T. palmi* that could act as refugia for individuals that could migrate to the crop. Mass trapping with blue sticky traps is a common practice in *M. charantia* fields in Thailand. Farmers are advised to install traps at flowering stage every 2 or 5 meters depending on the type of cultivation. Guidelines by the DOA suggest monitoring traps at least once a week and when thrips are observed farmers are advised to perform an intensive sampling to define the level of infestation. An economic threshold of 5 thrips/shoot is used for application of insecticides. Data on the efficacy of mass trapping, however, are not available.

The DOA recommends application of two active ingredients of insecticides against *T. palmi* on *M. charantia* fields, emamectin benzoate and spinosad. According to a study performed in Thailand with several insecticides against *T. palmi*, the highest efficacy observed was approximately 78% for spinosad and 81% for emamectin benzoate.

Fruit bagging is performed using paper bags 2–3 days after fruit setting. Bags are closed on both ends. Bags will act as barriers to prevent new infestations on *M. charantia* fruits, however, efficacy data against *T. palmi* are not available.

During harvesting, inspections are taking place by farmers and infested fruits are rejected at the farm level (Tables A.1 and A.2).

Uncertainties:

- Specific efficacy data are either not available or are limited
- Frequency of application of insecticides depends on farmers own decision
- Inspection by authorities at farm level occurs usually for administration issues

Table A.1: Overview, evaluation and uncertainties of measures applied in the field against *Thrips palmi* on *Momordica charantia* fruits from Thailand designated for export to the EU

Risk mitigation measure	Description of applied measure	Evaluation and uncertainties
Trapping of adults	Blue sticky traps are used for monitoring and mass trapping. Depending on the cultivation method, traps are placed at every 2 or 5 meters in a row (Dossier Section 2).	Uncertainties: Details on size of sticky traps are not provided. Data on detection thresholds are not provided. Data on efficacy of mass trapping are not provided
Registration of exporting fields	Fields for export have to be registered and these sites are under official control.	There is an official control on compliance with GAP recommendations by DOA inspectors. Inspections take place at least once a year.

Risk mitigation measure	Description of applied measure	Evaluation and uncertainties
Chemical control	Use of spinosad and emamectin benzoate is recommended by DOA when *T. palmi* population is above a threshold level of 5 thrips/shoot. According to the dossier, these insecticides are recommended to be used during the vegetative stages of production.	Based on data provided by the applicant, the highest efficacy observed was approximately 78% for spinosad and 48% for emamectin benzoate. During the fruiting period, no product is applied. Uncertainties: Number of thrips recorded after insecticide application, may also include other species of thrips
Weed control	Removal of weeds before cultivation (Dossier Section 1).	Reducing the availability of alternative host plants for *T. palmi* populations Uncertainties: Species that are removed are not specified Methodology and frequency not detailed This measure has low control efficacy
Cultural control (fruit bagging)	Fruits are covered when 3–5 cm long with brown paper bags. Bags are closed on both sides.	Fruit bagging can be effective against *T. palmi* as they put the bags when fruits are quite small soon after their formation. Nonetheless, bagging cannot prevent the development of eggs already present in flower buds or early-stage fruits. Bagging is probably targeted against other pests (e.g. Bactrocera) Uncertainties: Considering the small size of *T. palmi* (larvae), there is still the possibility of infestation. The bag should be very tight to prevent this. Efficacy data are not available
Monitoring and inspection	DOA inspectors conduct on farm monitoring at least once a year and in case of suspicion, without prior notice, inspectors assess the control plan. Growers regularly observe pest in their farms once a week. If *T. palmi* are detected on sticky trap, growers will survey *T. palmi* in farm by random sampling. A hundred *M. charantia* shoots will be sampled and the number of thrips will be counted. If the average number of thrips is ≥ 5 thrips/shoot, an insecticide must be applied in accordance with DOA recommendation. During harvest pest damaged fruits will be rejected at the farm.	Inspection is thorough as this occurs weekly by farmers. NPPO inspectors will visit farm once a year mainly for compliance checking. Uncertainties Examination of bagged fruits at farm level and detection of *T. palmi* is very difficult, especially for young larvae and eggs. Identification of thrips at species level in the field is difficult

Table A.2: Overview of insecticides and other phytosanitary products used for the control of *Thrips palmi* in *Momordica charantia* fields in Thailand based on the information provided in sections of the Dossier 1, 2

Product	Control effect	Efficacy as reported	Efficacy evaluation by the Panel
Spinosad 12% SC	Contact	High (66–90%)	*Medium-High on thrips, based on table 3 of the reply 60–79%
Emamectin benzoate	Contact, translaminar insecticide	High (66–90%)	*Medium-High effect, based on table 3 of the reply 60–81%

*: Data provided on efficacy were derived from experimental testing in Thailand (Dossier section 3).

A.1.1.3. Evaluation of measures applied in the packing house

The main control measures applied in the packing house are: (a) inspection before processing, (b) brushing and air blowing (c), washing, (d) fruit inspections before packing, and (e) individually wrapped with plastic film sheet and foam.

When *M. charantia* fruits are delivered to packing houses, quality control officer will take samples to inspect the quality and pest infestation on fruits. If the quality of *M. charantia* fruits is lower than standard or any pest infestation is noticed, the fruits will be refused to process in the packing house. However, data on frequency of rejections at packing houses were not made available. Fruits are brushed and air blown individually before washing with sanitising products such as peroxyacetic acid. However, these practices are not intended to remove pests such as thrips but mainly for disinfecting fruits. Finally, samples of fruits will be inspected by packing house personnel for signs of insect infestation (Table A.3).

Uncertainties:

- Data on efficacy of the above methods in removing *T. palmi* from fruits were not made available.

Table A.3: Overview of post-harvest measures used in *M. charantia* packing houses in Thailand based on the information provided in sections of the dossier

Risk mitigation measure	Description of applied measure	Evaluation and uncertainties
Inspection upon arrival to the packing house	When *M. charantia* fruits are delivered to packing houses, Quality control officer will take samples to inspect the quality and pest infestation on fruits. If quality of *M. charantia* fruits is lower than standard or any pest infestation notice over standard, fruits will be refused to process in the packing house. (Dossier Section 2)	This method is intended mainly as first filter to discard fruits infested by pests or do not fulfil quality (visual) requirements. As such, is not aimed to detect *T. palmi*. This method will only detect heavily infested fruits showing clear symptoms of infestation.
Sorting/Grading	Fruits are sorted out and graded (Dossier Section 1).	This method is intended mainly as first filter to discard fruits infested by pests or do not fulfil quality (visual) requirements. As such, is not aimed to detect *T. palmi*. This method will only detect heavily infested fruits showing clear symptoms of infestation.
Brushing and air blowing	Individual fruits are brushed and blown manually. (Dossier Sections 1, 2)	The brushing has no effect on eggs, especially when using soft brushing, as eggs are laid inside the fruit tissue. Brushing has low to intermediate effect on larvae and adults. Brushed adults may not be killed and therefore re-infest other fruits in the packing station. Uncertainties: Efficacy data are not provided
Manual Washing	Fruits are washed with water in backets with Peroxyacetic acid at 40-80 ppm for 1 minute (Dossier Section 1). Sodium hypochlorite may also be used.	The antimicrobial agents are mainly used to disinfect material and to prevent microbial infections. Manual washing has no effect on *T. palmi* eggs and there is a limited effect on larvae and adults. If water is not refreshed frequently, there is a risk of re-infesting clean material. Uncertainties Data on the efficacy of this method are not provided

Risk mitigation measure	Description of applied measure	Evaluation and uncertainties
Inspection in packing house	Samples of fruits are inspected by official quarantine inspectors at the packing site in a two-step procedure. First there is an inspection upon receiving the fruits in the packing house and one before packaging after the cleaning processing of the fruits. In both inspections a magnifier (10×) is used.	Inspections on fruit samples may detect adults or larvae or feeding damage by thrips. Uncertainties Eggs are present inside fruit tissues and may be difficult to detect during inspections. The size of the samples inspected is not specified.

A.1.2. Information from interceptions

There are 29 interceptions reported in Europhyt/Traces-Nt (1995–2020) of *T. palmi* on *M. charantia* fruits originating from Thailand with 3 of them in the last 10 years.

A.1.3. Overall likelihood of pest freedom

Rating of the likelihood of pest freedom	**Extremely frequently pest free** (based on the median)				
Percentile of the distribution	5%	25%	Median	75%	95%
Proportion of pest free fruits*	**9,496** out of 10,000 fruits	**9,787** out of 10,000 fruits	**9,902** out of 10,000 fruits	**9,963** out of 10,000 fruits	**9,994** out of 10,000 fruits
Proportion of infested fruits*	**6** out of 10,000 fruits	**37** out of 10,000 fruits	**98** out of 10,000 fruits	**213** out of 10,000 fruits	**504** out of 10,000 fruits
Summary of the information used for the evaluation	**Possibility that the pest could become associate with the commodity** Environmental conditions in Thailand are optimal for *T. palmi* development. *T. palmi* is widespread in Thailand and a commonly found pest on *M. charantia*. *T. palmi* is extremely polyphagous and many host plants are cultivated in Thailand such as eggplant and orchids. Adult thrips can fly and infest young *M. charantia* plants. Monitoring of *M. charantia* plants for thrips have shown to range from 1 to two individuals/shoot. **Measures taken against the pest and their efficacy** The main control measures applied in the field until harvest are soil tillage, weed control, mass trapping, chemical control, fruit bagging, and inspection during harvesting. According to a study performed in Thailand with several insecticides against *T. palmi*, the highest efficacy observed was approximately 78% for Spinosad and 81% for Emamectin benzoate (Dossier Section 2). Measures in the packing house include inspection before processing, brushing and air blowing, washing and pest inspections before packing. Measures in the packing house target mainly adults and larvae and have minimal effect on eggs. **Interception records** There are 29 interceptions reported in Europhyt/Traces -NT (1995–2020) of *T. palmi* on *M. charantia* fruits originating from Thailand with 3 of them in the last ten years. **Shortcomings of current measures/procedures** Application of insecticides is limited to two active ingredients. Continuous use of these insecticides is likely to cause development of resistant populations of *T. palmi.* Most measures applied in the packing house are not likely to have an effect on eggs that may be present on fruits.				

	Main uncertainties There are limited data on population dynamics of *T. palmi* on *M. charantia*. Since identification of thrips at species level is difficult in the field, it is possible that field observations of thrips refer to other species than *T. palmi* (e.g., mixtures other thrips and *T. palmi*) Specific efficacy data for field applied measures are either limited or not available. Data on efficacy of the methods applied in the packing house in removing *T. palmi* from fruits are not available. The level of insecticide resistance against the insecticides applied in Thailand is uncertain

*: Numbers rounded off to the nearest whole number.

A.1.3.1. Reasoning for a scenario which would lead to a reasonably low number of infested consignments

Pest pressure

- The surrounding environment provides very few hosts for *T. palmi* (i.e., population sources)
- There is general pest management in place for thrips in agricultural areas where *M. charantia* is cultivated
- Natural biological control agents are very active and preserved and keep *T. palmi* controlled
- Thrips monitored are not always *T. palmi*. There are other species of thrips
- Most of the time and locations *T. palmi* is under economic-damaging levels

Field measures

- Regular and frequent inspection/monitoring targeted to *T. palmi*
- There is an appropriate timing and use of active ingredients to control *T. palmi*

Measures in the packing house

- Low number of *T. palmi* flying inside the packing house
- Inspections at packing house and initial sorting of fruits are conducted properly and are effective in detecting and discarding infested fruits
- Cleaning measures (with water and other products) are effective against *T. palmi* and render pest-free fruits
- Water and other products are properly replaced in the washing area
- Additives and other products used have an effect on the mortality of *T. palmi*
- Large proportion of infestation is in adult stage and/or juveniles (mobile stages)

A.1.3.2. Reasoning for a scenario which would lead to a reasonably high number of infested consignments

Pest pressure

- The surrounding environment provides many hosts for *T. palmi*
- There are uncontrolled sites where the pest occurs (e.g., eggplant plantation without efficient control)
- Environment contains natural biological control agents that are not active and preserved to control *T. palmi* due to poor management in other crops
- Most monitored thrips are *T. palmi*
- *T. palmi* is above intervention thresholds and therefore action is needed (e.g. insecticides are used to manage populations)

Measures in the field

- Irregular inspection/monitoring and occasional inspections
- There is an inadequate timing and use of active ingredients that are not efficient against *T. palmi*

Measures in the packing house

- High number of *T. palmi* flying inside the packing house

- Inspections at packing house and initial sorting of fruits are not conducted properly and are not effective in detecting and discarding infested fruits
- Cleaning measures (with water and other products, manually or using machines) are not effective against *T. palmi* and do not render pest-free fruits
- Poor replacement of water and other products in the washing area
- Additives and other products used do not have an effect on the mortality of *T. palmi*
- Large proportion of infestation are eggs

A.1.3.3. Reasoning for a central scenario equally likely to over- or underestimate the number of infested consignments (median)

- The surrounding environment provides sufficient hosts for *T. palmi*
- Most monitored thrips are likely to be *T. palmi*
- Insecticides are applied on time following monitoring data
- Procedures in the packing house are effective in removing larvae and adult stages of *T. palmi* and detecting infested fruits

A.1.3.4. Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile/interquartile range)

- Identification of thrips at species level is difficult in the field and observations of thrips may refer to other species than *T. palmi* (e.g., mixtures other thrips and *T. palmi*) and leading to either over- or underestimations of *T. palmi* pressure in the field.
- Specific efficacy data for field applied measures are either limited or not available.
- Data on efficacy of the methods applied in the packing house in removing *T. palmi* from fruits are not available.
- It is uncertain to what extent infestation reported in the field on vegetative plant parts (e.g., leaves) is related to infestation numbers on the fruits
- The level of insecticide resistance against the insecticides applied in Thailand is uncertain
- The clarification is given by the level of uncertainty which is higher for the values below the median

A.1.3.5. Elicitation outcomes of the assessment of the pest freedom for *Thrips palmi*

The following Tables show the elicited values for pest freedom in *M. charantia* fruits according to a three-step approach (i.e. estimating pest pressure, effectiveness of the measures applied in the field and in the packing house) (Table A.4) to come to a final estimation of likelihood of pest freedom (Table A.5) (Figures A.1 and A.2)

Table A.4: Elicited values to estimate the likelihood of pest-freedom (i.e. no. of pest free fruits out of 10,000, elicited as 10,000 minus no. of infested fruits) and the fitted distributions in a three-step model (i.e. Import risk $r_{import} = p_{pressure} \times p_{field}/10{,}000 \times p_{packing}/10{,}000$; Pest freedom $PF_{import} = 10{,}000\ r_{import}$)

Percentile	Parameter	1%	25%	50%	75%	99%	Fitted distribution
Elicited values for pest pressure	$p_{pressure}$	5,000	6,000	7,000	8,300	9,700	Beta General (1.1912, 0.97802, 200, 5040)
Elicited values for measures in the field	p_{field}	3,300	5,500	7,500	8,500	9,500	BetaGeneral (0.80872, 1.2947, 480, 6950)
Elicited values for measures in the packinghouse	$P_{packing}$	6,000	7,200	8,300	9,100	9,900	BetaGeneral (0.95631, 1.2207, 75, 4100)
Resulting model values for the import risk after Monte Carlo simulation	r_{import}	2.4	34	90	213	816	Calculated with @Risk version 7.6
As pest free fruits		9,184	9,787	9,910	9,966	9,997.6	

Table A.5: The uncertainty distribution of fruits free of *Thrips palmi* per 10,000 fruits calculated by taking into account a three-step procedure and according to elicited values in Table A.4

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Values	9,184	9,331	9,463	9,604	9,708	9,787	9,840	9,910	9,951	9,966	9,978	9,987	9,992.7	9,995.7	9,997.6
EKE results	9,186	9,364	9,496	9,624	9,717	9,787	9,836	9,902	9,946	9,963	9,978	9,988	9,994.6	9,997.6	9,999.1

The EKE results are the fitted values.

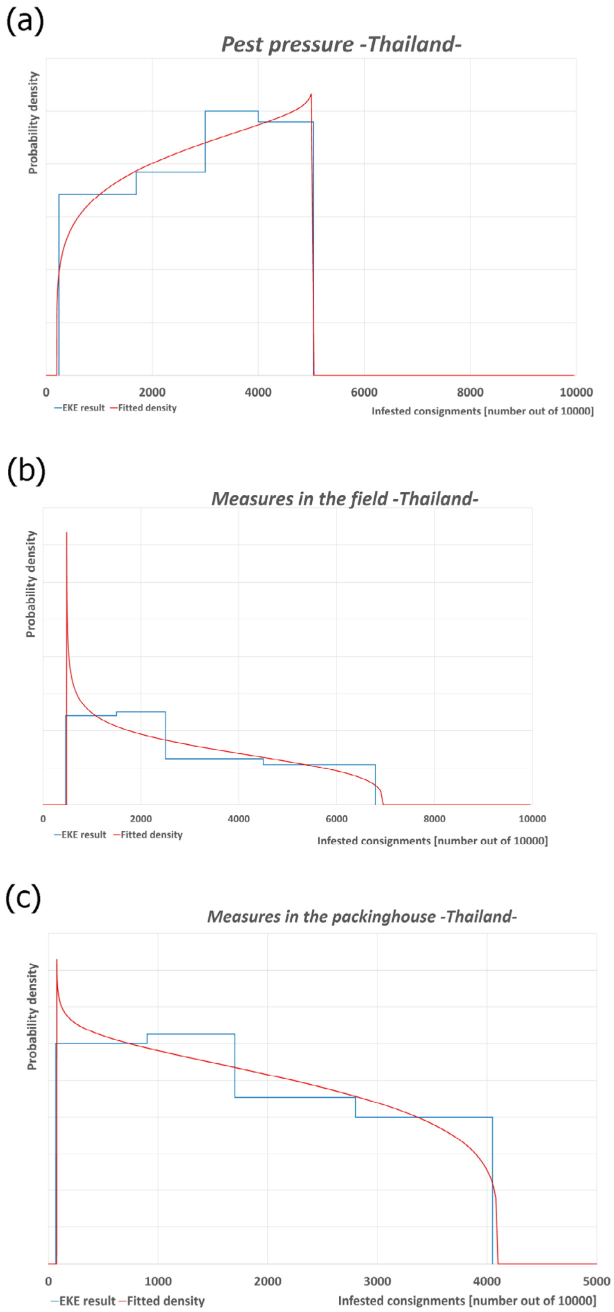

Figure A.1: Probability densities for the number of pest-free *Momordica charantia* fruits (x-axis) out of 10,000 designated for export to the EU introduced according to (a) estimated pest pressure in the field; (b) measures applied in the field; and (c) measures applied in the packing house for *Thrips palmi*

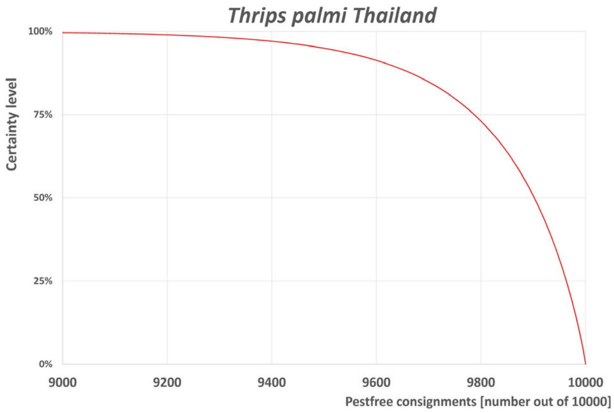

Figure A.2: Elicited certainty (y-axis) of the number of pest-free *Momordica charantia* fruits (x-axis; log-scaled) out of 10,000 plants designated for export to the EU introduced from Thailand for *Thrips palmi* visualised as descending distribution function. Horizontal lines indicate the percentiles (starting from the bottom 5%, 25%, 50%, 75%, 95%). The Panel is 95% sure that 9496 or more fruits per 10,000 will be free from *Thrips palmi*

A.1.4. Reference list

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Appendix B – Web of Science All Databases Search String

In the table below the search string used in Web of Science is reported.

Web of Science	TOPIC: (“Momordica” OR “*Momordica charantia*” OR “*M. charantia*” OR “Momordica anthelmintica Guin.” OR “Momordica elegans Salisb.” OR “Momordica muricata Willd.” OR “Momordica operculata Vell.” OR “Momordica senegalensis Lam.” OR “bitter gourd” OR “bitter melon” OR “Cucurbitaceae” OR “balsam apple” OR “balsam pear” OR “bitter balsam apple” OR “bitter cucumber” OR “bitter melon” OR “carilla gourd” OR “paria” OR “wild balsam-apple” OR “cucumber” OR “melon”) AND TOPIC: (“*Thrips palmi*” OR “melon thrips” OR “*Thrips palmi* Karny, 1925” OR “Chloethrips aureus Ananthrakrishnan & Jagadish, 1967” OR “Thrips clarus Moulton, 1928” OR “Thrips gossypicola (Priesner, 1939)” OR “Thrips gracilis Ananthrakrishnan & Jagadish, 1968” OR “Thrips leucadophilus Priesner, 1936” OR “Thrips nilgiriensis Ramakrishna 1928” OR “Oriental thrips” OR “southern yellow thrips”) AND TOPIC: (“pest pressure” OR “population build-up” OR “pesticide application$” OR “pesticide$” OR “risk reduction option$” OR “mitigation measure$” OR “efficac*” OR “resistance” OR “population dynamic$” OR “phytosanitary product$” OR “registered pesticide$” OR “high pressure water*” OR “air pressur*” OR “population dynamic$” OR “field densit*” OR “occurrence” OR “monitor*” OR “sticky trap$” OR “sticky trap$ efficac*”) AND TOPIC: (“Thailand”)