EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION
ORGANISATION EUROPEENNE ET MEDITERRANEENNE POUR LA PROTECTION DES PLANTES

12-17836

Pest Risk Analysis for

Keiferia lycopersicella

September 2012

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This risk assessment follows the EPPO Standard PM 5/3(5) *Decision-support scheme for quarantine pests* (available at http://archives.eppo.int/EPPOStandards/pra.htm) and uses the terminology defined in ISPM 5 *Glossary of Phytosanitary Terms* (available at https://www.ippc.int/index.php).

This document was first elaborated by an Expert Working Group and then reviewed by core members and by the Panel on Phytosanitary Measures and if relevant other EPPO bodies. It was finally approved by the Council in September 2012.

Cite this document as:
EPPO (2012) *Final pest risk analysis for* Keiferia lycopersicella. EPPO, Paris.

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12-17836 (12-17584, 11-17314)

Pest Risk Analysis for *Keiferia lycopersicella*

This PRA follows the EPPO Decision-support scheme for quarantine pests PM 5/3 (5). A preliminary draft has been prepared by the EPPO Secretariat. This document has been reviewed by an Expert Working Group that met in the EPPO Headquarters in Paris on 2011-09-19/22. This EWG was composed of:

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The PRA was further reviewed by the core members (Robert Steffek, Philippe Reynaud, Leif Sundheim, Dirk Jan Van der Gaag, Gritta Schrader, Alan MacLeod, Nursen Ustun, Lucio Montecchio, Françoise Petter) between 2011-12-05 and 2012-02-15.
The risk management part was reviewed by the Panel on Phytosanitary Measures on 2012-03.

Content *(you may click on the title to reach the selected section)*

Stage 1: Initiation

1.01 - Give the reason for performing the PRA
Identification of a single pest

1.02a - Name of the pest
Keiferia lycopersicella (Walsingham)

1.02b - Indicate the type of the pest
arthropod

1.02d - Indicate the taxonomic position
Domain: Eukaryota
Kingdom: Metazoa
Phylum: Arthropoda
Class: Insecta
Order: Lepidoptera
Family: Gelechiidae
Genus: Keiferia
Species: lycopersicella (Walsingham)

1.03 - Clearly define the PRA area
The PRA area is the EPPO region (see www.eppo.org for map and list of member countries).

1.04 - Does a relevant earlier PRA exist?

yes

A short PRA was prepared by the Ministry of Agriculture, Nature and Food Quality of the Netherlands in 2009, with the Netherlands as the PRA area (Potting, 2009).

Shutova (2004 - article in Russian, only abstract consulted) estimated that the pest presented a risk of establishment in tomato fields in Moldova, Central Asian countries belonging to the Commonwealth of Independent States (CIS), and the South of Ukraine and Russia, and in tomato glasshouses in Ukraine, Bielorussia, Baltic countries and the central region of Russia.

The PRA on *Tuta absoluta* (Meyrick) (tomato leafminer) (Potting *et al.*, 2010) was also used as both pests are Gelechiidae and have a similar biology and niche.

1.05 - Is the earlier PRA still entirely valid, or only partly valid (out of date, applied in different circumstances, for a similar but distinct pest, for another area with similar conditions)?

not entirely valid

The earlier PRA is a short PRA limited to the Netherlands. It needed to be extended to a full PRA for the whole EPPO region.

1.06 - Specify all host plant species. Indicate the ones which are present in the PRA area.
All known hosts belong to the family Solanaceae.

1. Cultivated hosts

Tomato (*Solanum esculentum Mill.*)	Tomato is the main host of *K. lycopersicella* according to most publications cited in this PRA. *L. esculentum* var. *cerasieforme* (cherry tomato) is also a host (e.g. Schuster, 1989). In laboratory trials, Batiste & Olson (1973) demonstrated that *K. lycopersicella* preferred tomato for oviposition over 12 other solanaceous plant species. Larvae feed on foliage and fruit.
Eggplant (*Solanum melongena* L.)	The pest is occasionally reported eggplant (e.g. Henry & Rudert, 1975; Poe, 1973). Thomas (1936, cited in Keifer, 1937) noted that damage on eggplant crops occurred when these were adjacent to infested tomato crops. Three recent publications refer to *K. lycopersicella* as a significant pest of eggplant: USDA (2010) lists it among major pests of eggplant in Florida; in Guyana, the Farmers Manual on eggplant (Ministry of Agriculture of Guyana, undated) reports it as a common pest of eggplant (feeding on leaves and sometimes attacking flowers and fruits), while the corresponding manual for tomato does not mention the pest; Sparks & Riley (2011) recommend plant protection products for control on eggplant in Georgia (USA).
Potato (*Solanum tuberosum* L.)	The pest is occasionally reported on potato (e.g. Saunders *et al.*, 1998; Henry & Rudert, 1975; Poe, 1973). From the publications available, potato seems less commonly attacked than eggplant. Elmore & Howland (1943) mention that damage on potato (larvae feeding on foliage) is not common but sometimes reported.
Solanum torvum Sw. (Susumber, gully bean)	This tropical weed, also cultivated for its fruits in tropical regions (and apparently used as rootstock for eggplant), is reported as being infested by *K. lycopersicella* in Jamaica (Henry & Rudert, 1975). This is the only mention of this plant as a host.

2. Wild hosts
No consolidated list of wild hosts of *K. lycopersicella* was found, but the following *Solanum* spp. are mentioned as hosts in the literature: *S. americanum var. nodiflorum* (Henry & Rudert, 1975, but see uncertainties under point 5 below), *S. bahamese* L. (Poe, 1973); *S. carolinense* L. (Poe, 1973, Thomas, 1936, cited in Keifer, 1937; Ferguson & Shipp, 2009), *S. puberolum* (Ramirez *et al.*, 1989), *S. viarum* Dunal (tropical soda apple, weed and invasive; Cuda *et al.*, 2002, reporting that it sustains populations of *K. lycopersicella*).

S. nigrum L. is taken into account in this PRA as it is widespread in the PRA area, but its host status is uncertain (Batiste & Olson, 1973; Swank, 1937).

Batiste & Olson (1973) state that *S. dulcamara* and *S. elaeagnifolium* (see experimental hosts below) may play a role in the population dynamics and distribution of *K. lycopersicella*.

In its area of current distribution, it is considered that tomato is the preferred host and *K. lycopersicella* will only be found on wild hosts mostly if tomato is not available and natural enemies' pressure is low. The related species *T. absoluta* has increased its host range when it has established in the EPPO region, it is considered that *K. lycopersicella* may do the same and therefore all solanaceous species may be at risk in the PRA area (except species recognized as non-hosts, see point 4 below).

3. Experimental hosts
Other hosts were identified only in experimental conditions: *S. sisymbrillfolium* Lam., *S. mexicanum* Willd., *S. citrullifolium* (larval feeding in test tube, Swank, 1937). *S. dulcamara, S. elaeagnifolium* (Batiste & Olson, 1973; glasshouse trials).

The following wild species of *Lycopersicon* (tested in the laboratory as possible sources of resistance; Schuster, 1977) were also all attacked by *K. lycopersicella* (level of resistance indicated between brackets): *L. pimpinellifolium* L. (susceptible), *L. peruvianum* L.(intermediate level of resistance), *L. cheesmani* f. *minor, L. glandulosum*, *L. hirsutum*, and *L. hirsutus* f. *glabratum* (significant level of foliar resistance).

4. Non-hosts
In the literature, some species have specifically been mentioned as non-hosts. These species are, therefore, not considered as possible pathways in this PRA (including major crops such as *Capsicum*, *Nicotianum tabacum* and *Petunia*). Nevertheless feeding behaviour of the pest may differ in different areas (see uncertainties, point 5a below).

Capsicum spp.	*Capsicum annuum* (glasshouse experiments, Schuster, 1989; larval feeding in test tubes, Swank, 1937). *Capsicum* sp. is not considered to be a host in several other publications (e.g. Geraud-Pouey *et al.*, 1997).
Solanum spp.	*S. nodiflorum*, *S. douglasi* (glasshouse experiments, Batiste & Olson, 1973), *S. americanum* (glasshouse experiments, Schuster, 1989), *S. aculeatissimum, S. glacile*, *S. capisicastrum* (larval feeding in test tube, Swank, 1937). On *S. munistrum,* slight feeding only (slightly longer life but no pupae formed, Swank, 1937).
Nicotiana spp.	*N. bigelovii* Torrey.(now *N. quadrivalvis*)*, N. clevelandii* Gray.*, N. glauca* Graham (glasshouse experiments, Batiste & Olson, 1973), *N. tabacum* L.(larval feeding in test tube, Swank, 1937).
Datura spp.	*D. meteloides*, *D. stramonium* L., *D. ferox* L.(now *D. quercifolia*) (glasshouse experiments, Batiste & Olson, 1973), *D. metel* Linn.; larval feeding in test tube, Swank, 1937). On *D. stramonium,* slight feeding only (slightly longer life, but no pupae formed, Swank, 1937).
Other Solanaceae	*Physaloides physaloides* (now *Nicandra physaloides*) *Physalis* sp., *Petunia hybrida* Hort.(larval feeding in test tube, Swank, 1937).
Other families	Several species in the families Compositae, Cruciferae, Gramineae, Liliaceae, Malvaceae, Phytulaccaceae (larval feeding in test tube, Swank, 1937).

5. Uncertainty on hosts
a- The record of *Solanum americanum* var*. nodiflorum* (Henry & Rudert, 1975) as a host seems to be a contradiction with the non-host status of *S. americanum* (Schuster, 1989) and *S. nodiflorum* (Batiste & Olson, 1973) as these 3 species names are apparently considered as synonyms.
b- *Gossypium* sp. and *Nicotiana tabacum* L. are mentioned as hosts only by CABI (2007), as well as *Oryza sativa* L. with an unknown host status. These plants are not mentioned in other publications. These have now been verified by CABI and deleted from the datasheet as erroneous.
c- *Solanum xanthii* and *S. umbelliferum*. These are listed as hosts by Poe (1973) but Elmore & Howland (1943) note that they are hosts of *Keiferia elmorei. K. lycopersicella* and K. *elmorei* are not synonyms (see answer to question 1.08) and these hosts are not mentioned in the host list of *K. lycopersicella* above.
d- Solanaceae in general. Geraud-Pouey *et al.* (1997, citing Povolný, 1973) mentions that *K. lycopersicella* attacks the majority of solanaceous plants cultivated in neotropics, except *Capsicum* spp.

6. Presence of host plants in the PRA area
All details are given in section 1.14. Tomato is present and widely cultivated in the PRA area ; this is also the case for eggplant and potato. Among wild host plants (see 2. above) and experimental host plants (see 3. above), *S. carolinense, S. dulcamara, S. elaeagnifolium* (EPPO A2 List) and *S. nigrum* (uncertain host) are present in the PRA area.

Solanum torvum Sw. is a tropical plant (Schippers, 2004) and is not considered further in this PRA because it is assumed not to occur in the PRA area.

1.07 - Specify the pest distribution for a pest initiated PRA, or the distribution of the pests identified in 2b for pathway initiated PRA
1- Known records of distribution

EPPO region: Absent (one outbreak in Italy but not established there, see note under point 3. below).

North America:

Canada:	Ontario : introduced in 1991 (Shipp *et al.*, 2001). Outbreaks were found in British Columbia in the 1970s but eradicated.	
Mexico		
USA:		
Alabama (Hamilton, 1998)	Hawaii (Keifer, 1937)	Ohio (Seal & McCord, 1996; OSU, 2010)*
Arkansas (McLeod *et al.*, 1996)	Maryland (Brust, 2008)	Pennsylvania (Keifer, 1937)*
Arizona (Elmore & Howland, 1943)	Mississippi (Keifer, 1937)	South Carolina (Hamilton, 1998)
California (Keifer, 1937)***	Missouri (Keifer, 1937)	Tennessee (USDA, 2002; Hamilton, 1998)*
Delaware (Keifer, 1937)	New Jersey (Kline & Walker, 2007)	Texas (Harding, 1971)**
Florida (Keifer, 1937)**	New Mexico (Elmore & Howland, 1943)	Virginia (Keifer, 1937)
Georgia (Hamilton, 1998, Sparks & Riley, 2008)	North Carolina (USDA, 2005)*	

*probably transient populations
**Overwintering outdoors;
***in California, the pest was not detected since approximately 2007 due to control (see Trumble pers.comm. 2011, see also question 6.01).

Central America: Costa Rica (Calvo Domingo *et al.* 1990), El Salvador (Oatman & Platner, 1989), Guatemala (Oatman & Platner, 1989), Honduras (Oatman & Platner, 1989), Nicaragua (Maes & Tellez Robleto, 1988), Panama (Guevara Chavez, 2000). It is generally considered that *K. lycopersicella* originates from Central America.

Caribbean: Bermuda (Keifer, 1937), Cuba (Elizondo *et al.*, 2005), Dominican Republic (Morales-Payan & Santos, 1998), Haiti (Keifer, 1937), Jamaica (Henry & Rudert, 1975), Trinidad and Tobago (Trinidad, Jones, 1985).

South America: Bolivia (Ward *et al.*, 1980), Colombia (Figueiroa Potes, 1951; Geraud-Pouey & Pérez, 1994), Ecuador (Rogg, 2000), Guyana (Pluke *et al.*, 1999), Peru (Keifer, 1937), Venezuela (Geraud-Pouey & Pérez, 1994).

2. Uncertainties regarding the distribution
Some uncertaintie are linked to the confusion with *K. elmorei* (see 1.08) : old records of *K. lycopersicella* from the time when it was considered as synonym of *K. elmorei* may relate to the latter.
1. USA. The records above leave some "blanks" on the US map. No records were found for some states that are surrounded or at the same latitude as others where the pest occurs, e.g. Louisiana, Oklahoma, Indiana, West Virginia, Kentucky (even if some tomato are produced in these states). For some of these states, extension publications mention the presence and control of "tomato pinworm", but this is not considered sufficient as a distribution record. These may correspond to summer populations.
2. Illinois, USA. Perlak & Fischhoff (1990) is used as the source of the record for Illinois in several publications. However, the full article was not available and the abstract relates to tests in Illinois and Florida on two pests including tomato pinworm, but does not specify that both pests were in both states.
3. Central and South America. No record was found for countries surrounded by or at the same latitude as others where the pest occurs, e.g. Belize, Brazil, Suriname, French Guyana.
4. Bahamas. The Bahamas are cited in several publications, presumably in relation to Elmore & Howland (1943) that mention interceptions of the pest on tomatoes from the Bahamas. However, no positive record of presence in the Bahamas was found and this record was not retained.
5. Caribbean. The pest seems quite widespread in the Caribbean (Schmutterer *et al.,* 1990), but records were found only from a few countries.

3. Additional notes on the distribution

EPPO region. In 2008, *K. lycopersicella* occurred in Italy (Liguria region) on three farms, on a total area of 0.5 ha of tomato crops (outdoors). *K. lycopersicella* represented 80-85% of larval populations found and the related species *T. absoluta* the rest. Some potato crops were adjacent to the infested tomato crops, but were apparently not infested. After identification of the pest in November 2008 the infested crops were destroyed and the soil was treated with a suitable insecticide. (Sannino, pers. comm. 2011). The pest disappeared and was not found again in the following years (Espinosa & Sannino, 2009; Sannino & Espinosa, 2009; Sannino & Espinosa, 2010). It is considered that the pest did not establish (EPPO, 2010).

The identification was made by the Consiglio per la Ricerca e la sperimentazione in agricoltura (Scafati, Italy) and the Department of Entomology and Zoology of the University of Naples 'Federico II' (Naples, Italy) comparing the genitalia of moths gathered from attacked plants with illustrations of genitalia reported in the several papers of Povolný and other authors. Both *Keiferia lycopersicella* and *Tuta absoluta* were found among the observed moths. A specialist confirmation of the determination was not deemed necessary, given the neat difference between genitalia of the two species (Sannino, pers. comm. 2011). This is not a standard procedure when a new species is found in a country and therefore this identification is sometimes not considered valid.

North America. In the USA, *K. lycopersicella* survives outdoors all year round mostly in warm areas such as parts of California, Florida, Texas, Arizona, Mexico. In other areas, it may survive in glasshouses and occasionally infest fields in summer. For example it is considered as sporadic outdoors in Georgia, Tennessee and North Carolina (USDA, 2002 & 2005; Kline & Walker, 2007).

In Canada, the pest was reported in 1946 in south-western Ontario (field and glasshouse), as well as in British Columbia (glasshouses) in 1970 and 1975, but it did not establish. In 1991, it occurred on glasshouse tomatoes in Ontario from a single tomato grower (1.2 ha), and by 1999 it had spread to 87 ha (total area infested). Larger infestations during summer are attributed to higher temperatures and increased migration of adults between glasshouses (Shipp *et al.*, 2001).

Cuba. Keifer (1937) is used in several publications as a record of presence of *K. lycopersicella* in Cuba, but the publication seems to refer to "Cuba" as a locality of Mexico. In any case this does not modify the distribution as there are other records for Cuba.

Stage 2: Pest Risk Assessment Section A: Pest categorization

Identity of the pest (or potential pest)

1.08 - Does the name you have given for the organism correspond to a single taxonomic entity which can be adequately distinguished from other entities of the same rank?

yes

The pest is a single taxonomic entity.

Synonyms. *Gnorimoschema lycopersicella*, *Phthorimaea lycopersicella*, *Eucatoptus lycopersicella,*
Common names. English: tomato pinworm; Spanish: numerous names in the literature, including enrollador de la hoja del tomate, gusano aguja, gusano alfiler, quemao, cogollero del tomate, minador del tomate, minador gigante, polilla de tomate.
Additional information. (From Lin & Trumble, 1983): The first findings of *K. lycopersicella* in the USA in 1923 were confused with *Phthorimaea glochinella,* the eggplant pinworm. In 1928 this pest was described as a new species, *Phthorimaea lycopersicella* (Busck, 1928). Busck consecutively synonymised Phthorimea with Gnorimoschema. *Phthorimea lycopersicella* became *Gnorimoschema lycopersicella.* Finally Busck created the new genus *Keiferia* in 1939 and attributed the pest to it. It was later found to be conspecific to *Eucatopus lycopersicella* (Walsingham, 1897). Povolný (1973) described *K. lycopersicella* as a superspecies containing several morphs.
Note. *K. elmorei* is a true species and *not* a synonym of *K. lycopersicella*. *K. elmorei* (Keifer, 1936) was originally considered as a distinct North American species and later synonymised with *K. lycopersicella* (CABI, 2007) (as well as *Gnorimoschema elmorei*, *Phtorimea elmorei*).The status of *K. elmorei* was revised back to species level in Powell & Povolný (2001). This view is being supported by one of the world specialists on Gelechiidae, Sangmi Lee (pers. comm., 2011 and Lee *et al*., 2010). It is noted that old records of *K. lycopersicella* from the time when it was considered as synonym of *K. elmorei* may relate to the latter.

1.10 - Is the organism in its area of current distribution a known pest (or vector of a pest) of plants or plant products?

yes (the organism is considered to be a pest)

K. lycopersicella is considered to be a major pest of tomato (including cherry tomatoes) in the field and glasshouses in areas where it occurs, such as in Central and South America (e.g. in Costa Rica - Calvo-Domingo *et al.*, 1990; in Venezuela - Geraud-Pouey & Pérez, 1994; in Panama - Guevara-Chavez, 2000), in the Caribbean (e.g. in Jamaica - Henry & Rudert, 1975; in Cuba - Elizondo *et al.*, 2005), in Mexico (e.g. Alvaro-Rodriguez, 1988; Alvaro-Rodriguez & Rivera-Rubio, 1990), in Canada (Ontario, in glasshouses) (Shipp & Ferguson, 2001), in the USA (Elmore & Howland, 1943; USDA 2002 & 2005).

On eggplant and potato, there are reports of occasional damage (Elmore & Howland, 1943; Saunders *et al.*, 1998). *K. lycopersicella* is also mentioned as a serious pest of eggplant in Florida (USDA, 2010), Guyana (Ministry of Agriculture of Guyana, undated) and Trinidad (Cock, 1985).

1.12 - Does the pest occur in the PRA area?

no

K. lycopersicella does not occur in the PRA area. An outbreak occurred in 2008 in Italy but the pest did not establish (see 1.07).

1.14 - Does at least one host-plant species (for pests directly affecting plants) occur in the PRA area (outdoors, in protected cultivation or both)?

yes

Tomato is widely cultivated throughout the PRA area in commercial cultivation (field, glasshouses, tunnels) and in gardens. Eggplant (protected and field crops) and potato are also widely cultivated, both commercially and in gardens. Eggplant has a more southern distribution outdoors than tomato and potato, although it is also grown in protected conditions in the northern and eastern parts of the PRA area. Annex 1 presents FAOSTAT data from 2005-2009 on area harvested and production of tomato, eggplant and potato in the PRA area.

Amongst the weed hosts, *S. carolinense*, *S. dulcamara* and *S. nigrum* (uncertain host) are present in the

PRA area (according to Flora europaea, 2011). *S. elaeagnifolium* is also present in some countries of the PRA area and is on the EPPO A2 List as an invasive alien plant in the EPPO region (EPPO, 2007).

1.15a - Is transmission by a vector the only means by which the pest can spread naturally?

no

K. lycopersicella is a free-living organism.

1.16 - Does the known area of current distribution of the pest include ecoclimatic conditions comparable with those of the PRA area or sufficiently similar for the pest to survive and thrive (consider also protected conditions)?

yes

The pest is currently known to occur in tropical and subtropical regions and in temperate zones (in summer).
- It is reported to survive and overwinter outdoors in the southern part of its range with mild winters (from South America to southern USA, see references under 1.07). The climate classification of Köppen-Geiger indicates a similarity of climate (especially with California) with a limited part of the EPPO region (see Annex 2).
- In other parts of its current distribution, i.e. the rest of its USA distribution and Canada (covering temperate zones with cold winters), *K. lycopersicella* can survive and cause damage under protected conditions, and can also be a sporadic pest in the field in summer (e.g. in Georgia, Tennessee and North Carolina; USDA, 2002, 2005; Kline & Walker, 2007). Similar ecoclimatic conditions are present in summer outdoors in part of the PRA area, and the conditions under protected conditions are appropriate for survival of the pest throughout the PRA area.

1.17 - With specific reference to the plant(s) or habitats which occur(s) in the PRA area, and the damage or loss caused by the pest in its area of current distribution, could the pest by itself, or acting as a vector, cause significant damage or loss to plants or other negative economic impacts (on the environment, on society, on export markets) through the effect on plant health in the PRA area?

yes

Economic damage is reported mostly on tomato. Damage on eggplant is reported only from Florida (USDA, 2010), Trinidad (Cock, 1985) and Guyana (Ministry of Agriculture of Guyana, undated). Damage to potato does not seem to be significant in the current area of distribution of *K. lycopersicella.* All these crops are widely grown in the PRA area. *K. lycopersicella* may have an impact mostly on tomato, possibly on eggplant, in the field and in protected conditions. Damage on these crops has the potential to be similar to that caused in its current distribution, i.e.

- direct damage and death of plants in commercial production and in gardens
- reduction of yield, including through primary damage by feeding on fruit and secondary damage due to development of rots on damaged fruit (mainly for tomato).
- indirect yield losses due to rejection of crops due to low tolerance of cosmetic damage (quality losses) for tomato and eggplant, and for the presence of larvae in fruit (for tomato; there is an uncertainty on whether such damage also occurs on eggplant fruit, but it is not reported from Florida – Schuster, University of Florida, pers.comm., 2011, USDA, 2010).
- environmental impact due to the likely increase of insecticide applications until integrated pest management strategies are reinstated for existing pest problems.
- potential loss or reduction in exports due to low tolerance for fruit damage in importing countries.

This pest could present a phytosanitary risk to the PRA area.

1.18 - Summarize the main elements leading to this conclusion.

- *K. lycopersicella* is a major pest of tomato, and to a certain extent of eggplant. Both are widely cultivated in the PRA area, as commercial crops and in gardens;
- *K. lycopersicella* is not yet present in the PRA area
- Other host plants, such as potato and some weeds, are also present in the PRA area
- Ecoclimatic conditions in parts of the current distribution of the pest seem to be present outdoors in the warmer tomato- and eggplant- growing regions of the PRA area, and conditions are similar throughout the PRA area under protected conditions.

Stage 2: Pest Risk Assessment Section B: Probability of entry of a pest

2.01a - Describe the relevant pathways and make a note of any obvious pathways that are impossible and record the reasons. Explain your judgement

Background on the life-cycle of the pest relevant for the pathways of entry is given below:
Eggs are laid on the foliage of host plants. There are four larval instars. The first two instars mine into the leaves. The last two instars feed on leaves (folding them or tying them together) and may bore in the fruits. At the end of their development, mature larvae lower themselves to the ground on a thread and pupae are formed at or near the surface of the soil. Pupation can also occur in leaf folds and fruits (Ferguson & Shipp, 2009) although Elmore & Howland (1943) consider that this is a rare case. Adult moths are nocturnal and hide in protected places during the day. Details on duration of life stages are given in 2.08 of the pathway "plants for planting of tomato and eggplant" and of life cycle in 3.17.

In the literature, common means of dissemination of the pest are identified as being: infested fruit; natural spread by moths flying within and between tomato fields; movement and planting of infested seedlings; picking and packing boxes carrying eggs, larvae or pupae from infested localities (e.g. Elmore & Howland, 1943). In addition, the Dutch short PRA (Potting, 2009) considered plants for planting of ornamental Solanaceae (no species indicated) as a possible entry pathway. Finally, pupae may be associated with soil or other growing media which, when moved as a commodity or with plants for planting (or as contaminant), could disseminate the pest.

<u>1. Pathways studied in detail in this PRA</u>

The three pathways below are studied in detail in the PRA. The origin considered for all pathways is "countries where *K. lycopersicella* occurs" although there is some uncertainty on the countries concerned (see section 1.07).

Fruits of tomato and eggplant from areas where *K. lycopersicella* occurs

All life stages may be associated with fruits of tomato and eggplant or with green parts attached.

Packaging (i.e. crates, boxes used for picking and packing tomato and eggplant fruits)

Packaging carrying tomato fruits are mentioned in the literature as a possible pathway for the pest. Such association has also been shown for the related pest *T. absoluta*. The situation is considered similar for packaging carrying eggplant fruits, although no evidence is given in the literature.

Plants for planting (except seeds) of tomato and eggplant from areas where *K. lycopersicella* occurs

The foliage of the plants may carry eggs, larvae and pupae of *K. lycopersicella.* The soil or growing medium associated with the plants may contain pupae. This pathway covers plants with or without associated soil and growing medium.

<u>2. Pathways less likely</u>

Soil (as such; or associated with seed and ware potatoes) from areas where *K. lycopersicella* occurs

Pupae might be associated with soil as they are formed in the shallow part of the soil (at or under the surface, at 0.6-3.8 cm; Poe, 1973). Soil associated with plants for planting of tomato and eggplant may contain pupae, and this is covered in the pathway for plants for planting. Even if potato is considered as a minor host, pupae might become associated with potatoes accompanied by soil at harvest. They may also be associated with soil traded as such. Soil associated with potato tubers and soil as such were studied in detail in a previous version of this PRA. Entry on this pathway was rated as very unlikely, mostly due to the very low trade of soil (associated with potatoes or as such) into the PRA area from countries where *K. lycopersicella* occurs, the stringent phytosanitary import requirements applying to such commodities in most countries of the PRA area and the low likelihood of transfer to a host plant.
Entry on other types of soil (association with other types of commodities or as contaminant) is considered even more unlikely. Pupae present in the soil after a host crop might survive for a certain duration in the following crop. However the soil would be prepared for the new crop (e.g. tillage) (or removed in the case of crops in protected conditions), and adults are unable to emerge from pupae that have been buried below from 5 cm (Poe, 1973). Soil preparation for planting new crops is also a measure used to destroy *K. lycopersicella* larvae.

Entry

Hitch-hiking of adults on containers, machinery and conveyances
This pathway was discussed by the EWG in comparison with the related pest *T. absoluta. T. absoluta* has shown to be attracted by light and by the smell of tomato, and adults can therefore become associated as hitch-hikers in containers, machinery or conveyances. In the case of *K. lycopersicella,* adults are are mainly attracted by the smell of tomato (Trumble, pers. comm., 2011) even if Elmore & Howland (1943) also report that they can be attracted by light. In theory, they may become directly associated with containers for airplane freight or airplanes used to transport fruits of tomato. However, there are no data available to analyse this pathway in detail, and it is not considered further in this PRA as the EWG considered it as a very minor pathway. If *K. lycopersicella* was introduced into the PRA area, hitch-hiking on machinery and conveyances (especially trucks containing tomatoes) could become an important mean of spread of the pest within the region.

Plants for planting (except seeds and tubers) of ornamental Solanaceae (except known non-hosts) from areas where *K. lycopersicella* occurs
As for plants for planting of tomato and eggplant, plants for planting of other hosts may carry eggs, larvae and pupae, and soil or growing medium associated with the plants may contain pupae. Some species of ornamental solanaceous plants are known not to be hosts (e.g. petunia, datura), but some other ornamental solanaceous plants that may be hosts may be traded. The pathway was considered in detail in the first draft of the PRA and it was considered that it results in a very low likelihood of entry. In particular the volumes of ornamental solanaceous plants entering the PRA area are thought to be very low (as some major solanaceous ornamentals are not hosts and due to prohibition of solanaceaous plants in many countries of the PRA area, such as in the EU and countries following similar legislation). There was a high uncertainty associated with whether some ornamental Solanaceae could be hosts, as they are not reported as hosts at origin, and on whether there is trade into countries of the PRA area where solanaceous plants are not prohibited.

3. Pathways not considered

Seeds of host plants. The pest is not associated with seeds.

Potato tubers. Potato is a host of *K. lycopersicella*, but none of its life stages attack potato tubers. However pupae might be associated with soil, which might in turn be associated with potato tubers. This is considered in the "soil" pathway.

Weed hosts. *K. lycopersicella* has a number of weed hosts (see section 1.06). These are more likely to be moved as seeds (in consignments of, for example, plant products or soil), and the pest is not associated with seeds.

Other hitch-hiking. Hitch-hiking of eggs, larvae, pupae is considered in the "packaging" pathway, and on airplanes and airplane containers in 2 above. Hitch-hiking on other commodities is not considered.

Natural spread. *K. lycopersicella* is reported only in the Americas and Caribbean. It is recorded to move with storm fronts within the Americas: it was collected during a study on movement of moths on weather fronts but only findings of *Helicoverpa armigera* were published (Wiesenborn et al., 1988; Trumble, pers.comm., 2011). This would not be a means of transmission from the Americas to the PRA area. Natural spread is not relevant here and is considered only under the "spread" section.

2.01b - List the relevant pathways that will be considered for entry and/or management. Some pathways may not be considered in detail in the entry section due to lack of data but will be considered in the management part.

- Fruits of tomato and eggplant from areas where *K. lycopersicella* occurs
- Packaging (i.e. crates or boxes used for picking and packing tomato and eggplant fruits) from areas where *K. lycopersicella* occurs
- Plants for planting (except seeds) of tomato and eggplant from areas where *K. lycopersicella* occurs

Pathway 1: Fruits of tomato and eggplant from areas where K. lycopersicella *occurs*

2.03 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account the biology of the pest?

likely

Level of uncertainty: low

tomatoes on the vine: very likely (low uncertainty)
other tomatoes: likely (low uncertainty)
eggplant: unlikely (high uncertainty)

The pest has overlapping generations and so several life stages, including late larval stages (which are significant - see below), may be present in a growing crop. Several life stages might be associated with fruits of tomato and eggplant at origin. However, eggplants are reported as hosts in very limited number of origins (Florida, Guyana, Trinidad), and eggplant is not the preferred host of the pest. Information from Florida suggests that damage to the eggplant fruit is usually cosmetic and not internal (Schuster, pers.comm., 2011). This would indicate that the pest is unlikely to be associated with eggplant fruit.

For tomato, third and fourth larval instars may bore into the fruit and are the most likely life stages to be associated with the fruit. At the time of harvest, it is likely that the fruit will be infested with larvae, even with low levels of pest infestation in the crop. Larvae normally enter the fruit under the calyx or at the stem or at points of contact between leaves and fruits. In heavily infested fields, 85% of the fruits might be infested (Trumble & Alvarado-Rodriguez, 1993); in addition, in heavily infested fields, 50% of the infested fruits might be damaged in other places than below the calyx or fruit stems (Elmore & Howland, 1943). In infested fruits, larvae most commonly bore towards the centre of the fruit, although they sometimes mine just under the surface (Swank, 1937).

Association of other life stages:
- *Eggs* are laid mostly on the leaves, but are not uncommon on calyx and stems, and might be associated with fruit consignments if green parts with leaves, calyx or stems are retained.
- *Adults* might be associated at origin if they contaminate consignments at or after harvest. Adults are nocturnal, and hide in daylight (Elmore & Howland, 1943). They might hide in fruit consignments.
- *Pupae* are normally not associated with fruit, and might be present in consignments only if larvae pursue their development to pupation within the consignment. However, Ferguson & Shipp (2009) report that pupae can be associated with leaves or fruits rarely.
- *Other larval stages*. Elmore & Howland (1943) also mention that immature larvae may move from leaves to fruit on pulled out plants when the foliage dries and fruit remain on the plants, but such fruits are not likely to be traded.

Given these elements, tomatoes that are harvested and traded with parts of branches (and therefore with calyx and leaves) seem to present a higher risk than other types of tomato, as eggs and early larval instars may be present and damage by late larval instars in fruit might not be noticed. Eggplant is also traded with the calyx attached (i.e. early larval instars may be present and damage by late larval instars in fruit may not be noticed).

2.04 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account *current management* **conditions?**

moderately likely

Level of uncertainty: low

tomatoes: moderately likely
eggplant: moderately likely (high uncertainty).

Where the pest occurs, tomato crops for fruit production are subject to control measures to bring infestation levels below the economic threshold (for current management practices see 6.04). However, control measures do not guarantee absence of the pest as it is difficult to control. Treatments target mostly the first and second larval instars, while the third and fourth larval instars are hidden in folded or tied leaves and in fruits, and are more difficult to reach. In addition, the generations overlap and all life stages might be present at any time, complicating the timing of applications. Fruit might be infested even in the case of low pest populations in the crop.

Entry: fruits of tomato and eggplants

Sorting of tomato fruit may detect some larval damage (mines) but damage is not conspicuous and can be easily overlooked at harvest (Jimenez *et al.*, 1988) and at packing (Ferguson & Shipp, 2009). Damage is also more difficult to detect when calyces and green parts are attached (tomatoes with vine, eggplant).

2.05 - Consider the volume of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this volume will support entry?

unlikely

Level of uncertainty: low

tomatoes: unlikely

eggplant: very unlikely (medium uncertainty)

Imports of tomato and eggplant fruit to countries of the PRA area seem to originate mostly from within the PRA area (see CIRAD, 2009, for EU countries). Data on imports of tomato and eggplant fruit from countries where the pest occurs are presented below (from CIRAD, FAOSTAT, and Eurostat see Tables 1-5). There are some discrepancies between data sources, but it seems that such imports are limited. The largest quantities (with regular imports) of tomato and eggplant fruit from countries where *K. lycopersicella* occurs originate from Colombia and the Dominican Republic for tomatoes, and from the Dominican Republic for eggplants. Quantities and exporting countries for both tomato and eggplant fruits vary over the years. However, there are regular imports from the Dominican Republic, with a 6-fold increase of exports of tomato fruit into the EU between 2005 and 2010 (see Table 3). It is interesting to note that the quantities of tomato fruit imported from countries where *K. lycopersicella* occurs, although minor, are similar to the quantities of tomato fruit imported from countries where *T. absoluta* occurs in 2001-2006.

For eggplant, there were no imports (at least to the EU) of eggplant fruit from countries where the pest is reported as problem on this crop (USA-Florida, Guyana and Trinidad), while no record of *K. lycopersicella* as a pest on eggplant has been found in the literature for the main exporter, the Dominican Republic (see Tables 4 and 5 below).

Table 1. Tomato and eggplant fruits: quantities (in tonnes) imported into the EU27 in 2008 - total quantities and quantities from countries where K. lycopersicella occurs (extracted from CIRAD, 2009).

Import into the EU	Tomato	Eggplant
from EU countries	2 347 933	154 962
from non-EU countries, including	472 337	8461
Colombia	121	0
Dominican Republic	127	885

Table 2. Tomato: quantities (in tonnes) imported into countries of the PRA area, as declared by exporting (importing) countries for 2008 from countries where K. lycopersicella occurs (from FAOSTAT)

Origin/Destination	Dominican Rep.*	USA	Colombia	Venezuela
France	(127)	21	93 (121)	
Italy		6		
Malta				3
Netherlands		4		
Norway			(1)	
Russia		2 (2)		
Ukraine		8		
Total	(127)	41 (2)	93 (122)	3

* in FAOSTAT, no export data available from this country, but some import data available from the importing country.

Table 3. Tomato - Quantities (in 100 kg) imported into EU countries (Eurostat). (Only EU countries with imports and years with imports are indicated in this table)

Partner	USA			Colombia						Costa Rica				Cuba	Dominican Republic					
year	05	06	07	05	06	07	08	09	10	05	06	07	10	05	05	06	07	08	09	10
Spain	:	25	:	:	:	:	:	:	:	:	:	:	:	290	:	:	:	:	:	:
France	254	:	66	4537	1449	1242	1211	292	648	220	50	308	195	111	1456	1212	1095	1298	3085	9641
Italy	:	:	:	:	:	:	:	:	:	:	:	:	:	4	:	:	:	:	:	:
NL	2	0	:	:	:	:	:	4	14	:	:	:	:	:	:	:	105	:	1	:

Entry: fruits of tomato and eggplants

Partner	Ecuador		Mexico	Panama		Peru				Venezuela		
year	2005	2010	2008	2009	2010	2006	2007	2008	2010	2005	2006	2007
Bulgaria	:	:	:	:	:	1	:	:	:	:	:	:
Germany	:	:	:	:	:	:	:	:	2	:	:	:
Spain	20	5	:	:	:	:	101	:	38	:	:	:
France	:	:	:	101	156	:	:	2	:	100	120	17
Italy	:	:	1	:	:	:	25	:	:	:	:	:

Table 4. Eggplant - quantities (in tonnes) imported into countries of the PRA area, as declared by exporting (importing) countries for 2008 from countries where K. lycopersicella occurs (from FAOSTAT)

	Dominican Rep.*	USA	Honduras	Panama*	Costa Rica*	Peru*
Belgium	(16)					
Bulgaria		7 (0)				
Finland			16			
France	(219)					
Italy	(8)					
Netherlands	(165)					
Portugal	(9)					
Russia				(1)	(1)	
Spain	(4)					
Switzerland	(234)					
UK	(463)					(3)
Total	(1118)	7 (0)	16	(1)	(1)	(3)

* in FAOSTAT, no export data available from this country, but some import data available from the importing country.

Notes: For other countries where *K. lycopersicella* occurs, no export of tomato or eggplant fruit to the PRA area was reported (Canada, Mexico, Nicaragua, Guyana, Guatemala; FAOSTAT). In addition the following data for 2008 are not available in FAOSTAT (i.e. not provided by countries) :
- imports by the following countries in the PRA area: Algeria, Guernsey, Jersey, Jordan, Tunisia, Uzbekistan.
- exports from El Salvador, Panama, Bahamas, Bermuda, Cuba, Haiti, Jamaica, Trinidad and Tobago, Bolivia (and no imports recorded by countries of the PRA area).

Table 5. Eggplant - Quantities (in 100 kg) imported into EU countries (Eurostat). (Only EU countries with imports and years with imports are indicated in this table)

Partner	USA	Colombia	Cuba			Dominican Republic						Ecuador	Guatemala		Jamaica	Peru	
Reporter/Period	2006	2009	2005	2007	2008	2005	2006	2007	2008	2009	2010	2008	2009	2010	2006	2005	2008
Austria	:	:	:	:	:	2	6	1	4	11	1	:	:	:	:	:	:
Belgium	:	10	:	:	:	:	:	7	160	24	10	:	:	:	:	:	:
Germany	:	:	:	:	:	43	112	42	:	29	1.751	:	:	:	:	:	:
Denmark	:	:	:	:	:	:	:	:	:	2	1	:	:	:	:	:	:
Spain	:	:	:	:	:	:	:	122	39	12	10	:	:	:	:	:	:
France	:	:	:	:	:	254	339	1.442	2.191	2.236	2.102	:	:	:	:	:	:
UK	18	:	:	:	:	244	1.082	3.538	4.632	5.299	4.427	:	:	:	7	10	27
Italy	:	:	:	:	:	:	25	24	81	:	:	:	:	:	:	:	:
Netherlands	:	:	1	18	1	442	559	1.770	1.650	799	0	13	3	7	:	:	:
Portugal	:	:	:	:	:	:	16	30	93	65	23	:	:	:	:	:	:
Sweden	:	:	:	:	:	:	:	:	:	0	1	:	:	:	:	:	:

Uncertainty for eggplant: no import from countries where *K. lycopersicella* is reported on eggplant and no record on eggplant in Dominican Republic.

2.06 - Consider the frequency of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this frequency will support entry?

likely

Level of uncertainty: low

Frequency of entry of tomato fruits into the EU is illustrated in Fig1. Imports relate to small quantities. The frequency depends on the origin. For most origins, consignments enter between October and January, while from the Dominican Republic (the main exporter into the PRA area), consignments are imported all year round (source : Eurostat, 2011). However imports might occur at any time of the year, and the pest might be associated at origin at any time of the year due to overlapping generations. For UK, tomato fruit from USA and Peru was available all year round (reference to 2008 source in PRA for *Pepino mosaic virus* (Werkman & Sansford, 2010).

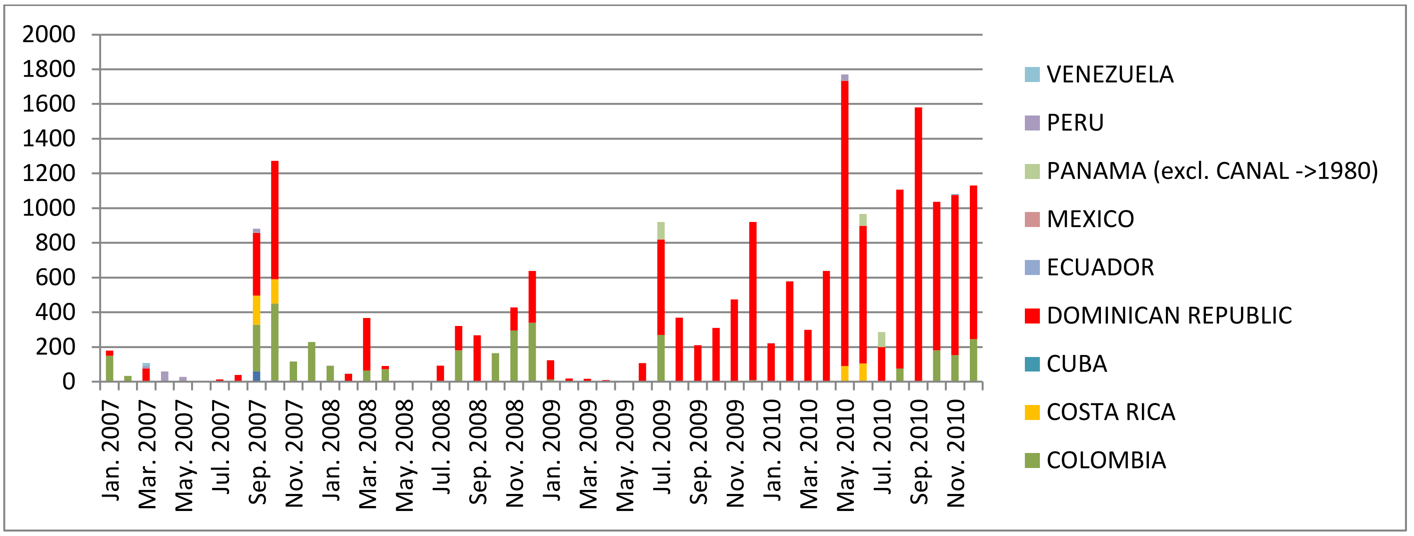


Fig 1. Quantity (in 100 kg) of tomato fruit imported into the EU from countries where *K. lycopersicella* is present, per month over the period 2007-2010 (based on Eurostat data, 2011)

2.07 - How likely is the pest to survive during transport or storage?

likely

Level of uncertainty: low

Fruits of tomato and eggplant are harvested, sorted, packed, delivered and marketed within a few days. The whole process, from harvest to reaching final destination, could range between 2 to 5 days. Storage is only for a few days. If conditions are suitable, third or fourth instar larvae could survive and feed in the fruits. Pupae could be formed within the consignment. If eggs or larval instars are associated with green parts, they would probably survive for short durations. If adults emerge during transport and storage, they would find limited food (foliage), but they are able to survive without food for several days (Swank, 1937; Elmore & Howland, 1943; see 2.08 for "plants for planting of tomato and eggplant").

Survival is influenced by several parameters, in particular temperature. On plants, the pest may develop at a temperature of ca. 11°C for all life stages on tomato (Lin & Trumble, 1985) or ca. 9.5°C on cherry tomato (Weinberg & Lange, 1980). Lin & Trumble (1985) explained this difference between tomato and cherry tomato because of the form and thickness of leaves.

There is uncertainty as to whether transport would occur at suitable temperatures for survival. The optimum temperatures for short-term storage and transport are as follows. Mature green tomatoes: 12.5° to 15° C (55° to 60° F); partially to fully ripe tomatoes, 10° to 12.5° C (50° to 55° F); eggplant fruit 10° to 12.5° C (50° to 55° F) (University of California, undated). According to information gathered from Turkish exporters, transport temperature is between 5-8°C for tomato and eggplant in Turkey (Kılıç, pers comm., 2011). From data provided from Spain, normal temperature for tomato trade and storage is about 8.2 ºC (Monserrat, pers.comm., 2011). It is likely that some life stages could survive at such temperatures for the duration of storage and transport, especially pupae (see 3.03 : pupae may survive below 0°C). Larvae of the related pest *T. absoluta* can survive during transport and storage of tomato fruit from South America.

Entry: fruits of tomato and eggplants

Studies have shown that survival of all larval stages is generally higher on young and mature leaves (rather than senescing leaves and fruit) (Lin & Trumble, 1985). On fruit, survival of first instar larvae was higher on green fruit and of third instar on mature green or red fruit (Lin & Trumble, 1985).

Details on uncertainty: medium. Influence of the stage of transport of fruits (ripeness).

2.08 - How likely is the pest to multiply/increase in prevalence during transport or storage?

very unlikely

Level of uncertainty: low

Transport and storage of fruit would not be long enough and not at suitable temperatures to allow emergence of adults, reproduction and egg laying. Even if adults emerge, they would find a limited amount of material suitable for feeding and egg laying. Senescing leaves are not suitable as a host substrate (Lin & Trumble, 1985) and leaves associated with fruit might therefore not be suitable. In addition adults normally lay eggs on the foliage of plants, although Elmore & Howland (1943) mentions that in cages eggs are deposited on all parts of the plant or on cages.

2.09 - Under current inspection procedures how likely is the pest to enter the PRA area undetected?

very likely

Level of uncertainty: low

When fruits are inspected at origin for the presence of pests; this may allow detection of *K. lycopersicella*, in particular for late infestation when secondary fruit rot developed. However, the pest is difficult to detect. Swank (1937) notes that the presence of larvae or mines in the fruit is often difficult to detect especially if the larva has entered the fruit under the calyx, which is still in place. Even if the calyx is removed, entry holes are small and may be filled by a thin web, which is not easily seen. Black frass held in this web may be the only sign of presence. If eggs are present on green parts, they will be difficult to detect due to their size. Damage is easily overlooked at harvest and at packing (Jimenez *et al.*, 1988; Ferguson & Shipp, 2009).

Fruit of tomato and eggplant is also not subject to specific phytosanitary import requirements against *K. lycopersicella* in most countries of the PRA area (see 7.10 for this pathway). In the absence of such specific requirements, fruit will not be submitted to measures aiming at ensuring absence of the pest. Even if a phytosanitary certificate (PC) is required for fruit of tomato and eggplant, leading to some general inspection or targeted inspections against other pests, it is not certain that *K. lycopersicella* would be detected, for the reasons given above. No interception of K. *lycopersicella* has been reported to EPPO.

2.10 - How likely is the pest to be able to transfer from the pathway to a suitable host or habitat ?

moderately likely

Level of uncertainty: low

packing and handling close to growing facilities: moderately likely (Northern part PRA area); likely (Southern part PRA area)
direct to consumers: unlikely

Fruit of tomato or eggplants are imported for consumption or processing, which would reduce the probability that the pest transfers to a suitable host, except where they arrive in areas close to production facilities. Another factor limiting transfer would be the possibility for larvae to exit ripe fruit. Swank (1937) noted that by the time tomatoes are ripe, few larvae found their way out of the fruit; either they would have left before, or they would not have found a way out due to change of position of the fruit, or fungus or juice from broken tissues obstructing the galleries. For transfer to be successful, temperature outdoors should be suitable for the pest to survive and reproduce. Therefore probability of transfer with fruit directly provided to the consumer or used for processing is considered unlikely.

However, transfer to a host is considered as moderately likely or likely if packing and handling facilities are located near production areas. Firstly, consignments of tomato fruit are generally present for several days (sometimes weeks) at packing stations before being fully processed. Several life stages may also remain associated with packaging which has carried fruit (e.g. crates and boxes) (see the pathway 2 for packaging). In addition, green parts associated with fruit or infested/damaged fruit may be discarded; if they carry life

stages of *K. lycopersicella,* development might continue*.*
Pupae present in consignments pose the highest risk, while eggs and first instars larvae have a very low probability of completion of the life cycle and transfer. If *K. lycopersicella* is close to emergence from pupae (durations of life stages are given under question 2.08 of "plants for planting of tomato and eggplant"), it may complete its development, escape the packing station or discarded material, and find suitable hosts in the vicinity (i.e. tomato, eggplant, potato or weeds), as these are common in commercial cultivation and gardens in the PRA area and may be close to packing stations. The PRA for *Pepino mosaic virus* (Werkman & Sansford, 2010) stated that in the Netherlands sorting of imported tomatoes usually takes place at central sites amid greenhouses for production of tomatoes. In the UK some packing facilities and production greenhouses are in very close proximity on the same site. It is worth noting that the related species *T. absoluta* was found several times at packing stations in the UK and the Netherlands, and outbreaks were recorded in greenhouses close to these packing stations. Some companies sort, pack and produce tomatoes in one building, and in such case transfer is very likely (Potting *et al.*, 2010). However, due to the introduction of other pests (e.g. viroids, PepMV), some producers would have stopped doing this (Sansford, Fera, pers. comm. 2011).

2.11 - The probability of entry for the pathway should be described

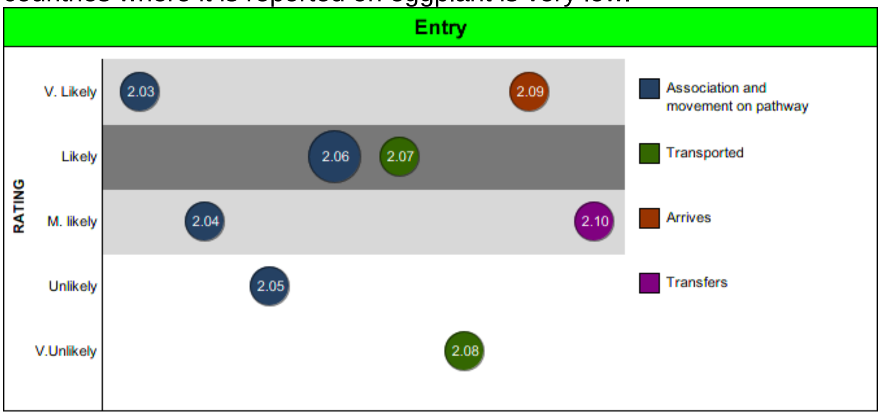
likely

Level of uncertainty: low

tomatoes with vine: likely
other tomatoes: moderately likely
eggplant: unlikely (medium uncertainty - import data and association with eggplant fruits)

Answers are illustrated below (for tomato with vine). The volume of this pathway into the PRA area is low and the pest is very unlikely to multiply in transport, but all other parameters are favourable to entry. The probability of entry is therefore rated as "likely" for tomatoes with vine. Due to the removal of green parts and associated life stages, the probability is lower for other tomatoes.
This assessement was considered consistent with the fact that *T. absoluta* was probably introduced in the EPPO region with infested tomato fruit. It should be noted that, according to Eurostat, import of tomato fruit from USA and South America only began after 1999. Volumes of import have recently increased (in particular from Domican Republic).

Eggplant is rated with a lower probability as the pest is less likely to be associated and volume from countries where it is reported on eggplant is very low.



Pathway 2: Packaging (i.e. crates or boxes used for picking and packing tomato and eggplant fruits) from areas where K. lycopersicella *occurs*

2.03 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account the biology of the pest?

moderately likely

Level of uncertainty: low

The pest is likely to be associated with fruits of tomato and eggplant and may become associated with packaging that has been used to transport such fruit. In a similar way, it may also become associated with packaging used to transport plants for planting.
Ferguson & Shipp (2009) mention that crates that have been used to transport tomatoes could carry adults, infested leaves or fruits. Only third and fourth larval instars that are inside the fruit are not likely to become associated with packing material.
The life stage which is most likely to be associated with packaging is pupae. Adults may be attracted to packaging carrying the fruit.

Elmore & Howland (1943) noted that in cages, eggs are deposited on all parts of the plant or on cages. In a similar manner, if adults are in crates at the time of oviposition, they might lay eggs on the packing material. First and second instar larvae present on fruit might wander onto other material. Larvae transforming to pupae would normally descend to the ground, but, if in packing material, could reach the surface of the crate. Pupae are normally formed in the soil (and in a few rare cases in leaf folds, or the fruit or the side of breeding cages) (Elmore & Howland, 1943). Adults are nocturnal and spend the day hidden between leaves or in enclosed spaces. They could be present on crates (Korycinska & Eyre, 2010). Packaging is considered to be a pathway of spread of *T. absoluta* within the EPPO region (Potting *et al.*, 2010).

2.04 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account *current management* conditions?

unlikely

Level of uncertainty: high

unlikely if packaging is new (not re-used).

The likelihood is similar to that for fruit of tomato and eggplant, as the pest is likely to become associated with packing carrying infested fruits. However it is not known whether packing material such as crates would be subjected to any management measures. In the USA, packaging material is not re-used (Trumble, pers. comm., 2011).

Details on uncertainty. High. No data were found on management of packaging.

2.05 - Consider the volume of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this volume will support entry?

unlikely

Level of uncertainty: medium

The likelihood is estimated to be similar to that for fruit, i.e. unlikely, although packaging used to carry tomato and eggplant fruit might be used for other produce while still carrying life stages of the pest.

Details on uncertainty: Medium. Whether the pest would remain associated with crates for enough time to facilitate entry with another commodity.

2.06 - Consider the frequency of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this frequency will support entry?

likely

Level of uncertainty: medium

As for fruit.

Entry: Packaging

2.07 - How likely is the pest to survive during transport or storage?

likely

Level of uncertainty: low

Transport of fruit of tomato and eggplant takes place within a few days. If pupae are present on crates, they are likely to survive as this stage may last up to 30 days depending on temperature. Adults may also survive for several days (e.g. 6-20 days, see details in 2.08 in the pathway plants for planting of tomato). Swank (1937) reports that *K. lycopersicella* adults emerged from infested sacks 3-10 days after arrival.

2.08 - How likely is the pest to multiply/increase in prevalence during transport or storage?

very unlikely

Level of uncertainty: low

As for fruit.

2.09 - Under current inspection procedures how likely is the pest to enter the PRA area undetected?

very likely

Level of uncertainty: low

The pest would be even more likely to remain undetected than on fruit, as inspection (if any) would mostly target the commodity itself.

2.10 - How likely is the pest to be able to transfer from the pathway to a suitable host or habitat ?

moderately likely

Level of uncertainty: low

Moderately likely if imported into a facility where tomatoes are also grown
Unlikely if directly to consumer.

Swank (1937) notes that containers in which tomatoes have been transported may become a source of infestation even some time after the tomatoes were consumed. In particular pupae might be able to complete their development and find a suitable host depending upon where the packaging material is held. Crates used for infested tomato might be reused for harvesting tomatoes, thereby putting the pest in contact with its host. If used to pack tomatoes in the vicinity of production facilities there is a risk of transfer to tomato crops (or eggplant, weeds, etc. depending upon the location).

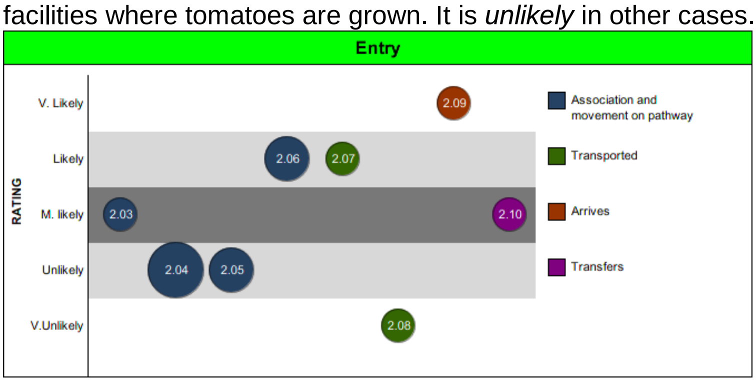
In the UK and the Netherlands reports of outbreaks of *T. absoluta* in glasshouses are probably linked to infested packing material delivered to the two companies (Potting *et al.*, 2010; Sansford, *pers. comm., 2011*).
[
The risk will depend on the end use of the crates.

2.11 - The probability of entry for the pathway should be described

moderately likely

Level of uncertainty: low

Answers can be visualized below. As for fruit, the volume is low and the pest is very unlikely to multiply in transport. Although transfer would be more difficult than from plants, it has been shown to still be possible (Potting *et al.* 2010). The probability of entry is still rated as *moderately likely* if the crates are destined to facilities where tomatoes are grown. It is *unlikely* in other cases.



Pathway 3: Plants for planting (except seeds) of tomato and eggplant from areas where K. lycopersicella *occurs*

2.03 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account the biology of the pest?

very likely

Level of uncertainty: low

Tomato, very likely
Eggplant, very likely

Eggs and larvae of *K. lycopersicella* may be present on plants for planting. The following text refers to tomato. In the USA, tomato seedlings are consistently mentioned as the means by which the pest reaches northern parts of its distribution, from its range in the southern part of the country (e.g. Elmore & Howland, 1943; USDA, 2002).

- Eggs are laid singly or in little groups (2-3) on the foliage. Eggs are deposited on both leaf surfaces. While Elmore & Howland (1943) found high percentages of eggs on upper leaf surfaces, Pena (1983) found 89% of eggs on lower leaf surface.
- The first larval instars mine into the leaves. On seedlings, it is the first and second larval stages that are more likely to be associated with the plant. The third and fourth larval instars may feed within leaves that they tie together or folded portions of a leaf (they may also be present in fruits but plants for planting are normally traded without fruit). In Jones et al. (1991) it is stated that, in the USA, tomato transplants are produced for shipment within 9 weeks when they are produced in the field whereas it will take 4-8 weeks for containerized transplants. In Turkey, seedling growing period is approximately 5 weeks (Kılıç, pers. comm., 2011). Based upon the duration of larval stages (2.08), all larvae stages of *K. lycopersicella* can be associated with seedlings.
- If plants are associated with soil or growing medium, pupae might be present, but it is unlikely due to the age of the plants (pupae would not have formed). These are formed at the surface or in the shallow part of the soil or growing medium.
- All life stages might occur at any given time and generations may overlap. In favourable conditions the pest may be present all year round (Alvarado-Rodrigues & Rubio, 1990). Development of all stages may continue, at a retarded rate, during winter where tomato plants survive outdoors, and may cease altogether except for survival of pupae in the soil or growing medium and moths in protected places (Elmore & Howland, 1943).

2.04 - How likely is the pest to be associated with the pathway at the point(s) of origin taking into account *current management* **conditions?**

moderately likely

Level of uncertainty: medium

Tomato seedlings are consistently mentioned as the means by which the pest reaches northern parts of its distribution, from its range in the southern part of the country (e.g. Elmore & Howland, 1943; USDA, 2002).

Boyhan GE & Kelley WT (2010) note that in Georgia tomato seedlings are produced by specialist growers. They are produced in trays or flats usually in peat for 5-7 weeks. Although they are produced in greenhouses, transplant may be moved outside for several days prior to transplanting to harden the transplants.

If plants are produced in screenhouses, with appropriate monitoring measures, association is unlikely. If the soil or the growing medium is removed and sterilised after each seedling production cycle, it is unlikely that pupae will be present. In other conditions, the probability is higher. This is the case for example in Guyana where tomato seedlings are produced outdoors in soil (Ministry of Agriculture of Guyana, undated).

Details of uncertainty. It is not known how seedlings are produced in all countries where the pest occurs.

2.05 - Consider the volume of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this volume will support entry?

very unlikely

Level of uncertainty: medium

In the EU, according to Council Directive 2000/29/EC (EU, 2000), the importation from third countries of plants for planting of *Solanaceae* is prohibited (except from European countries and countries in the Mediterranean region). Young plants of tomato are likely to be produced within the country or imported from neighbouring countries (draft PRA on Candidatus *Liberibacter solanacearum*, EPPO, 2011a). The Netherlands is a major producer of tomato seedlings and exports about 50% to other EU countries, especially neighbouring countries (Werkman & Sansford, 2010). Data gathered by the EPPO Secretariat from NPPOs of the Netherlands, Germany and Italy regarding imports of plants for planting in 2010 show that *Lycopersicon* originate mostly from Israel (and to a minor extent from Tunisia and Turkey), and eggplant mostly from Tunisia.

Not all countries in the PRA area have specific requirements on imports of plants for planting of tomato or eggplant (see section 7.10 for this pathway). Trade to these countries is not known, but it is supposed that if seedlings are imported, they would mostly come from within the PRA area. Note that trade data, for example from EUROSTAT, do not allow differentiation of planting material for tomato or eggplant from each other or from other non-woody plants for planting. However, Data gathered by the EPPO Secretariat from NPPOs of the Netherlands, Germany and Italy regarding imports of plants for planting in 2010 show that some countries where *K. lycopersicella* occurs are potential origins for export to countries of the PRA area where such plants for planting are not prohibited. In 2010 2 consignments from countries where *K. lycopersicella* occurs (8 *Lycopersicon* plants from the USA; circa 550 *Solanum melongena* from the Dominican Republic) were inspected. As these species are prohibited such consignments were rejected. This nevertheless shows the existence of possible origins for such plants for planting.

Details of uncertainty: medium. No data are available on the volume of imports of tomato or eggplant plants for planting for EPPO countries, but the volume of plants for planting from countries where the pest is known to occur is thought to be low (prohibited, at least in the EU countries).

2.06 - Consider the frequency of movement along the pathway (for periods when the pest is likely to be associated with it): how likely is it that this frequency will support entry?

likely

Level of uncertainty: medium

There are no data. If seedlings are imported from areas where *K. lycopersicella* occurs, they would arrive at the time appropriate for planting either in the field or under protection.

Details of uncertainty: medium - no data on frequency of import.

2.07 - How likely is the pest to survive during transport or storage?

very likely

Level of uncertainty: low

All life stages associated with plants for planting can survive during transport or storage. Eggs or larvae colonising the plants could remain viable. Larvae could continue feeding on the plants. Pre-pupae and pupae associated with soil or growing medium are also likely to survive for the duration of the transport. If adults emerge, they could survive for some days in the consignment (see duration of life stages in 2.08). Leaves on such young plants would also not be senescing, and studies have shown that survival of all larval stages is generally higher on young and mature leaves (rather than senescing leaves and fruit) (Lin & Trumble, 1985).

Transport is likely to occur under favourable temperature conditions as these have to be favourable for the hosts. McGinley (2004) reports that typical temperatures for transport of seedling was 18°C, but recommended a temperature of 12-14°C for best development of the seedlings after transport.
Lowest temperature thresholds (for development of the pest) reported in the literature are ca. 11°C for all stages on tomato (Lin & Trumble, 1985) and 9.5°C on cherry tomato (Weinberg & Lange, 1980). Duration of transport will not be long enough to have a significant impact on the insect, even if it occurs below 11°C. Storage is not considered here as plants are unlikely to be stored before use.

Entry: conclusion

2.08 - How likely is the pest to multiply/increase in prevalence during transport or storage?
unlikely

Level of uncertainty: low

Transport and storage is likely to be short for plants for planting of tomato and eggplant, while the life cycle of the pest is comparatively long. This would not be favourable for multiplication in transport and storage. However, life stages associated with the plants at origin might pursue their development during transport. Emergence of adults is rather unlikely considering the duration of transport, but may occur if pupae close to emergence are present. If adults emerge, they could reproduce and lay eggs on plants. In general adults begin laying eggs in the first or second night after emergence and lay most eggs within a few days (Elmore & Howland, 1943). Adults can survive over several days (see Table6 below).

Several publications report on duration of life stages for *K. lycopersicella* in different conditions:

Table 6 Durations of life stages of K. lycopersicella

	Average durations, if not otherwise specified, in days,						
	Egg incubation	1st larval instar	2nd larval instar	3rd larval instar	4th larval instar	pupa	Adult
Elmore & Howland (1943)	8.9 d (min. 4; max. 30) T: 7,8-10°C to 27-29.5°C	11.5 d (min. 5) (leaf mining larvae)		9.5 d (min. 3) (leaf folding stages)		prepupae 6.9 d (min. 1) pupae 30.2 d (min. 15)	7 d (water only), 8.5 d (honey solution) at mean T 24-27°C; 20.5 d (water only), 22.8 d (honey solution), at mean T 10-13°C
Swank (1937)		2.33	2.65	3.33	2.04	-	Females: 6 to 25 days after copulation without food. Survival of some virgin moths with food after 28 days. Males would die before the 6th day, frequently after 48 h.
Comparison Florida (California)	6.7 (8.9) min. 4(4) max. 9(30)	9.8 (27.9) min. 9 (9); max. 17 (63)				11.0 (30.2) min. 7 (15); max.17 (52)	
Lin & Trumble (1985)	4-8 d (22-24°C)	10 d at 24-26 °C				8-20 d (depending on temperature)	7-9 d (24-26 °C); 23 d (13 °C).
Geraud-Pouey *et al.* (1997)	5 d	ca. 11 d				7-8 d	7.28 d (female) 8.11 (male)
Weinberg & Lange (1980)	7.8 d (20°C)	18.7 d (hatch to pupation at 20°C)					
		30 d (hatch to adult emergence at 20°C)					

2.09 - Under current inspection procedures how likely is the pest to enter the PRA area undetected?
likely

Level of uncertainty: low

In many EPPO countries (e.g. the EU) import of host plants is forbidden.

In EPPO countries where imports of such plants are allowed, a PC is generally required (see answer to 7.10 for this pathway). Plants for planting are supposed to be inspected at origin for the presence of pests and visual inspection may allow detection of *K. lycopersicella*. Visual inspection for larvae of *K. lycopersicella* is also used to remove low levels of infestation (Shipp *et al.*, 2001) or for monitoring prior to treatment (see 6.04). However, this would require targeted inspections.
The pest is difficult to detect at early stages. Eggs or first instar larvae are the most likely stages to be present and may be easily overlooked even with targeted inspection.

In EPPO countries where imports of such plants are allowed, current inspection procedures at import may allow detection of the pest depending on the requirements made by the country (see 7.10 for this pathway):
- In most of these countries, the pest is not subject to specific phytosanitary import requirements. A PC may be required, leading to some general inspection or targeted inspections against other pests. However, it is

not certain that *K. lycopersicella* would be detected during such inspections.
- In some of these countries *Phthorimaea operculella* is a quarantine pest (e.g. Kazakhstan, Azerbaijan, Belarus, Russia, Ukraine; EPPO-PQR 2011). This pest belongs to the same family as *K. lycopersicella* and has the same host plants, so inspections targeting *P. operculella* may help detection of *K. lycopersicella*.
- *K. lycopersicella* is a quarantine pest for Moldova, targeted inspection are more likely to be conducted and thefore to detection the pest on imported plants.

2.10 - How likely is the pest to be able to transfer from the pathway to a suitable host or habitat ?

very likely

Level of uncertainty: low

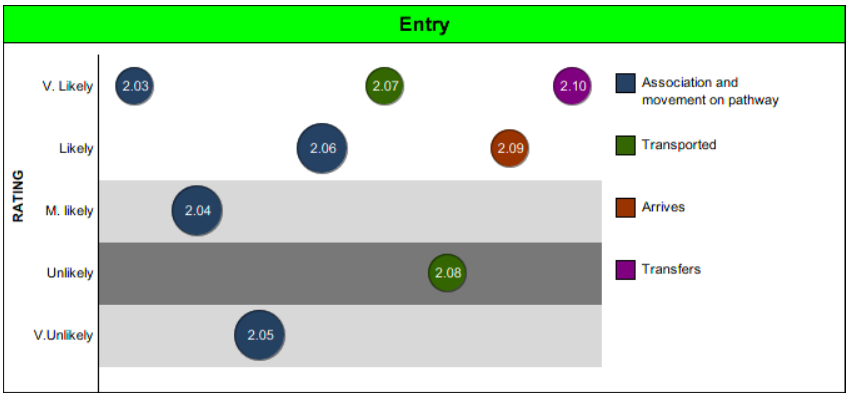
Plants for planting will be planted in favourable conditions for their development and therefore the pest will be able to complete its development on the plants for planting on which it was imported and transfer to another host. In the USA, *K. lycopersicella* is reported to reach glasshouses on infested seedlings and later infest neighbouring fields (Trumble, pers. comm., 2011). The imported plants for planting will be used in facilities or fields of tomato- and eggplant-growing regions. They are likely to be in the vicinity of commercial or garden tomato or eggplant. Other hosts are also widespread in the PRA area, including potato, and host weeds.

2.11 - The probability of entry for the pathway should be described

unlikely

Level of uncertainty: low

Answers are visualized below. All parameters considered are favourable for entry of the pest on plants for planting of tomato and eggplant, except the volumes of imports. Consequently the probability of entry is considered to be *unlikely*. Where imports of Solanaceae are prohibited (e.g. EU), the probability of entry is very unlikely (with low uncertainty). If the volumes were to increase or prohibition lifted, that probability would be higher.



2.13b - Describe the overall probability of entry taking into account the risk presented by different pathways and estimate the overall likelihood of entry into the PRA area for this pest (comment on the key issues that lead to this conclusion).

likely

Level of uncertainty: medium

Fruit of tomato with vine present the highest probability of entry of the pest. Fruit of tomato without vine and packaging used for fruit of tomatoes or eggplant present a moderate likelihood of entry. Plants for planting of tomato and eggplant would be a better pathway for entry than tomatoes with vine but the volumes traded are seemingly very low, and they are prohibited in many countries of the PRA area. The risk of entry would be higher if volumes increased. From data available from Florida, entry of the pest on eggplant fruit is unlikely as the pest is not likely to be associated with eggplant fruit (cosmetic and not internal damage); however, there is a high uncertainty regarding the situation of this pest on eggplant in other countries where it is mentioned as a pest on eggplant (known countries : Trinidad and Guyana), and in particular whether larvae may be present within fruit.

Pathway	**Probability of entry**	**Uncertainty**
Fruits of tomato with vine	Likely	Low
Other fruits of tomatoes	Moderately likely	Low
Packaging	Moderately likely if destined to facilities close to places where tomatoes are grown Unlikely in other cases	Low
Plants for planting (except seeds) of tomato and eggplant*	Unlikely*	Low
Fruits of eggplant	Unlikely	High

* This pathway is subject to prohibition in many countries of the PRA area (e.g. EU), and the probability is therefore not relevant for these countries.

Stage 2: Pest Risk Assessment Section B: Probability of establishment

In a first step, assessors should select the ecological factors that influence the potential for establishment.

No.	Factor	Is the factor likely to have an influence on the limits to the area of potential establishment?	Is the factor likely to have an influence on the suitability of the area of potential establishment?	Justification
1	Host plants and suitable habitats	Yes (see 3.01)	Yes (see 3.09)	
2	Alternate hosts and other essential species	No	No	The pest does not need alternate hosts. Although the role of host weeds or other plants in maintaining populations in the absence of a preferred host is unknown, it does not need to be considered here.
3	Climatic suitability	Yes (see 3.03)	Yes (see 3.11)	
4	Other abiotic factors	No	No	Ozone and acid rain have been shown to have an effect on increase of populations (Trumble *et al.*, 1987). Although this might have an effect on the development of populations once the pest is established, it is not considered likely to influence establishment. The situations at origin and in the PRA area regarding ozone and acid rains were not compared further.
5	Competition and natural enemies	No	Yes (see 3.13)	Natural enemies will not prevent establishment, but they are likely to have an effect on the level of populations once the pest is established. This question is therefore considered mainly in relation to competition.
6	The managed environment	No	Yes (see 3.14&3.15)	In no part of the PRA area is the managed environment such that it would prevent establishment of *K. lycopersicella*. Although management measures are applied in tomato, eggplant and potato crops (see 3.15), they might not necessarily prevent establishment of the pest.
7	Protected cultivation	Yes (see 3.07)	Yes (see 3.16)	

Identification of the area of potential establishment

Host plants and suitable habitats

3.01 - Identify and describe the area where the host plants or suitable habitats are present in the PRA area outside protected cultivation.

Tomato, eggplant and potato are widely grown in the EPPO region (see question 1.14) outside protected cultivation in the field and in gardens.
- Tomato. Commercial production in the field occurs in the southern and south-eastern part of the region (e.g. Italy, Spain, France, Greece, Turkey, Morocco, Romania, Portugal). Production occurs in gardens throughout the PRA area except in the northern areas.
- Eggplant. Commercial cultivation in the field occurs mostly in the southern part of the PRA area (e.g. Italy, Azerbaijan, Jordan, Turkey, Romania, Spain). Production in gardens occurs mostly in southern areas.
- Potato. Commercial production in the field occurs in the whole PRA area except the extreme northern areas. Production in gardens occurs throughout the PRA area.

Climatic suitability (outdoors)

3.03 - Does all the area identified as being suitable for establishment in previous question(s) have a suitable climate for establishment?

No

The pest is generally considered to not be able to survive outdoors in winter at low temperatures. However, it is unclear at which temperatures the pest will not survive.

Ferguson & Shipp (2009) note that in Canada it is considered that the pest is unable to survive winter; however, it might survive in crop debris left in the field or other relatively protected locations. Elmore & Howland (1943) note that in California development of all life stages continues on plants left in the field, if the temperature permits survival of the plants; if low temperatures kill the plants (e.g. <2°C), pupae in the soil (or growing medium) are often able to survive during the remaining period and emerge during the early growth stages of the new tomato crop. In studies on the survival of prepupae and pupae at low temperatures, Elmore & Howland (1943) found that some prepupae and pupae were able to develop at mean temperatures of 8.8°C, with a minimum temperature of -5,5°C, although with very low emergence rates. Pupae are able to withstand some periods of temperatures below 0°C (Trumble, pers.comm., 2011).

In contrast to these, Weinberg & Lange (1980) and Lin & Trumble (1985) found higher thermal thresholds for development of all life stages of the pest, respectively on cherry tomatoes and tomatoes (differences are partly due to the differences of form and thickness of leaves of the different cultivars):
- Lin & Trumble (1985) found no survival at temperatures below 11°C or above 41°C, for any life stage (including pupae), with the egg stage having the highest mortality at these temperatures. Lower thermal thresholds were 11.4°C, 10.9°C and 11.0°C, respectively for egg, blotch leaf mining stage (i.e. first and second larval instar) and tentiform leaf mining stage (i.e. third and fourth larval instar).
- Weinberg & Lange (1980) found lower thermal thresholds of 9.6°C, 9.3°C and 9.5°C, respectively for oviposition to hatch, oviposition to pupation, oviposition to emergence. Thermal requirements for oviposition to adult was 456°C days based on a threshold temperature of 9.5°C (444-495°C in glasshouse).

These data explain why only sporadic infestations are reported from some areas (e.g. New Jersey, Kline & Walker, 1997; Tennessee, North Carolina, USDA 2002 & 2005) because the pest cannot survive outdoors in winter there.

Regarding oviposition, Ferguson & Shipp (2009) mention that flight and egg-laying of adults continues through the night if the temperature is above 16°C.

Climate maps and temperature graphs comparing some locations of presence of the pest with the PRA area are given in Annex 3. Given its current distribution in the Americas, it is thought that the pest would be able to establish and overwinter outdoors predominantly around the Mediterranean Basin. There is uncertainty as to the northern limit of the area of establishment, but transient field populations are possible in northern areas.
K. lycopersicella seems to be better adapted to high temperatures than *T. absoluta* (Annex 3). The arid areas of the PRA area are more at risk because of the high temperatures which supports a higher number of generations.

Protected Cultivation

3.07 - Are the hosts grown in protected cultivation in the PRA area?

Yes

Tomato and eggplant are widely grown under protected conditions (plastic, tunnel, glasshouse) in the PRA area. In the southern part of the PRA area, tomatoes and eggplants are grown extensively under protected conditions (in addition to field cultivation), ensuring all-year round production (e.g. Liguria in Italy, Andalusia in Spain). Tomato in particular, but also eggplant, are extensively grown under protected conditions in the northern and eastern part of the PRA area. In the UK, 150 ha of tomatoes are grown commercially including many premium crops (Korycinska & Eyre, 2010) (216 ha harvested in 2008; Werkman & Sansford, 2010). In the Netherlands 1500 ha of tomato and 90 ha of eggplant were grown under protected cultivation in 2009 (Potting *et al.*, 2010). Data by Meijaard (1992) on glasshouse tomato in northwest Europe (Netherlands, Belgium, Germany, UK, Denmark, Sweden), although out-of-date, can be used as an indication: there were 17,000 ha of tomato grown in total in glasshouses. Tomato was the most important of all glasshouse crops in Belgium, and about one-quarter of the total glasshouse area in the UK and the Netherlands was occupied by tomato crops.

Glasshouses also serve as a source of pest for the infestation of nearby fields when the climatic conditions are appropriate outdoors. Glasshouse conditions are appropriate for establishment, as shown in North America, e.g. in Ontario, Canada (Ferguson & Shipp, 2009). In glasshouses, infestations are initially found close to doorways, along walkways and near wall vents (Shipp *et al.*, 2001). In the USA, initial infestations in glasshouses are recorded to be mostly due to use of infested seedlings.

3.08 - By combining the cumulative responses to previous questions with the response to question 3.07, identify the part of the PRA area where the presence of host plants or suitable habitats and other factors favour the establishment of the pest.

Under protected conditions: the whole PRA area.
In the field, the Mediterranean Basin (with an uncertainty on the northern limit because of conflicting data on thermal threshold for the pest).

Suitability of the area of potential establishment

Host plants and suitable habitats

3.09 - How likely is the distribution of hosts or suitable habitats in the area of potential establishment to favour establishment?

very likely

Level of uncertainty: low

The abundance of plants and the type of plants will influence the suitability (e.g. all-year tomato crops, mixed eggplant-tomato areas, solely eggplant, volunteer plants). In particular, in North Africa, tomato may be grown outdoor all year round. In the countries in the north of the Mediterranean Basin (e.g. Spain or Turkey), tomato are grown outdoors only during part of the year (March-November), which will be less favourable. In many areas where tomato is grown outdoors, tomato is also grown indoors, which would favour establishment.
The pest can establish under protected conditions throughout the PRA area.

Climatic suitability (outdoors)

3.11 - Based on the area of potential establishment already identified, how similar are the climatic conditions that would affect pest establishment to those in the current area of distribution?

largely similar

Level of uncertainty: low

The Mediterranean Basin will be suitable for establishment of sustainable field populations, while the rest of the PRA area (except far North) will be suitable only for part of the year for transient populations (see Annex 3). This will be similar to where the pest occurs in North America.

Competition and natural enemies

3.13 - Based on the area suitable for establishment already identified, how likely is it that establishment will occur despite competition from existing species, and/or despite natural enemies already present?

very likely

Level of uncertainty: low

Competition. Competition is unlikely to prevent establishment. There is one case where competition with the related species *T. absoluta* is thought to have prevented establishment (Sannino & Espinosa, 2010). However, the management practices against *T. absoluta* may have affected *K. lycopersicella* more than competition.

Natural enemies. A large number of species have been identified as natural enemies of *K. lycopersicella* (see Annex 4). Some of these species are present in the PRA area (Fauna Europeae, 2011). However it is not thought that they would be sufficient to prevent establishment of the pest.

Details of uncertainty. Role of competition with *T. absoluta*. Natural enemies occurring in the PRA area. Other species in the PRA area that might attack *K. lycopersicella*.

The managed environment

3.14 - How favourable for establishment is the managed environment in the area of potential establishment?

Highly favourable

Level of uncertainty: low

Host plants (tomato, eggplant, potato) are grown both in the field, in gardens and under protected conditions. In some parts of the PRA area, solanaceous hosts are grown all year round (e.g. in the Mediterranean area), which will favour establishment of the pest. The importance of this factor was also identified where the pest currently occurs. Other hosts (e.g. weeds) that may favour establishment are present. Host plants are also widespread in gardens, with minimal management. Reuse of packing boxes or crates will favour establishment..

3.15 - How likely is the pest to establish despite existing pest management practice?

likely

Level of uncertainty: medium

Existing pest management practices in the field or under protected cultivation

Monitoring. Commercial crops are subject to monitoring, but this might not allow detection of the pest before it is established. Adult, larvae and mines of *K. lycopersicella* may easily be confused with the related species *T. absoluta* or *P. operculella,* which are already present in some areas. The pest is therefore less likely to be identified early after its introduction in these areas.

Pest management practices: tomato, eggplant

Pest control strategies are in place in the PRA area on these crops.

In the Northern part of the PRA area, tomato and eggplant are only cultivated under protected conditions whereas they are cultivated both in fields and under protected conditions in the Southern part.

Tomato.

Strategies followed against *T. absoluta* are presented under 6.04. The main control methods are specific treatments, mass trapping with pheromone traps, use of natural enemies, cultural methods (rotation, sanitation, removal of crops following last harvest, removal of volunteers). The EWG considered that, to the exception of mass trapping, they would also have an effect on *K. lycopersicella*. However, there is an uncertainty on whether this would be the case throughout the region.

Eggplant. Pests that are common in eggplants in protected cultivation include: *Bemisia tabaci* (Genn.), *Trialeurodes vaporariorum* (West.) (Hemiptera:Aleyrodidae), *Tetranychus* spp. (Acarina:Tetranychidae), *Thrips tabaci* Lind., *Frankliniella occidentalis* Pergande (Thysanoptera: Thripidae) and *Spodoptera* spp. (Lepidoptera: Noctuidae).

Establishment

In the field in the PRA area, there are no Gelechiidae pests in eggplant and plant protection products applied against other pests are unlikely to have an effect on *K. lycopersicella*. In Turkey, *Bemisia tabaci,Tetranychus spp., Phyllotreta* spp., *T. tabaci, F. occidentalis* and aphids are common in outdoor eggplant production. Cultural measures can be summarized as removing host weeds or debris and crop rotation. 3-4 insecticide treatments are applied during vegetation period for each pest (Kılıç, pers. comm., 2011).The pesticides efficient against *K. lycopersicella* are mentioned in Table 8 under 6.04, paragraph 3.

<u>All cultivated hosts in organic production or in gardens</u>
Pest management options currently available in organic farms will fail to prevent establishment. In gardens, tomato and eggplant, would normally not be much managed and not subject to insecticide treatments.

Details of uncertainty: medium – practices in other countries in the PRA area. Practices on eggplant

Protected Cultivation

3.16 - Is the pest likely to establish in protected cultivation in the PRA area?

Yes

Level of uncertainty: low

In Canada, the pest cannot survive outdoors but has established in protected cultivation in Ontario. Nevertheless, it should be noted that it was previously recorded in 1946 in Ontario, and in 1970 and 1975 in British Colombia, but did not establish at that time (Shipp *et al.*, 2011). One favourable factor for establishment may have been continuous tomato cropping with a short time between crops (e.g. 1 week; Trumble, personal comm., 2011). In the PRA area, the period free from the host plants is relatively short (1-3 months) and may allow survival of pupae, except in areas with very cold winters when temperature in the greenhouse will be bellow 0°C for several weeks. The current pest management practices under protected conditions (see 6.04) are not likely to prevent establishment, except in areas where *T. absoluta* occurs. In areas where the pest could establish outdoors, the probability of establishment in greenhouses is even larger.

3.17 - How likely are the reproductive strategy of the pest and the duration of its life cycle to aid establishment?

likely

Level of uncertainty: low

The duration of the life cycle was found to vary according to locations and ecoclimatic conditions. It was found to be as low as 18 days at 35°C to over 118 days at 14°C (see table 7 below). The pest normally has several generations per year. Where it is active all year round, it can have over 7 (e.g. Jimenez *et al.* (1988) to up to 10 generations per year. Generations overlap and all stages are available all the time after the first generation (Swank, 1937). This complicates control.

Table 7. Total duration of the life cycle of K. lycopersicella

Publication	Duration	Conditions / comments
Elmore & Howland (1943)	26.4 days 99.7 days	average T: 24-27°C average T: 10-13°C
Swank (1937)	Average: 27.5 days */67.0 days* Minimum : 20 */ 28* Maximum : 43 */ 145*	Comparison Florida / *California*
Geraud-Pouey *et al.* (1997)	26.76 days ± 2.53	T 27.11°C ±1.24; relative humidity 75.5%±10.61; 10 h light
Ferguson & Shipp (2009)	26 days 100 days	24-26°C 10-13°C
Lin & Trumble (1985)	118.4 days 18.6 days 49.9 days	14°C 35°C 20°C
Weinberg & Lange (1980) Cherry tomatoes	Average 37.8 days Average 24.8 days	20°C 30°C

Females lay moderate numbers of eggs (50-140, Swank, 1937). Elmore & Howland (1943) report 42 eggs for unfed females at 21°C, 79 eggs for fed females at 10.3°C and 94 eggs for fed females at 20.5°C. Geraud-Pouey *et al.* (1997) indicate 41 eggs on average per female.

Some other features may favour establishment. Although the pest does not have a resting stage, it is reported that pupae will survive and adults can survive in protected places when conditions are not favourable for normal continuation of the life cycle (Elmore & Howland, 1943; Ferguson & Shipp, 2009). Females (mated or not) were also found to survive for up to 25 days with or without food (see Table 6 in 2.08 of the pathway "plants for planting of tomato and eggplant").

The duration of the life cycle of *K. lycopersicella* and number of eggs are similar to those of *T. absoluta*.

3.18 - Is the pest highly adaptable?

No, moderately adaptable or less

Level of uncertainty: low

K. lycopersicella is considered to be moderately adaptable. It has a narrow host range, limited to few species in the family Solanaceae. There is no indication that it has moved to other hosts during its past expansion. Although it can complete its life cycle in a wide range of temperatures, it seems to also be limited by climatic conditions, especially temperature, and does not survive all year round in some areas (although it is not clear whether this is due to the temperature or to the lack of hosts). Finally competition with *T. absoluta* was suspected in Italy as having prevented establishment of *K. lycopersicella* (Sannino & Espinosa, 2010).

Despite this, a certain degree of adaptability to new conditions can be assumed, as for other Gelechiidae such as *T. absoluta*. The latter was found attacking a plant species outside of its host range (bean) in glasshouses previously used to grow tomato and heavily infested (Sannino & Espinosa, 2010). In addition *K. lycopersicella* has adapted to protected conditions in new areas. It has also developed resistance to several plant protection products under conditions of systematic application of broad-spectrum insecticides, with significant loss of control of the pest (carbamate, methomyl, fenvalerate; Schuster, 2006, Schuster *et al.*, 1996, Brewer *et al.*, 1993).

Details on uncertainty: medium. Host adaptability unknown

3.19 - How widely has the pest established in new areas outside its original area of distribution? (specify the instances, if possible; note that if the original area is not known, answer the question only based on the countries/continents where it is known to occur)

moderately widely

Level of uncertainty: medium

The origin of *K. lycopersicella* is unclear, but is probably around Mexico. The pest seems to have spread to new areas in the Americas and the Caribbean region, although it is not always clear whether some detections were due to new introductions or to emergence as a pest of a species already present.

In North America, the pest was first identified in 1923 (California) and was reported by Elmore & Howland (1943) to have spread northwards in the USA. It has also more recently reached some areas where it is sporadic or present only in glasshouses (e.g. Ontario, 1991, with previous outbreaks; Shipp *et al.* 2001).

In Central America, it is also difficult to determine if the first observations correspond to new introductions or to emergence as a pest (e.g. Venezuela, 1978 - Geraud-Pouey & Perez, 1994; Costa Rica, 1985 - Trivelato, 1989).

In the Caribbean, Cock (1985) mentions that it became prominent in Trinidad in the 1970s, but no reference was found to its introduction. In Jamaica, the first record (Henry & Rudert, 1975) seems to be related to an introduction. Elmore & Howland (1943) report interceptions from the Bahamas and Cuba, suggesting that this pest was already present in the Caribbean region.

K. lycopersicella is not reported outside the Americas or the Caribbean. There was one finding reported in the literature from Italy in 2008 but the pest did not establish (Sannino & Espinosa, 2010). Although the source of the pest is not known, it is suspected to have been transported in international trade or exchange of material.

The only interceptions found in the literature are those on tomatoes from the Bahamas and Cuba (Elmore & Howland, 1943). No interception of *K. lycopersicella* was reported in the EPPO Reporting Service 2006-2011, and no other mention of recent interceptions was found.

Details of uncertainties. Whether new detections correspond to introductions, or to situation where an insect that was already present suddenly emerged as a pest.

3.20 - The overall probability of establishment should be described.

high

Level of uncertainty: low

The overall probability of establishment is high. The pest could establish in greenhouses throughout the PRA area and outdoors in the Mediterranean Basin. Hosts are available, there is a good climate match between the Mediterranean Basin and part of the area of origin, and the reproductive strategy of the pest would favour establishment.

Stage 2: Pest Risk Assessment Section B: Conclusion of introduction

c1 - Conclusion on the probability of introduction.

The overall probability of entry is likely, and the probability of establishment is considered as high. The volume of all pathways is low. For fruit of tomato, there has been a significant increase of imports particularly from the Dominican Republic over the past 5 years. In many countries of the PRA area (incl. the EU), there is no compulsory inspection of fruit. The overall probability of introduction is rated as moderate to high.

A worst-case scenario (with the highest probability of introduction), would be entry on fruits of tomato with vine to the Mediterranean Basin (where hosts are grown both in the field and under protected conditions, and where the pest can survive outdoors). Another important factor would be if these tomatoes are destined to facilities near to where tomatoes are grown.

In relation to establishment, the most important factors are that host plants are widespread and that the climate is suitable in the area of potential establishment. The managed environment and natural enemies in areas where *T. absoluta* occurs could have a negative effect on establishment.

Stage 2: Pest Risk Assessment Section B: Probability of spread

4.01 - What is the most likely rate of spread by natural means (in the PRA area)?

moderate rate of spread

Level of uncertainty: medium

There are two means of natural spread by adults.

Flight. Precise data are lacking, especially on distances, but a few elements are mentioned in the literature. Adults are nocturnal. During the day, if disturbed, they take flight in an erratic manner or in a spiral and land on plants within a few metres (Poe, 1973, Swank, 1937). During the night, adults have longer flights and may move within or between fields (Poe, 1973). Swank (1937) noted that natural spread is probably longer at night and accounts for spread within a given area (although specifying that natural spread is unlikely if fields are separated by miles of uncultivated land). Movement of adults between fields is recorded (Wiesenborn *et al.*, 1990, Poe, 1973). For this reason it is necessary to ensure there is sufficient isolation between fields treated with pheromone for mating disruption and non-treated fields so as to prevent the entry of mated females from other fields (van Steenwyck & Oatman, 1983). Movements of adults between infested glasshouses and fields has also been reported.

Wind. Within North America, *K. lycopersicella* is transported on storm fronts (it was collected during a study on movement of moths on weather fronts but only findings of *Helicoverpa armigera* were published by Wiesenborn et al., 1988, Trumble, pers.comm., 2011). In the case of *T. absoluta*, natural spread by dominant winds related with high populations was observed in the area of Murcia and Almeria (Monserrat, pers.comm., 2011).

Details on uncertainty: Medium. lacking data on distances of adult flight.

4.02 - What is the most likely rate of spread by human assistance (in the PRA area)?

high rate of spread

Level of uncertainty: low

The pest can move with fruit, plants for planting, soil and conveyances (especially crates which have carried infested tomatoes). There is a massive movement of tomato and eggplant fruits between countries of the EPPO region (CIRAD, 2009). Countries within the EPPO region tend to produce their own seedlings (see 2.05). However there is some movement of plants for planting of tomato and eggplant (Werkman & Sansford, 2010). Crates which have been used to transport tomatoes have been identified as sources of movement of *T. absoluta* in the UK and the Netherlands, and a similar situation could occur for *K. lycopersicella*. Movement on vehicles (hitch-hiking) has been observed for *T. absoluta* (Monserrat, pers.comm., 2011), but this was observed only in the case of very high populations of *K. lycopersicella* (Trumble, pers.comm., 2011).

In relation to local spread, adults of the pest may be transported on workers' clothing.

4.03 - Describe the overall rate of spread

high rate of spread

Level of uncertainty: low

The rate of spread would be high in the absence of control of movement of host plants and plant products, and packaging material which has carried infested consignments.

4.04 - What is your best estimate of the time needed for the pest to reach its maximum extent in the PRA area?

Level of uncertainty: high

The situation of the related species *T. absoluta* (same family, same main host and similar management practices) can be used to help determine the response. *T. absoluta* has shown a rapid spread since its introduction to the PRA area in 2006. This pest has not established in some countries where eradication has been possible at each finding because the pest entered under protected conditions, but it would have done so if measures had not been taken. In a similar way, the time for *K. lycopersicella* to reach areas suitable for its establishment outdoors would be greater than 5 years. As for *T. absoluta* it is assumed that it will be possible to prevent its establishment under protected conditions in some areas of production.

If the point of entry is a country in the Mediterranean Basin, the scenario would be the same as for *T. absoluta*, with a fast rate of spread throughout the area of potential establishment. Where *T. absoluta* occurs, it is likely that the current experience and management will limit populations and slow the spread of the pest. However, if the points of entry is a country where tomatoes are grown only under protected conditions, the spread would be slower and it would take longer to reach its maximum extent without human assistance.

The pest has not spread, either in Italy or across the EPPO region, since the outbreak in outdoor crops in Italy in 2008.

4.05 - Based on your responses to questions 4.01, 4.02, and 4.04 while taking into account any current presence of the pest, what proportion of the area of potential establishment do you expect to have been invaded by the organism after 5 years?

Level of uncertainty: low

The pest does not occur in the PRA area. If it was introduced to the Mediterranean Basin, it could be envisaged that after 5 years it would have reached a significant part of the area suitable for its survival outdoors, as well as part of the tomato production under protected conditions. If it was introduced in the north of the PRA area where most tomato crops are grown under protected conditions, after 5 years it is unlikely it would have spread to other countries (as eradication is possible). Multiple introductions in different areas would allow spread to be more rapid within the PRA area.

Stage 2: Pest Risk Assessment Section B: Eradication, containment of the pest and transient populations

5.01 - Based on its biological characteristics, how likely is it that the pest could survive eradication programmes in the area of potential establishment?

likely

Level of uncertainty: low

The likelihood to survive eradication programmes would depend on the conditions of the introduction, and is rated as follows:
- Very unlikely: introduction outdoors (field or garden) in an area where *K. lycopersicella* cannot survive outdoors (but in this case the likelihood is due to its impossibility to overwinter, and not to eradication measures).
- Unlikely: introduction under protected conditions in an area where *K. lycopersicella* cannot survive outdoors
- Likely: introduction under protected conditions in an area where *K. lycopersicella* can also survive outdoors.
- Very likely: introduction outdoors (field or garden) in an area where *K. lycopersicella* can survive outdoors.

Due to the pest's life habits (hidden stages, high number of generations, number of eggs), eradication would be difficult, in a similar manner to *T. absoluta*. The worst situation for eradication would be if the pest was introduced outdoors (field or gardens) in an area where it can also overwinter outdoors. Some natural spread would occur and the pest could find cultivated hosts (commercial or in gardens), volunteer plants or wild hosts. *K. lycopersicella* also has a large number of generations per growing season in favourable conditions.

In the case of introductions under protected conditions, eradication would be possible if it occurred before the pest has multiplied and before it escapes outdoors. The pest is reported to readily infest fields outside of glasshouses in which it has arrived. Eradication would be easier in areas where the crop is grown only under protected conditions or when climatic conditions are not suitable to its overwintering outdoors.

In some situations, eradication is likely to require application of more stringent measures, including the application of plant protection products and appropriate sanitation in the glasshouse.

Eradication would in all cases rely on early detection of the pest and application of measures. Early detection requires trapping and monitoring of leaves to detect larvae (Schuster, 2006). It also requires identification capabilities as the pest might be confused with other Gelechiidae leaf miners present in the PRA area, e.g. *T. absoluta* or *P. operculella*. However identification keys exist and several publications detail the differences (e.g. Sannino & Espinosa, 2009, ChemTica Internacional, undated). Small populations may be detected using pheromone traps. The pest might be monitored using specific traps with pheromones (e.g. sticky board traps or soapy water traps - ChemTica Internacional, undated; Pherocon 1C traps baited with pheromone dispensers - Schuster, 2006) or general traps such as yellow sticky traps, with identification of trapped insects.

The disappearance of *K. lycopersicella* from Italy following an outbreak in 2008 is not considered to be an eradication, but that it was due to unfavourable competition with *T. absoluta* (Sannino & Espinosa, 2009 & 2010). It should be noted that in November 2008 the infested crops were destroyed and the soil was treated with a suitable insecticide (Sannino, pers. comm. 2011).

5.02 - Based on its biological characteristics, how likely is it that the pest will not be contained in case of an outbreak within the PRA area ?

Moderately likely

Level of uncertainty: low

Very likely: for field crops and gardens
Moderately likely: under protected conditions in an area where *K. lycopersicella* can also survive outdoors
Unlikely: under protected conditions in an area where *K. lycopersicella* cannot survive outdoors

In case of an outbreak outdoors, it is very likely that the pest will not be contained. Natural spread will occur if ecoclimatic conditions are favourable to survival of the pest. Adults fly and may find host plants in the vicinity (cultivated plants in commercial cultivation or gardens, volunteer plants). Adults may be transported by wind. Weeds may act as alternative hosts. *K. lycopersicella* also has a large number of generations and a

short life cycle in favourable conditions.
However it should be noted that, after years of intensive pest management based on mating disruption over a wide area, the pest has been largely suppressed from tomato field in California (Trumble, pers. comm., 2011)

In the case of an outbreak under protected conditions, the pest might be contained if appropriate measures can be taken. This is more likely in areas where the pest cannot survive outdoors, as it is reported to readily infest fields outside of glasshouses in which it has arrived. As for eradication, containment would depend on early detection and application of control measures (see 6.04 for measures that may be applied).

5.03 - Are transient populations likely to occur in the PRA area through natural migration or entry through man's activities (including intentional release into the environment) or spread from established populations?

Yes

Level of uncertainty: low

Transient populations may occur if the pest enters gardens or outdoor cultivation in the part of the region where the pest cannot overwinter outdoors, if the pest enters these areas at an appropriate time of the year (e.g. on infested plants for planting, packaging or fruit, or escaping from infested glasshouses, transported by wind). Unless the pest is present or enters glasshouses, these infestations would be transient and the pest would disappear with the end of the crop and the arrival of winter.

Among other examples where the pest is transient, Kline & Walker (2007) note that *K. lycopersicella* is a sporadic pest in New Jersey, USA. It does not typically overwinter, although it may overwinter in sheltered areas like glasshouses.

Stage 2: Pest Risk Assessment Section B: Assessment of potential economic consequences

6.01 - How great a negative effect does the pest have on crop yield and/or quality of cultivated plants or on control costs within its current area of distribution?

minor (with IPM in place)
Major (without IPM)

Level of uncertainty: medium

Reports of pest damage in the literature vary depending on whether they were made before the development and implementation of integrated measures (especially for early introductions or in areas where integrated pest management is not widely used in tomato) or after. The importance of *K. lycopersicella* as a pest has diminished in places where IPM is implemented (e.g. California, Mexico). The fruit loss is minor but there are still control costs in Mexico. The current situation in Central America, South America and the Caribbean is not known as no recent literature was found for these countries.

Larval feeding on leaves may lead to losses of plants (destruction of large number of young tomato plants in seedbeds mentioned by Swank, 1937), diminution of the growth of plants and diminution of yield. However the most serious damage is that done by larvae to fruit. Larvae cause direct damage to fruit. In tomato, the following is reported: loss of yield and quality, rejection of crops (as some markets have a low tolerance for cosmetic damage) and indirect losses by development of secondary rots. Tomatoes attacked when small become leathery and remain green in the centre when mature; the interior of the seed cavity might turn black (Swank, 1937). Minor damage to fruit may make them unmarketable where there is a low tolerance of insect presence and damage to fresh produce (Brewer *et al.*, 1993, Korycinska & Eyre, 2010). Secondary rot in the wounds makes the fruit unsuitable for consumption. Larval fragments might be present in processed tomato products (Swank, 1937, Morales-Payan & Santos, 1998). Such contamination of the final product of tomatoes for processing is also mentioned by Sannino & Espinosa (2010) in relation to the related pest *T. absoluta* in Italy, with larvae (that are about the same size as *K. lycopersicella*) found in canned peeled tomatoes.

In the USA, in the early years of infestation following the detection of *K. lycopersicella* in 1923, the pest was reported to cause heavy losses, such as: 85% of tomato fruit infested in a field, 60-70% infestation of fruit, 40% loss or abandonment of fields due to damage; 8-99% infestation in surveys in fields in southern California; 87% infestation in glasshouse. Losses were more severe in areas of almost continuous tomato production or where outdoor crops were sown before the residues of the previous crop had been destroyed (Elmore & Howland, 1943). However *K. lycopersicella* has been reported as a major pest mainly since the 1970s. In California, complete crop losses were reported despite frequent insecticide applications (Batiste & Olson, 1973). Fruit infestation in autumn harvest period ranging from 0.25% in 1973 to 39.2 % in 1977 (with peak at 70.2 %) (southern California, Oatman *et al.*, 1979). In Florida, the pest became a concern in late 1972 when populations attained economically damaging levels (resulting from cultural practices, intensified plant production and shifts in the nature of plant protection products; Poe *et al.* 1974). Jimenez *et al.* (1988) noted that the pest has become a serious pest of cherry tomato probably as a result of the long production season and cultural practices unique to the crop (host available for 6-9 months; 6-7 generations during a season). In the USA the pest is now controlled mostly through IPM strategies (except where it is sporadic) but is still recorded as a pest and recommendations are made for its control (e.g. USDA, 2010; Trumble, 1997). Control is IPM based on mating disruption and "as needed" use of avermectin (first developed in Mexico, Trumble & Alvarado, 1993, and later applied in the USA). Implementation of IPM in USA started in 1991 and by 2001 the pest was no longer a significant problem. By 2007 *K. lycopersicella* could not be found in the field. It has largely been eliminated in California (not trapped nor found in the field for nearly a decade; Trumble, pers. comm., 2011).
In the USA, it is considered that the cost of managing all tomato pests (including *K. lycopersicella)* is about 200 USD per ha for pesticides plus 200-300 USD per ha for the specific pheromone for mass trapping (Trumble, 1998; Trumble, pers. comm, 2011).

In Mexico, *K. lycopersicella* emerged as the most important pest of tomatoes in the 1980s. It is mentioned as the most important pest of processing and fresh market tomatoes in several areas of Sinaloa (major tomato-production area of Mexico). Percentage of loss of tomato fruit linked to all insect pests ranged from 25-100% (Alvarado-Rodriguez & Rivera-Rubio, 1990) despite frequent use of broad-spectrum insecticides (metamidophos, methomyl, permethrine, fenvalerate - 10-25 applications per crop), in situations where the host is available all year round. In 1986-1987, harvesting was unprofitable due to high infestation. In the 1980s quality standards of processing tomato for exports to the USA were affected due to insect fragments in fruit and pesticide residues in tomato paste. Fresh market tomato producers also faced problems of high residues and adverse effects on natural enemies (among others). The development of an IPM programme started because of extensive attacks/damage leading to up to 40 applications of 2-6 pesticides per crop without commercially acceptable control. Fruit production was lost from entire fields, and shipments for export to the USA and Canada were routinely rejected (Trumble & Alvarado-Rodriguez, 1993; Trumble, 1997). Nowadays IPM is implemented and *K. lycopersicella* is no longer considered as a major pest (Trumble, pers. comm., 2011).

In Central America, *K. lycopersicella* has been reported to be a severe pest of tomatoes locally, especially when insecticides have reduced populations of its natural enemies (CABI, 2007). In Panama, losses of 10-50% were reported on tomato (Guevara-Chavez, 2000). In Costa Rica, *K. lycopersicella* was reported as an important pest in tomato in the mid-1980s. In 1985 100% damage was reported in a field, with variable damage in several other tomato growing regions (10-60% losses). In 1987, in one area of the country the pest caused 22% fruit damage on average (9.5 to 35%), with 18% yield loss on average (Calvo-Domingo *et al.*, 1990; Trivelato, 1989; Ramirez *et al.*, 1989).

In Colombia, larval attack produced losses calculated as 30-40% for some municipalities. Larvae cause damage to fruits, floral forms and leaves, although leaf injury is not often serious (Figueroa Potes, 1951).

In the Caribbean, the pest was reported to cause problems in Jamaica when it was first detected (Henry & Rudert, 1975), with serious outbreaks. In the Dominican Republic, direct damage to tomatoes and indirect damage (fruit decay pathogens, presence in the product of processing) are mentioned (Morales-Payan & Santos, 1998). In Cuba, the pest became a major pest under protected conditions. Approximately 80% infestation was found in a survey of 4 Cuban glasshouses (Elizondo Silva *et al.*, 2005; Sierra Peña *et al.*, 2009). In Trinidad, *K. lycopersicella* is a pest of tomatoes and eggplant and became important since the 1970s, probably as a result of intensive usage of insecticides and destruction of natural enemies. Heavy damage was reported in commercial crops in the 1970s with sporadic outbreaks, but data at the beginning of the 1980s showed low fruit infestation level ranging from 0.22 to 1.89 % under different conditions; the low damage was attributed to the presence of a large number of natural enemies (Cock, 1985; Jones, 1985).

On eggplant. Occasional damage is reported and it is considered to be a major pest of eggplant in Florida, for which control is implemented and in Guyana (USDA, 2010; Ministry of Agriculture of Guyana, undated; Sparks & Riley, 2011). It is also a pest of eggplant in Trinidad (Cock, 1985). Damage results from the larvae feeding on leaves, stems and fruit (USDA, 2010). In the USA, damage on fruit is cosmetic and larvae do not enter into the fruit (Schuster, pers.comm.). No details are available from Guyana and Trinidad.

6.02 - How great a negative effect is the pest likely to have on crop yield and/or quality of cultivated plants in the PRA area without any control measures?

massive

Level of uncertainty: low

The level of damage will vary but is likely to be massive for tomato and eggplant in the absence of measures. The pest would cause a direct decrease in yield. Whole fruit harvests may also be unmarketable due to low tolerance for quality defects and presence of larvae in fruit (for consumption or processing). Less than 1 larva per plant can result in economic damage (Wisenborn *et al.*, 1990; Pena, 1986; Ramirez *et al.*, 1989) (see 6.01).

6.03 - How great a negative effect is the pest likely to have on yield and/or quality of cultivated plants in the PRA area without any additional control measures?

moderate/major

Level of uncertainty: medium

Major where measures are not applied against *T. absoluta*
Moderate where measures are applied against *T. absoluta*

Control methods successfully applied against *T. absoluta* where it occurs (with the exception of mass trapping as such method is species-specific) are likely to have an effect on *K. lycopersicella*. The measures applied against *T. absoluta* that would also have an effect on *K. lycopersicella* are described in 6.04.

In the part of the PRA area where no measures are applied against *T. absoluta*, although some measures applied against other pests may have an effect on *K. lycopersicella*, it is likely that their mode of action and/or timing would not be adequate to control *K. lycopersicella* and avoid damage. It has been regularly observed that efforts to control other tomato pests with insecticides might favour *K. lycopersicella* (and the reverse) by having negative effects on its natural enemies (CABI, 2007; UC-IPM, 2008; Chirinos & Geraud-Pouey, 1996; Geraud-Pouey *et al.*, 1997). On eggplant (USDA, 2010) *K. lycopersicella* is often seen when non-selective insecticides are used for management of whitefly and where this has reduced populations of natural enemies. Such situations may also arise in the PRA area if there are natural enemies. In potato, control measures applied against the related *P. operculella* might have an effect but might not have appropriate timing to control *K. lycopersicella* as they are applied late in the season.

In countries where *T. absoluta* does not occur, control measures on tomato crops include (from draft PRA on Ca. *L. solanacearum*, EPPO, 2011a, Sannino & Espinosa, 2011):

- *Pest control*. Technical advice for protected crops is highly developed in most parts of the PRA area. However, cropping under protected conditions often relies on IPM strategies targeting specific pests, including targeted biological control agents.
- Important pests of tomato are aphids, whiteflies (*Trialeurodes vaporariorum*), mites (*Tetranychidae*) and thrips, and active substances are registered against these pests in some countries. In Germany for example, approved substances are: thiamethoxam, imidacloprid, buprofezin, fenbutatin-oxid, cypermethrin, abamectin, lambda-cyalothrin, deltamethrin, azadirachtin. A few of these are also effective against *K. lycopersicella*, but would have to be registered for this purpose.
- *Monitoring*: Tomatoes are grown over 9 to 11 months per year. A regular monitoring of pests is usually performed and might allow detection of the pest. Yellow traps are normally used and could trap *K. lycopersicella*. However there is a risk of confusion with *T. absoluta* and *P. operculella*.
- *Crop rotation*. Crop rotation might be used in glasshouse tomatoes against some pathogens; or pests, such as spider mites (*Tetranychus urticae*), several species of aphids, leaf mining flies (*Liriomyza bryoniae*), thrips (*Frankliniella occidentalis*) (EPPO draft PRA on Ca. L. solanacearum, EPPO 2011a). However, such crop rotation is not commonly used because tomato producers are generally highly specialised and tomato crop under protected conditions may remain at the same place for several years.

Potting (2009) estimates economic consequences of the establishment of the pest for the Dutch tomato industry to be 5-25 million EUR per year due to crop losses and 4 million EUR per year due to pest management in a worst case scenario.

Details of uncertainty. Medium. Current measures applied in eggplant production are not known.

6.04 - How great a negative effect is the pest likely to have on yield and/or quality of cultivated plants in the PRA area when all potential measures legally available to the producer are applied, without phytosanitary measures?

moderate

Level of uncertainty: medium

Minor for highly managed/technical protected crops, especially where *T. absoluta* already occurs. Moderate for all others.

The rating varies depending on the type of crop, as well as on the pests already present and how they are managed. The impact may be major in the first years before there is experience with the new control techniques and necessary plant protection products/pheromone are registered. Where *T. absoluta* is present in the PRA area, most of the measures that would be used to control *K. lycopersicella* are already applied, and the additional measures to be applied would only be detection (pheromone, visual inspection, yellow sticky trap) and mating disruption.
There is an larger uncertainty on what will happen if *K. lycopersicella* enters in some parts of the PRA area where there is no experience with *T. absoluta*.

From the literature available from the USA and Canada (see 6.01), the pest has a minor impact when appropriate measures are applied. As is the case for these countries, the threshold of economic damage on tomato or eggplant fruit is expected to be low in the PRA area, as there is a similarly low tolerance for quality defects or presence of larvae in fruit for the fresh market or for processing. The pest is therefore still likely to cause some level of damage despite control measures. In the first phase of its introduction, *K. lycopersicella* would presumably cause disruption of integrated plant protection programmes due to an increase in the use of insecticides, where *T. absoluta* does not occur. Producers would presumably be faced with a similar situation for *K. lycopersicella* as reported by Desneux *et al.* (2010) for *T. absoluta* some years after its introduction in Europe: *T. absoluta* triggered extensive insecticide use (with potentially undesired side-effects and development of resistance), fully satisfactory effective management options were lacking and there was an urgent need for economically-sound, environmentally-friendly and effective IPM strategies.

Control measures that may be applied by producers against *K. lycopersicella* in the PRA area
Control should be aimed at bringing the level of infestation below the economic damage threshold. This will vary and is dependent upon a number of factors. In places where the pest overwinters outdoors, measures should also aim at reducing the overwintering population, as this can later attack crops (UC-IPM, 2008). Mota-Sanchez *et al.* (2003) notes that control measures need to be targeted at field edges where infestations tend to start. Awareness of growers is important in all cases for an early detection and effective control of the pest.

In tomato production
Current control strategies where the pest occurs rely on a combination of cultural control methods, chemical control timed based on the results of monitoring, and in some situations, mating disruption. Where *K. lycopersicella* is a major pest, measures are commonly integrated with those targeting other pests of tomato, including in integrated pest management systems. IPM strategies have been successful in controlling the pest in California where it has largely been eliminated from tomato production (Trumble, pers. comm., 2011).

The following measures would be effective in controlling *K. lycopersicella* on tomatoes in the PRA area as part of an integrated approach:
1- detection (pheromone, visual, yellow sticky trap)
2- mating disruption and mass trapping
3- insecticides
4- cultural control
5- biological control

It is noted that the negative effects may be greater in production of tomato for processing as the margin is lower. Management options will be more limited for such tomato.

1- Detection
Monitoring relies on use of traps and visual inspection. Use of pheromone traps in fields near tomato fruit packing stations will be useful to detect early infestation linked to the import of infested fruits. Use of pheromone for monitoring does not need a specific registration in most EPPO countries.

Monitoring can be done using pheromone traps. Yellow sticky traps can also be used and are recommended for early detection of infestations in glasshouses (e.g. Ferguson & Shipp, 2009). Use of pheromone for monitoring would not require an official registration, in many countries of the PRA area (e.g. the EU) but registration may be needed in some countries (e.g. Turkey). Experience in Spain showed that there may be accidental captures of *T. absoluta* in pheromone traps for *K. lycopersicella* in the case of high populations of *T. absoluta (*Monserrat, pers. comm., 2011). Careful examination of traps by specialists is therefore needed to confirm the first detections.

In most cases, *K. lycopersicella* is typically present first on the edge or near the stakes in the fields, and in glasshouses near the edges. Visual inspection should target these places. In the crop, visual inspection most typically targets larvae on leaves, but may target damage on fruit (including frass around the calyx) (Sparks & Riley, 2008). Visual inspection may be difficult if other leafminer species are present. Surveys start as soon as seedlings are well established and are conducted weekly until treatments are necessary.

Examples of monitoring programmes and thresholds are given below.
- In Mexico (Troyo-Diéguez et al., 2006). Plant inspection by sampling directly small fruits on 10 plants at each sampling point, and 20 sampling points per ha in a zigzag, with an action threshold of 2-3% of fruit infested by larvae. Trapping with 20 sex pheromone traps per ha and action threshold of 20 adults in traps.
- In Florida (reported in Kline & Walker, 2007). Sampling of the lower leaves and treatment when the larval population exceeds 0.7 larvae per plant. Once threshold populations are present, the crop is treated weekly. Schuster el al., 2000 recommend implementing mating disruption above the threshold of 5 moths/trap/night.
- In California (UC-IPM, 2008). Pheromone traps set at planting (one trap for 10 acres –about 4 ha- but no fewer than two traps per field; and one trap without a lure as the control), distributed throughout the field. Trap inspection twice a week from planting to harvest. When adults start being trapped, monitoring of foliage for larvae starts. The foliage is surveyed for mines and folded leaf shelters in several sections of the row (each 6 feet long – about 1.8 m) chosen at random throughout the field. Treatments start when an average

of 1 to 2 larvae per row section are found (broad spectrum insecticide treatments may have to be pursued until harvest).
- Staked tomato plants grown in the autumn in southern California (Wiesenborn et al., 1990). Sampling larvae on foliage to time the start of weekly insecticide applications, when the threshold reaches approximately 0.5 larvae per plant (based on plant density of 6.5 plants per 3 m).

2- Mating disruption and mass trapping
Use of pheromones for mating disruption will be efficient but would first need registration in many countries of the PRA area (e.g. EU, Turkey). This may delay the use of such technique for a few years after the pest introduction.

Mating disruption is one main component of IPM programmes against *K. lycopersicella* both under protected conditions and in the field (Trumble & Alvarado-Rodriguez, 1993; Casagrande & Jones, 1997; Troyo-Diéguez *et al.*, 2006; Jimenez *et al.*, 1988, USDA, 2005, Mota-Sanchez *et al.*, 2003). McLaughlin *et al.* (1979) demonstrated the existence of the pheromone and the crepuscular mating behaviour of the pest. These require proper distribution and rates of pheromone emitters (Swanson & Stansly, 1995), as well as appropriate dispensers and formulations (Schuster *et al.*, 2000). Mating disruption is generally combined with a monitoring programme in order to determine when populations reach treatment thresholds; insecticides are then applied (UC-IPM, 2008). Mating disruption is reported to work well for *K. lycopersicella* provided that populations are relatively low (i.e. mating disruption should be applied before population build-up) and the treated area is large or isolated from other sources of pest (to avoid damage due to mated females dispersing from infested fields into the treated area, and when preceding crops do not provide immigrant moths). It allows growers to reduce the number of pesticide treatments per season (e.g. from 12-16 to 1-2 according to Jimenez *et al.*, 1988). Pheromones used to be considered as expensive to produce and costly to use (e.g. USDA, 2002), but newer formulations are less expensive (e.g. less than a couple of pesticide application), easy to use and a single application last the entire cropping season.

Attract and kill methods have been used in the USA (e.g. Jimenez *et al.*, 1988).

There is no information on use of mass trapping at origin, but it is a method which has proved effective against *T. absoluta* in some situations and could be used against *K. lycopersicella* (e.g. in the glasshouse) (see e.g. Chermiti or Jacobson, in the EPPO/OIBC/FOA/NEPPO joint international Symposium on management of *Tuta absoluta,* EPPO 2011b).

3- Application of plant protection products
Control of tomato pests including *K. lycopersicella* initially relied on the application of broad spectrum insecticides, with negative effects on populations of natural enemies and triggering outbreaks of other pests. In addition, build-up of populations in the season is often observed following multiple use of broad spectrum insecticides (Sparks & Riley, 2008). Large number of sprays were applied: in Costa Rica, 20 sprays on average during the dry season and 33 during the wet season to control insects and fungi of tomato (Trivelato, 1989); in Panama, up to 24 sprays in winter against tomato pests (Guevara-Chavez, 2000). Resistance to plant protection products has arisen (carbamate, methomyl; fenvalerate; esfenvalerate; Brewer *et al.*, 1993, Schuster, 2006, Schuster *et al.*, 1996). It is now regocginzed that broad spectrum insecticides should be avoided or used with care. Rotating plant protection products is advised where intensive use of insecticides is necessary in order to avoid the appearance of resistance (Seal & McCord, 1996). The development of IPM programmes was advocated to limit the quantity of plant protection products applied.

Applications of pesticides against *K. lycopersicella* mostly target the first and second larval instars, but timing is complicated because of the long ovipositional period, short generation time, overlapping generations and movement of adults between fields (Wiesenborn *et al.*, 1990). In tomato insecticide treatment programmes are generally applied weekly when a certain incidence is reached, and may lead to 7-9 applications where mating disruption is not used.

Of the active substances mentioned in the literature, the ones listed in Table 8 are considered to be effective where the pest is present (from Schuster, 1982; Williamson & Murray, 1993; Jansson *et al*., 1997, Morales-Payan & Santos, 1998; Kline & Walker, 2007; UC-IPM, 2008; Sparks & Riley, 2011; OSU, 2010; USDA, 2002; USDA 2005 - data from older publications are not given here), or likely to have an impact based upon the experience with *T. absoluta* in the PRA area. In theory they could be used against *K. lycopersicella* in the PRA area. For tomato production, most of these active substances are already registered in some (but not all) countries of the PRA area. In the UK for example only has 4 of those listed in the table below as approved for use in tomato and eggplant (i.e. abamectin, *Bacillus thuringiensis* subsp. *kurstaki*, indoxacard, spinosad), They may still need to be registered for specific use against *K. lycopersicella* even where they have approval for use in these crops..

Table 8. Active substances used against *K. lycopersicella* in tomato production in the USA and registered in at least some EPPO countries in tomato production for control of Lepidoptera pests including *T. absoluta* (source: references listed above, EWG and EPPO 2011b)

Active substance	**Remark**
abamectin	(also used in eggplant production in Turkey)
azadirachtin	registered in some countries of the PRA area against *T. absoluta (*e.g. Turkey). No data on specific efficacy against *K. lycopersicella*. Authorized in organic production.
Bacillus thuringiensis subsp. *kurstaki*	can work on 3rd/4th instars - not eggs, or 1st and 2nd instars. authorized in organic production. registered in Turkey, Greece against *T. absoluta* on tomato.
chlorantraniliprole	already registered against Lepidoptera in general, including *Tuta*, in some countries of the PRA area (e.g. Spain, Greece)
deltamethrin	not compatible with IPM
emamectin benzoate	Authorized temporally at national level e.g. in Spain, Greece but not yet registered at the EU level (Status under EU 2009 Reg. No 1107/2009: pending). Registered in Turkey against *Heliothis armigera, Heliothis viriplaca* on tomato, and *Spodoptera littoralis* on eggplant.
esfenvalerate	resistance problem in the USA
flubendiamide	Registered in Greece against *T. absoluta* on tomato
indoxacarb	(also used in eggplant production in Turkey)
lambda-cyhalothrin	not compatible with IPM
metaflumizone	registered in some EPPO countries (e.g. Turkey, Italy) against *T. absoluta.* No data on specific efficacy against *K. lycopersicella*
methomyl	resistance problem in the USA
novaluron	registered in Turkey against *Heliothis armigera, Heliothis viriplaca* and *Spodoptera littoralis* on tomato not registered yet in the EU according to Reg. (EC) No 1107/2009:
spinetoram	not compatible with IPM
spinosad	authorized in organic production (also used in eggplant production in Turkey)
zeta-cypermethrin	not compatible with IPM

4- Cultural control

The following cultural control methods are mentioned in the literature against *K. lycopersicella*. Most (except the first one) are already implemented where *T. absoluta* occurs in the PRA area.

- use of *K. lycopersicella*-free seedlings (Poe, 1973; Pena & Waddil, 1985; UC-IPM, 2008, Schuster, 2006)
- safe removal and destruction of plant residues after harvest.
- removal and destruction of plant tissue, infested fruits and packing materials where larvae may pupate (CABI, 2007)
- disinfestation of crates and packing cases between facilities and before entering production areas
- destruction of volunteers (Schuster, 2006). In certain situations (e.g. Spain) some volunteer plants are kept or planted for the purpose of maintaining natural enemies of *T. absoluta*.
- destruction of solanaceous hosts in the field's vicinity (UC-IPM, 2008), of plants growing from seed in compost heaps (Poe, 1973) and cleaning of drainage ditches and irrigation canals where alternative hosts grow (Alvarado-Rodríguez & Rivera-Rubio, 1990; Mota-Sanchez *et al.*, 2003), cleaning of harvesting equipment, prevention of movement with machinery
- establishment of host-free periods to break the cycle of pest reproduction (Elmore & Howland, 1943, UC-IPM, 2008; Mota-Sanchez *et al.*, 2003). To be effective this should be applied on an area-wide basis. Crop rotation is already applied on field tomato in some parts of the PRA area. It might help

control the pest, although it would be difficult to eliminate all alternative hosts and volunteer plants. UC-IPM (2008) advises that crop rotation as a management tool for this pest is not practical because it must be practiced on an area-wide basis and include the removal of solanaceous weeds. Pena & Waddil (1985) observed that larval levels of *K. lycopersicella* and the number of volunteer tomato plants were higher when beans or other vegetables were planted immediately after tomato (than when the field was disced or left abandoned), presumably due to irrigation and herbicides used in the new crops (as these did not control tomato volunteers).

5- Use of biological control agents

Annex 4 lists known natural enemies of *K. lycopersicella* in the area of origin. In Ontario, several publications mention *Trichogramma pretiosum* as a promising tool for controlling *K. lycopersicella* in glasshouses to complement mating disruption, which is the main method used (Shipp *et al.*, 2001; Ferguson & Shipp, 2009; Wang & Shipp, 2004). No later publications were found on whether *T. pretiosum* is now used in practice. Wang & Shipp (2004) also mention that the cost of control would be 450 USD per ha at a release rate of 75 parasitoids per plant; economic damage trials on glasshouse tomatoes to determine the relationship between the number of pests and economic damage to the fruit had not been conducted at that time. Release of *T. pretiosum* is also mentioned by Trumble & Alvarado-Rodriguez (1993), used in conjunction with intensive sampling, mating disruption technique and applications of *Bacillus thuringiensis* and abamectin (with a maximum of 25% of parasitised eggs). Several earlier attempts of release of biological control agents have failed in Trinidad and Hawaii (Funasaki *et al.*, 1988; Jones, 1985).

In the PRA area where *T. absoluta* is present, biological control has been used. This includes using natural enemies naturally present or releasing them. Generalist species that are effective against *T. absoluta* and may be effective in controlling *K. lycopersicella*, are for example: *Nesidiocoris tenuis*, *Macrolophus* spp., *Diciphus tamaninii, Trichogramma* spp., *Necremmus* spp., *Closterocerus clarus*. It takes several years to develop a good biological control programme. Natural enemies for releases may need registration for the specific use in some countries.

6- Specific measures in protected crops

The measures described above would apply in protected crops, and in addition the following measures may also be applied (Poe *et al.*, 1974; Ferguson & Shipp, 2009, Korycinska & Eyre, 2010; Kline & Walker, 2007):

- Use of *K. lycopersicella*-free seedlings
- Screening greenhouses. Screens used against *T. absoluta* (9 x 6 threads per cm²) or whiteflies (16 x 10 threads per cm²) would be effective.
- Cleaning of structures
- Disinfection of the glasshouse before a new crop is planted (e.g. solarization, shutting down greenhouses in the winter to allow for freezing to prevent overwintering, or in summer to increase temperature and kill the pest)
- Tillage immediately after harvest (as research has shown that burial of pupae in sand prevents emergence of adults)
- Physical hand removal of larvae and removing infested leaves at early stages.

Crop rotation is recommended for glasshouse tomatoes in case of the occurrence of some pests, such as spider mites (*Tetranychus urticae*), several species of aphids, leaf mining flies (*Liriomyza* spp.*)*, thrips (*Frankliniella occidentalis*) and might hinder colonisation by *K. lycopersicella*. However, it might not be easy to implement in practice as glasshouse structures are often highly specialised. Crop rotation in glasshouses also depends on contracts between production companies and commercial enterprises or syndicates for the delivery, processing and marketing of the vegetable products. When crop rotation is not possible, sanitation becomes critical before the new crop is put in place.

Control in eggplant production

Similar measures could be applied. USDA (2010) notes that removing host plants (either crop or weed) from the fields is the cultural insect/mite management practice reported by eggplant growers in Florida. The active substances available in some countries on eggplant are indicated in table 8 above.

Organic production

Control of *K. lycopersicella* in organic production will be difficult, although some methods might be compatible with it (e.g. mating disruption, *B. thuringiensis* – Bt). According to Eurostat (2011), in 2009 2852 ha of tomato were grown in organic production in the EU (about 1% of the total tomato area). Most of the organic production of tomato in the EU is grown in Italy (2666 ha out of 2852 ha). Organic potato production is increasing in the EU although quite limited (about 16,000 ha out of 2 million, i.e. less than 1% of the area – Eurostat 2011). Mating disruption is compatible with organically certified produce in California and could be used in the PRA area (may need prior registration). Organic schemes leading to certification varies between countries in the PRA area. Bt, spinosad and azadirachtin are authorized in some countries for use in organic production. However, only spinosad is considered as fully effective against *K. lycopersicella* and it may lead to resistance.

Tomato and eggplant in gardens
All the cultivated hosts are also grown in gardens. Private owners are unlikely to be able to implement the level of measures needed to control the pest. This would favour maintenance of populations, on non-commercial crops, hence reducing efficacy of control on commercial crops.

6.05 - How great an increase in production costs (including control costs) is likely to be caused by the pest in the PRA area in the absence of phytosanitary measures?

moderate

Level of uncertainty: medium

Where *T. absoluta* is not present : major (low uncertainty)
Where *T. absoluta* is present : moderate to major (open field in arid areas) (medium uncertainty)

Optimal control management strategies will need to be developed and will cause increased costs in terms of plant protection products, pheromones, equipment, labour (sanitation and cultural methods, monitoring, sorting of fruits). Control is likely to rely on increased applications of insecticides, before IPM programmes are adjusted. Mating disruption against *K. lycopersicella* would be a new expense for growers in the PRA area. Because *K. lycopersicella* is more tolerant of high temperatures and low humidity or rainfall than *T. absoluta*, the more arid parts of the PRA area (North Africa) will be more at risk, in particular for open field tomato crops.

Where *K. lycopersicella* occurs, Mota-Sanchez *et al.* (2003) estimate that the cost of pest control in commercially-grown tomatoes in Sinaloa was 350 USD per ha in 1988-1989 using conventional insecticides, and further decreased from 96 to 55 USD between 1989 and 2001 with the application of IPM programmes on tomato.

A key control method for the control of *K. lycopersicella* is the use of mating disruption with a specific pheromone. However this pheromone is not yet registered for use in the PRA area for this purpose and, based on the experience with registration of pheromone for mating disruption against *T. absoluta*, it will be a long and costly process to register it.

The worst-case scenario would be that mating disruption cannot be used, and 10-20 insecticide applications (in glasshouses) have to be used per crop per growing season. In Spain where *T. absoluta* occurred in tomato in 2008-2009 the cost for treatments was about 600-800 €/ha (only insecticide costs for 20-30 treatments of non-specific products) but this still resulted in 15-40 % fruit damage. Now in Spain, the average number of treatments against Lepidoptera is 2-6 treatments and the cost is estimated at 200-300 €/ha (only insecticide cost) (for losses below 1%). (Monserrat, pers. comm., 2011)

In greenhouses in northern Europe, growers rely on pollination by bumblebees and biological control against a variety of pests (whiteflies, acari, aphids) and that system is disrupted if insecticides have to be applied. This happened in Mediterranean countries where IPM systems were in place when *T. absoluta* was introduced. For *T. absoluta*, the reinstatement of an IPM system took 2-3 years.

Where *T. absoluta* occurs, some pesticide applications are already made. It is uncertain if additional treatments are necessary to specifically control *K. lycopersicella*.

In Turkey in the first year following the introduction of *T. absoluta* (2010), 10-15 insecticide treatments were applied against *T. absoluta* in greenhouses on a growing season (October to June). In 2011 the application number decreased : 5 to 7 chemical treatments are applied. In Turkey, the total cost of chemical control against *T. absoluta* on a growing season was approximately 200 € per ha including an average of 6 insecticide treatments in greenhouses (Kılıç, pers. comm., 2011).

In Tunisia, under tunnel production, the government supported insect-proofing and mass trapping against *T.absoluta* (respectively 30% of the cost, and total support of the cost of pheromone for monitoring) and, after 3 years, the number of treatments decreased. The number of treatments against *T. absoluta* is now 2-3 treatments per growing season. The cost against *T. absoluta* including labour is 200-300 € per ha. In open field, the number of applications is 2-7 (average 3) (Chermitin, pers. comm., 2011)

In the UK, the first finding of *T. absoluta* at a production site was in 2009. The pest is still confined to one main tomato production area in the west of England. In general, British tomato growers tend not to use pesticides (British Tomato Growers' Association, undated). In 2010, in the framework of a eradication of *T. absoluta* in a glasshouse, the total cost of pesticide use for the control of *T. absoluta* (and '*other problems*') was costed at 2700 € per ha. The total cost of production including labour was approx. 149,000 € per ha. The gross margin was 200,000€ per ha. (Hypothetical figures supplied by ADAS to Fera – based upon tomato production in rockwool in Yorkshire; MacLeod, Fera, pers. comm. to Sansford 2011).

In the Netherlands, growers have monitoring systems in place with traps, and use approximately 1 treatment specifically targeted against *T. absoluta* and adjust their biological control intensity if *T. absoluta* is present (extra release of *Macrolophus*). The cost of insecticide treatment is 100 € per ha, and *Macrolophus* 100 € per ha, which results in 200 € extra cost if *T. absoluta* is present. Screening greenhouses in the Netherlands is extremely expensive and is done by only one grower. Potting (2009) estimates economic consequences of the establishment of the pest for the Dutch tomato industry to be 4 million EUR per year due to pest management in a worst case scenario.

In Italy, in relation to the related pest T. absoluta, Sannino & Espinosa (2010) mention costs incurred in Liguria for establishment of physical barriers hindering entry into glasshouses, control (products, biological control agents), monitoring. In total producers apply 11 treatments per crop for a total cost of 200-250 € per crop.

In the field-grown crops across the PRA area, considering the gross margins, it is generally considered that growers will not apply more than 3-4 broad spectrum insecticides.

Details on uncertainty. Medium. Difficult to estimate which additional costs would be incurred in areas where *T. absoluta* is already present.

6.06 - Based on the total market, i.e. the size of the domestic market plus any export market, for the plants and plant product(s) at risk, what will be the likely impact of a loss in export markets, e.g. as a result of trading partners imposing export bans from the PRA area?

moderate

Level of uncertainty: low

Many countries in the PRA area, especially EU countries, export tomato and eggplant fruits (CIRAD, 2009). The trade between countries of the PRA area would be affected (e.g. North African countries are major exporters of tomato fruit to the EU). The presence of the pest in one country is likely to have immediate moderate effects on export market.

According to data obtained from exporters of tomato in Antalya, Turkey, the related pest *T. absoluta* caused a 22 % decline of all Turkish fruit tomato exports in May 2010. Growers were not successful in controlling *T. absoluta* in 2010 and some of them did not plant tomato during the next production period because they were concerned that they might be unsuccessful in controlling the pest. Therefore the production area decreased and this lead to an increase in the price of tomato (Kılıç, pers. comm., 2011)

Exports of tomato from the EU to the USA resulting from the presence of *T. absoluta* in the PRA area have decreased, because US phytosanitary requirements regarding T. absoluta (USDA, 2011) are very expensive and difficult to fulfil (Guitian Castrillon, pers. comm., 2011).

Effects on exports of plants for planting are expected to be lower as most countries produce their own seedlings, and plants for export are already produced under strict conditions.

6.07 - To what extent will direct impacts be borne by producers?

major extent

Level of uncertainty: low

Costs of plant protection products, monitoring, control, labour will be borne by the producers. When *T. absoluta* was introduced, part of the cost (e.g. development of IPM programmes, provision of pheromones) was supported by the government in some countries, e.g. Tunisia, Spain, Turkey.

6.08 - How important is the environmental impact caused by the pest within its current area of invasion?

N/A

Level of uncertainty: low

Not known. *K. lycopersicella* is an agricultural pest.
There is no record of direct environmental damage linked to the pest. In the area where it occurs, it has had an indirect impact on the environment due to the need for intensive insecticide control programmes in infested areas (Trumble, 1997). However, integrated measures or IPM strategies have generally been adopted for tomato crops, eventually limiting that impact.

6.09 - How important is the environmental impact likely to be in the PRA area?

N/A

Level of uncertainty: low

Not known. The pest is likely to have a similar impact with an increase of pesticide application. No increase in applications is expected in places where *T. absoluta* is already established.

6.10 - How important is social damage caused by the pest within its current area of distribution?

minimal

Level of uncertainty: low

Trumble (1997) noted that there were concerns on impact of pesticides with mammalian toxicity on human health because of the labour-intensive tomato production in Sinaloa. The impact of pesticides on human health is minimal now that IPM has been adopted (Trumble, 1997). Abandonment of fields is mentioned in some earlier publications (e.g. Elmore & Howland, 1943), but recent publications do not mention such an effect.

6.11 - How important is the social damage likely to be in the PRA area?

minor

Level of uncertainty: low

Social damage might be high locally in areas where widespread damage occurs, at least on the short term after its introduction. The establishment of *T. absoluta* in Morocco and Algeria for example resulted in a dramatic increase of tomato price in the first years so that the local population faced difficulties to buy it. Prices were four times higher in Algeria (40 DA in 2009 vs. 10 DA in 2008) (Ounas, 2009) and twice higher in Morocco (Fa, 2009), while price of tomato did not change in the EU.
However, it is unlikely that *K. lyopersicella* would make the production of fruit and plants of tomato and eggplant uneconomic. In situations where the presence of the pest had an effect on the profitability/viability of individual farms, there might be loss of employment or internal migration of people. Specialised producers might have to switch to other crops. Organic producers and production would be threatened by the need to use insecticides or by yield losses in cases where the grower tried to continue organic production. Biological control methods (e.g. mating disruption) are available but will probably need some years before being registered.

6.12 - To what extent is the pest likely to disrupt existing biological or integrated systems for control of other pests?

major

Level of uncertainty: medium

Where *T. absoluta* occurs: minor
Where *T. absoluta* does not occur: major (medium uncertainty)

Where *T. absoluta* does not occur, the pest is likely to disrupt IPM programmes in place for the control of other pests and to increase heavy reliance on insecticides, in a similar manner as for *T. absoluta* (Desneux *et al.*, 2010). In Turkey, the IPM programmes in tomato greenhouses were disturbed when insecticide applications were increased (indoxacarb and spinosad, used to control *T. absoluta*) (Kılıç, pers comm., 2011). In Spain the IPM strategy needed to be completely modified ºC (Monserrat, pers.comm., 2011). Natural enemies and bumble bees can be negatively affected (Potting *et al.,* 2010). In the Netherlands, IPM systems were not disrupted by the presence of *T. absoluta*. In much of the PRA area (e.g. EU), most tomatoes are produced in IPM systems.

6.13 - How great an increase in other costs resulting from introduction is likely to occur?

moderate

Level of uncertainty: low

Other costs would be linked to the need for additional research on host plants, management, biological control agents, plant protection products, economic thresholds, monitoring programmes, registration of pheromone-based products, training and communication with farmers. Monitoring programmes would have to be conducted to delimitate the pest distribution, on various known or possible host plants. The efficacy of active substances and products will need to be studied, and some authorised for use (Espinosa & Sannino, 2009).

In Tunisia, when *T. absoluta* was introduced, the government supported the cost of insect proof screens (30% of the cost), offered free pheromone lures for monitoring and tried to decrease their prices by international invitations to tender. Two years after the introduction of *T. absoluta* in Tunisia, the price of fresh tomato increased and this is still high even though growers are better at controlling *T. absoluta*, especially under greenhouses. Nevertheless it is considered locally that increase of tomato price cover product costs (Chermiti, pers. comm. 2011).

6.14 - How great an increase in the economic impact of other pests is likely to occur if the pest can act as a vector or host for these pests or if genetic traits can be carried to other species, modifying their genetic nature?

minimal

Level of uncertainty: low

No such effect is documented in the literature.

6.15a - Describe the overall economic impact *(sensus stricto)*

moderate

Level of uncertainty: medium

The pest is likely to have a moderate economic impact over the whole PRA area, the impact will vary depending on areas and the pest management against *T. absoluta* in different areas.

One key component of control would be the use of pheromones for mating disruption, and there is an uncertainty on whether mating disruption will be applied in the PRA area (due to the need for registration).

6.15b - With reference to the area of potential establishment identified in Q3.08, identify the area which is at highest risk from economic, environmental and social impacts. Summarize the impact and indicate how these may change in future.

moderate

Level of uncertainty: medium

It is likely that an economic impact would result across the whole area of potential establishment. Environmental and social impacts are likely to be minor.

Mediterranean Basin. The highest likelihood of impact is on outdoor crops and organic crops, particularly in arid areas. However, if *T. absoluta* is present and under control, it is likely that *K. lycopersicella* will also be brought under control.

Protected crops are at risk throughout the PRA area if they do not have control against *T. absoluta*.

Considering the experience with *T. absoluta*, the impact in the first years will be greatest before IPM systems are adjusted, especially in places where *T. absoluta* does not occur.

Stage 2: Pest Risk Assessment Section B: Degree of uncertainty and Conclusion of the pest risk assessment

c2 - Degree of uncertainty : list sources of uncertainty

Major uncertainties:

- Whether pest management currently applied in the different countries of the PRA area will be effective against *K. lycopersicella* (3.15)
- Time before the pheromone will be registered to be used for mating disruption in the PRA area (due to the need for registration as a crop protection agent in many EPPO countries).
- Area of potential establishment : northern limit of the area where sustainable populations could establish outdoors, whether *K. lycopersicella* can adapt to those places where *T. absoluta* is not adapted, e.g. arid places, with the growing practices used in these areas.

Other uncertainties

- Distribution in the USA (list of states), Caribbean and South America
- Plants for planting (except seeds) of tomato and eggplant : association of the pest with the commodity considering current management practices at origin (2.04)– volume and frequency (2.05, 2.06)
- Packaging: may the pest be associated with empty packaging after infested tomatoes where removed. How much is packaging being reused in the PRA area?
- Management practices for tomato in the area of origin, management practices on eggplant
- Whether *Trichogramma* produce the same level of control on *K. lycopersicella* and *T. absoluta*
- Whether new detections correspond to introductions or emergence as a pest (3.19)
- What would be the distances of adult flight and passive flight with wind in the PRA area (4.01).
- Time needed to reach maximum extent in the PRA area (4.04).
- Impact: exact impact at origin in recent years (6.01), cost of control measures in the PRA area.

c3 - Conclusion of the pest risk assessment

The probability of introduction is rated as high to moderate, depending on the pathway, the conditions of the introduction (outdoors, under protected conditions) and the part of the PRA area. The pathways for entry were rated as follows:

Fruits of tomato with vine	Likely	Low uncertainty
Other fruits of tomatoes	Moderately likely	Low uncertainty
Packaging	Moderately likely if destined to facilities where tomatoes are grown Unlikely in other cases	Medium uncertainty
Plants for planting (except seeds) of tomato and eggplant*	Unlikely*	Low uncertainty
Fruits of eggplant	Unlikely	High uncertainty

* This pathways is subject to prohibition in many countries of the PRA area (e.g. EU), and the probability is therefore not relevant for these countries.

Overall probability of entry	**Likely**	**Low uncertainty**
Probability of establishment	**High**	**Low uncertainty**
Overall rate of spread	**High**	**Low uncertainty**
Magnitude of impact (with all potential measures available to growers)	**Moderate**	**Medium uncertainty**

The pest has the potential to establish in greenhouses throughout the PRA area as well as outdoors in the Mediterranean Basin, which has a good climate match with part of the area of origin.

Natural spread (flight) and spread with human assistance (plants, conveyances, packaging material etc.) could occur.

If *K. lycopersicella* was introduced to the Mediterranean Basin, after 5 years it would probably have reached

part of the area suitable for its survival outdoors, as well as part of the tomato production under protected conditions. Eradication and containment are likely to be feasible only in very limited situations (i.e. early detection).
If it was introduced in the north of the PRA area where most tomato crops are grown under protected conditions, after 5 years it is unlikely it would have spread to other countries (as eradication is possible under these circumstances). Multiple introductions in different areas would allow spread to be more rapid within the PRA area.

In the case of introduction and spread, the pest would have economic impacts on tomato and possibly on eggplant production, both commercially and in gardens. It is likely to cause an increase in costs for its control and there would be costs associated with research to develop controls, as well as negative effects on exports from countries where it occurs.
In absence of any measures, the impact is expected to be massive. In areas where IPM is used against *T. absoluta* the impact may be “medium” and in other areas “high”. After implementation of additional measures, including the use of a pheromone which will first need registration, the impact (yield losses) is assessed to be minor but growers will have additional control costs.

K. lycopersicella is considered to present an unacceptable risk. Measures should be taken to prevent its introduction
The analysis should continue to Stage 3 Pest risk management.

Stage 3: Pest Risk Management

7.01 - Is the risk identified in the Pest Risk Assessment stage for all pest/pathway combinations an acceptable risk?

no

The risk is not considered acceptable for several pathways. The pathway of tomato fruit is considered in detail at the management stage. Due to the low likelihood of entry on eggplant fruit, the EWG did not consider this pathway at the management stage, but measures as defined for tomato fruit could be applied. *The Panel on Phytosanitary Measures decided that measures should also be required for eggplant fruit as eggs of the pest may be associated with green parts attached to the fruit.*

The risk management section was not carried-out specifically for packaging, but measures regarding packaging were added under the fruit and the plants for planting pathways (only new packaging should be used).

Despite the low likelihood of entry on plants for planting of tomato and eggplant, this pathway was considered as it would be the most favourable for entry of the pest if the volumes traded increased or the current prohibitions on imports of solanaceous plants were lifted.

7.02 - Is natural spread one of the pathways?

no

Pathway 1: Fruits of tomato from areas where K. lycopersicella *occurs*

7.06 - Is the pathway that is being considered a commodity of plants and plant products?

yes

Due to the low risk of entry, no measures are considered for eggplant fruit under this pathway.

7.09 - If the pest is a plant, is it the commodity itself?

no

7.10 - Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?

no

Level of uncertainty: medium

K. lycopersicella is a quarantine pest in Moldova, which might help prevent its introduction in that country (EPPO, 2010). In the rest of the PRA area, the pathway seems open to some countries from some origins. As described below, fruits of tomato and eggplant are covered by general requirements for all fruits and vegetables (or solanaceous fruits and vegetables) (e.g. PC, packing, free from soil, etc.), requirements for all fruits targeting other pests, and in a few cases specific requirements for tomato or eggplant fruits (but not directly targeting *K. lycopersicella*) (checked from EPPO collection of phytosanitary regulations - for non-EU countries, 1999 to 2003 depending on countries - and EU Directive 2000/29, EU 2000):

- Albania (requirement for all fruits: import permit, PC)
- Algeria (requirements for all fruits: packed in cases, sacks or other containers, PC)
- EU countries, Norway, Switzerland (specific requirements for eggplant: from country free from *Thrips palmi* or immediately prior to export, inspected and found free from *T. palmi*)
- Israel (for all fruits: requirement for import permit, PC)
- Jordan (requirement for all fruits: import permit, PC, free from soil)
- Kyrgyzstan (requirements for all fruits: import permit, PC, free from soil; place of production requirements for A1/A2 pests; fumigation or refrigeration of fruits for imports between certain dates)
- Moldova (requirement for all fruits: import permit, PC, disinfection; *K. lycopersicella* is a quarantine pest)
- Morocco (requirements for all fruits: pest free; specific requirements for tomato and eggplant fruits:

free from soil, debris, named pests; specific requirements for cleaning, grading and packing)
- Norway (during 16 April-30 September: PC)
- Russia (requirement for all fruits: PC)
- Tunisia (requirement for all fruits: PC)
- Turkey (requirement for all fruits: PC, free from A1/A2 quarantine pests)
- Ukraine (requirement for all fruits: import permit, PC, free from A1/A2 quarantine pests or disinfested at point of entry)

In the EU (and Norway and Switzerland), there are no requirements for imports of tomato fruit.

Options at the place of production

7.13 - Can the pest be reliably detected by visual inspection at the place of production ?

yes in a Systems Approach

Level of uncertainty: low

Possible measure: visual inspection at the place of production

Sampling for the presence of larvae or damaged fruit, entry holes or frass around calyces is used as a method for timing applications of products. However, this might not allow the detection of low populations of the pest, or those that might not cause economic damage in the country of origin. In fruit consignments, visual inspection might allow the detection of some damage. However, larvae enter fruit under the calyces and are difficult to detect if calyces are present (e.g. vine tomatoes).

7.14 - Can the pest be reliably detected by testing at the place of production?

no

Level of uncertainty: low

Not relevant.

7.15 - Can infestation of the commodity be reliably prevented by treatment of the crop?

yes in a Systems Approach

Level of uncertainty: low

Possible measure: specified treatment of the crop

Treatment of the crop would not eliminate all individuals. The pest also has hidden life stages that are difficult to control (larvae rolled in leaves, in fruit). Generations may overlap. Larvae in fruits would not be eliminated. However, treatments would prevent high infestations.

7.16 - Can infestation of the commodity be reliably prevented by growing resistant cultivars?

no

Level of uncertainty: low

Resistance of wild *Lycopersicon* spp. has been investigated to identify possible sources of resistance to *K. lycopersicella* (Schuster, 1977; Lin & Trumble, 1986). However no resistant cultivar of tomato is available. No resistant cultivar of eggplant is reported in literature.

7.17 - Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?

yes in a Systems Approach

Level of uncertainty: low

Possible measure: specified growing conditions of the crop

It is possible to cultivate the plants under protected conditions excluding the pest (e.g. by using screened glasshouses). In glasshouses the presence of the pest can be better monitored (with pheromone traps) and control measures better applied (e.g. mating disruption). Screened glasshouses will provide a better control. Stringent sanitation measures should be applied, including removal of plant debris from earlier crops (see also under 6.04 – cultural control methods).

7.18 - Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?

no

Level of uncertainty: low

The pest might be present in the crop all year round, in suitable conditions in the field and always in glasshouse.

7.19 - Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?

no

Level of uncertainty: low

Not relevant for fruit production.

7.20 - Based on your answer to question 4.01 (moderate rate of spread with medium uncertainty), select the rate of spread.

Moderate rate of spread

Level of uncertainty: low

Possible measure: pest-free area or pest free place of production

**7.21 - The possible measure is: pest-free area or pest free place of production
Can this be reliably guaranteed?**

yes

Level of uncertainty: low

PFA is a possible measure as described in ISPM 4. It will in particular require the use of pheromone traps to check for absence of the pest. Pest-free seedlings should be used. There should be control on movement of tomato and eggplant fruit and plants, other hosts, equipment and packaging, etc. in and out of the area.

Pest free place of production is considered possible for screened glasshouses with use of pest-free seedlings. This should be checked using pheromone traps. Pheromone traps will reliably detect the presence of the pest at the place of production. PFPP would be difficult to maintain outdoors; however it might be possible in limited situations, especially as the pheromone traps for *K. lycopersicella* are very effective.The Panel on Phytosanitary Measures considered that the option of maintening a PFPP outdoors should not be recommended.

Options after harvest, at pre-clearance or during transport

7.22 - Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import?

yes in a Systems Approach

Level of uncertainty: low

Possible measure: visual inspection of the consignment

Infestation of fruit is difficult to detect, as larvae might be hidden below the calyx, especially for fruits accompanied by green parts. In addition the hole is sometimes filled with webspin, which makes it difficult to see (see 2.09). Other life stages are also difficult to detect on this pathway. However, visual inspection at the time of export or at the point of entry may assist as part of a systems approach.

7.23 - Can the pest be reliably detected by testing of the commodity ?

no

Level of uncertainty: low

Not relevant

7.24 - Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?

no

Level of uncertainty: low

Possible measure: specified treatment of the consignment

Fumigation with methyl bromide may allow destruction of the pest including larvae present in the fruit. Methyl bromide fumigation of tomato fruit is considered effective against *T. absoluta* for import of tomato fruit from infested areas (USDA, 2011). This measure is not recommended because methyl bromide will be phased out in 2015 and its use is not favoured in many EPPO countries because of its environmental consequences, see IPPC Recommendation *Replacement or reduction of the use of methyl bromide as a phytosanitary measure* (FAO, 2008). Efficacy of alternative fumigation (e.g. with methyl iodine) would need to be evaluated. There is no data on efficacy of fumigation for eggplant fruit.

Treatment of the fruit will not be an option if it damages the fruit or if there is no or a low tolerance for larvae remaining in the final product.

7.25 – Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment?

Yes in a Systems Approach

Level of uncertainty: medium

The pest may be present on the fruit, but also the inside. Tomato fruit ‘on the vine’ may also contain larvae or eggs in the leaves and stems. Removal of green parts will reduce the concentration of the pest (for adults and eggs) and allow a better detection of larvae inside the fruit (as entry holes are usually near the calyx but will not guarantee pest freedom. This measure is only applicable for tomato fruit.

7.26 - Can infestation of the consignment be reliably prevented by handling and packing methods?

yes in a Systems Approach

Level of uncertainty: low

Possible measure: specific handling/packing methods

Some infested fruits will be discarded during handling and packing at origin but this will not guarantee complete freedom of the pest. Handling and packing methods can be used as part of a systems approach. Reinfestation following harvesting and packing is unlikely.

Packaging used at origin for tomato and eggplant fruit should be new as some life stages may be associated with packaging (see 2.01a, as well as entry section for packaging 2.03-2.11).

After import, packaging should be destroyed or safely disposed of.

Options that can be implemented after entry of consignments

7.27 - Can the pest be reliably detected during post-entry quarantine?

no

Level of uncertainty: low

Not relevant for fruit.

7.28 - Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?

no

Level of uncertainty: low

Consignments of tomato not on the vine and eggplant may be imported during winter time (when the outside temperature is below 5 C) for immediate processing or direct consumption where *K. lycopersicella* cannot survive outdoors. In any case, no handling or packing should be done in or in close proximity of a place producing host plants. However it is difficult to guarantee that this 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. In addition, it would suppose that larvae or fragments of larvae are acceptable in the final product or can be removed. If green parts are discarded, some individuals might be able to complete development. Adults that have developed during transport might also escape.–

7.29 - Are there effective measures that could be taken in the importing country (surveillance, eradication, containment) to prevent establishment and/or economic or other impacts?

no

Level of uncertainty: low

After import, packaging should be destroyed or safely disposed of.

In the northern part of the PRA area where the pest cannot survive outdoors in winter, measures could theorically be taken in the importing country. This would require the separation of trade and production flows (separate facilities for imported consignments and for growing tomato and eggplant) and a good surveillance system (including trapping at packing stations). Eradication is considered possible in greenhouses in that part of the PRA area (see 5.01). This would be possible only as long as the trade volumes are very low. However, the Panel on Phytosanitary Measures considered that this option was not easy to include in phytosanitary regulation and to implement in practice and should therefore not be recommended.

In the rest of the PRA area, although some measures may be applied they would not be sufficient. Surveillance could be put in place with traps (e.g. yellow traps or pheromone traps) at points of entry, around packing houses, in cultivation areas and in glasshouses, with regular inspections to allow early detection. However, containment and eradication would be difficult. It would suppose early detection of outbreaks. Correct identification would be complicated by the fact that *K. lycopersicella* may be confused with other species, such as *T. absoluta* and *P. operculella*, which already occur in part of the PRA area.

7.30 - Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest?

yes

Q.	Standalone	Systems Approach	Possible Measure	Uncertainty
7.13		X	visual inspection at the place of production	low
7.15		X	specified treatment of the crop	low
7.17		X	specified growing conditions of the crop	low
7.20	X		pest-free area	low
7.22		X	visual inspection of the consignment	low
7.25		X	removal of green parts	medium
7.26		X	specific handling/packing methods	low

7.31 - Does each of the individual measures identified reduce the risk to an acceptable level?

no

Level of uncertainty: low

Only PFA reduces the risk to an acceptable level.

7.32 - For those measures that do not reduce the risk to an acceptable level, can two or more measures be combined to reduce the risk to an acceptable level?

yes

Level of uncertainty: low

Pest free place of production could be used with appropriate additional requirements (screened glasshouses with use of pest-free seedlings, monitoring with pheromone traps).
Growing under screenhouse, visual inspection at the place of production, monitoring and specified treatment of the crop (mating disruption), handling and packing methods, removal of green parts and visual inspection of the consignment can also be used as part of systems approaches.

7.34 - Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

Level of uncertainty: low

The measures interfere to a certain extent with trade of fruits of tomato, but there is a limited trade from countries where *K. lycopersicella* occurs, although it has been increasing in the last 5 years. Treatment of fruit may however result in unacceptable fruit due to the presence of larval remains in the fruit, and treatment itself may damage the fruit; in addition the only treatment available is with methyl bromide. Pest free area would be difficult to establish and maintain in many countries where *K. lycopersicella* occurs, and could severely interfere with trade from these countries.

7.35 - Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

Level of uncertainty: low

The cost of most of the measures proposed will be beared by the exporting countries. Only for measures described under 7.29 for countries where *K. lycopersicella* cannot survive outdoors in winter, the costs will be supported entirely by the importing country.

Measures would have costs linked to monitoring, establishment and maintenance of pest free areas. However similar measures are applied against other pests and control is already performed against K. lycopersicella where it occurs. Production under protected conditions with conditions ensuring exclusion of the pest might not be feasible because of the high cost.

K. lycopersicella would be difficult to eradicate if introduced. The possible measures have lower costs than attempting eradication or bearing the costs of the impact and likely spread of K. lycopersicella if it established in the PRA area. I

7.36 - Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

yes

Phytosanitary measures:

As stand-alone measures:

- PFA

As part of systems approaches:

- Pest free place of production with appropriate additional requirements (screened glasshouses with use of pest-free seedlings, trapping with pheromone traps, handling and packing at the place of production).
- Growing under screenhouse
- Visual inspection at the place of production
- Handling and packing methods
- Removal of green parts
- Visual inspection of the consignment.

Pathway 3: Plants for planting (except seeds) of tomato and eggplant from areas where K. lycopersicella *occurs*

7.06 - Is the pathway that is being considered a commodity of plants and plant products?

yes

7.09 - If the pest is a plant, is it the commodity itself?

no (the pest is not a plant)

7.10 - Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?

no

Level of uncertainty: low

Measures are in place in some countries of the PRA area that would prevent introduction of the pest on this pathway to these countries:
- In the EU, Norway and Switzerland, import of plants for planting of *Solanaceae* is prohibited (except from European countries and countries in the Mediterranean region) (EU Directive 2000/29/EC).
- In Moldova, *K. lycopersicella* is a quarantine pest. (Additional measures applying to all plants are: IP and disinfection; plants with roots free from soil)

Consideration of measures is needed for other countries of the PRA area as plants of Solanaceae are generally subjected to measures, but not directly targeting *K. lycopersicella*. Such measures might ensure that inspections are carried out, but detection of the pest would be difficult. The pathways therefore seem to be open for some countries in the PRA area from some origins (checked from EPPO collection of phytosanitary regulations summaries, for non-EU countries, 1999 to 2003 depending on countries).

- Albania (requirements for all plants: import permit and PC)
- Algeria (requirements for all plants: PC; plants of tomato: free from *Xanthomonas vesicatoria*; plants of Solanaceae: free from stolbur phytoplasma).
- Israel (requirements for all plants: import permit, free from soil)
- Jordan (requirements for all plants: import permit, PC, free from soil)
- Kyrgyzstan (requirements for all plants: import permit, PC, freedom from A1/A2 pests; specific requirements for Solanaceae plants in relation to several pests)
- Morocco (requirements for all plants: PC; plants accompanied by soil should be pest-free)
- Russia (requirements for all plants: free from quarantine pests; specific requirements/prohibitions in relation to specific pests)
- Tunisia (requirements for all plants: PC, free from *Frankliniella occidentalis*; plants prohibited from countries where *Fusarium oxysporum albedinis* occurs),
- Turkey requirements for all plants: import permit, PC freedom from A1/A2 pests; specific requirements (additional declarations) for Solanaceae plants (potato, tomato, eggplant and pepper) in relation to several pests. For all Solanacae for planting: Pest free growing medium and free from Potato Stolbur Phytoplasma.
  In addition, specifically for tomato: Pest free growing medium and planting material free from *Bemisia tabaci, Tomato yellow leaf curl begomoviru*s, *Ralstonia solanacearum, Liriomyza bryoniae, Liriomyza huidobrensis*, *Liriomyza trifolii*, *Liriomyza sativae* and *Amauromyza maculosa.*
  Specifically for eggplants: Pest free growing medium and planting material free from *Liriomyza bryoniae, Liriomyza huidobrensis*, *Liriomyza trifolii*, *Liriomyza sativae* and *Amauromyza maculosa.*
- Ukraine (requirements for all plants: import permit, PC; freedom from A1/A2 pests or disinfection at entry).

Options at the place of production

7.13 - Can the pest be reliably detected by visual inspection at the place of production ?

yes in a Systems Approach

Level of uncertainty: medium

Possible measure: visual inspection at the place of production

The pest is difficult to detect (see 2.09 for this pathway) but some mines may be observed in leaves.

7.14 - Can the pest be reliably detected by testing at the place of production?

no

Level of uncertainty: low

Not relevant.

7.15 - Can infestation of the commodity be reliably prevented by treatment of the crop?

yes in a Systems Approach

Level of uncertainty: low

Possible measure: specified treatment of the crop

Treatment would not eliminate all individuals, especially late larval stages that are hidden in leaf folds or in fruits. However, it would help preventing a high level of infestation.

7.16 - Can infestation of the commodity be reliably prevented by growing resistant cultivars?

no

Level of uncertainty: low

Resistance of wild *Lycopersicon* spp. has been investigated to identify possible sources of resistance to *K. lycopersicella* (Schuster, 1977). However no resistant tomato cultivar is available. No research on resistant eggplant cultivar is reported in the literature.

7.17 - Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?

yes in a Systems Approach

Level of uncertainty: low

Possible measure: specified growing conditions of the crop

It may be possible to cultivate the plants under protected conditions excluding the pest (e.g. the use of screened glasshouses). In glasshouses the presence of the pest can be better monitored (with pheromone traps) and control measures applied. Screened glasshouses will provide a better control. Stringent sanitation measures should be applied, including removal of plant debris from earlier crops (see also under 6.04 – cultural control methods).

7.18 - Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?

no

Level of uncertainty: low

The pest might be present all year round, and this is not relevant for plants for planting.

7.19 - Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?

no

Level of uncertainty: low

Not relevant for an insect.

7.20 - Based on your answer to question 4.01 (moderate rate of spread with medium uncertainty), select the rate of spread.

Moderate rate of spread

Level of uncertainty: Medium

Possible measure: pest-free area, pest free place of production

As for fruit.

7.21 - The possible measure is: pest-free area
Can this be reliably guaranteed?

yes

Level of uncertainty: low

PFA is a possible measure as described in ISPM 4. It will in particular require the use of pheromone traps to check for absence of the pest. There should be control on movement of tomato fruit and plants, other hosts, equipment and packaging etc. in and out of the area.

Pest free place of production would be possible for screened glasshouses. This should be checked using pheromone traps. In the case of plants for planting, it is unlikely that freedom of any pests (e.g. virus, viroids) can be garanteed if the plants are grown outdoors, and consequently, PFPP outdoors is not considered possible. Only new packaging should be used. Handling and packing should be done within the pest-free place of production.

Options after harvest, at pre-clearance or during transport

7.22 - Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import?

yes in a Systems Approach

Level of uncertainty: medium

Possible measure: visual inspection of the consignment

Some damage might be noticed, such as mines, or rolled or tied leaves. However, the most likely stages to be associated with seedlings are eggs and first larval instar because of the age of the plants, and these are the most difficult life stages to detect (see 2.09 for this pathway). However, visual inspection at the time of export or at the point of entry may assist as part of a systems approach.

7.23 - Can the pest be reliably detected by testing of the commodity?

no

Level of uncertainty: low

Not relevant.

7.24 - Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?

yes in a Systems Approach

Level of uncertainty: medium

Possible measure: specified treatment of the consignment

Treatment of plants for planting with a specific systemic insecticide with a persistency for several days (e.g. spinosad, chlorantraniliprole, flubendiamide) prior to export will ensure a good control of the pest, especially as the most likely stages to be associated with the plants are eggs and first instar larvae. Although such treatment is considered effective for crop production, there is no data to evaluate it in the framework of a quarantine requirement.

7.25 - Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment?

no

Level of uncertainty: low

Elimination of infested leaves is mentioned as a control measure in several publications(e.g. Ferguson & Shipp, 2009), in cases of low infestation. However, it would require careful inspection to make sure that no infested leaf is forgotten and would reduce the value of the plants.

7.26 - Can infestation of the consignment be reliably prevented by handling and packing methods?

yes in a Systems Approach

Level of uncertainty: low

Possible measure: specific handling/packing methods

The pallets or pots used for the plants for planting should be new. Transport conditions should ensure that reinfestation does not occur.

Options that can be implemented after entry of consignments

7.27 - Can the pest be reliably detected during post-entry quarantine?

no

Level of uncertainty: low

This is not practical for seedlings.

7.28 - Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?

no

Level of uncertainty: low

There would be a risk of an outbreak under glasshouses in any part of the PRA area. The pest might also occur on plants at different times of the year.

7.29 - Are there effective measures that could be taken in the importing country (surveillance, eradication, containment) to prevent establishment and/or economic or other impacts?

no

Level of uncertainty: low

Although some measures may be applied they would not be sufficient. Surveillance could be put in place with traps (e.g. yellow traps or pheromone traps) at points of entry, in cultivation areas and in glasshouses, with regular inspections to allow early detection. However, containment and eradication would be difficult. It would suppose early detection of outbreaks. Correct identification would be complicated by the fact that *K. lycopersicella* may be confused with other species, such as *T. absoluta* and *P. operculella*, which already occur in part of the PRA area.

7.30 - Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest?

yes

Q.	Standalone	Systems Approach	Possible Measure	Uncertainty
7.13		X	visual inspection at the place of production	medium
7.15		X	specified treatment of the crop	low
7.17		X	specified growing conditions of the crop	low
7.20	X		pest-free area	low
7.22		X	visual inspection of the consignment	medium
7.24		X	specified treatment of the consignment	medium
7.26		X	specific handling/packing methods	low

7.31 - Does each of the individual measures identified reduce the risk to an acceptable level?

no

Level of uncertainty: low

Only PFA reduces the risk to an acceptable level.

7.32 - For those measures that do not reduce the risk to an acceptable level, can two or more measures be combined to reduce the risk to an acceptable level?

yes

Level of uncertainty: low

Pest free place of production under screened glasshouses should be combined with the use of pheromone traps. In addition, handling and packing should be done within the pest-free place of production and only new packaging should be used.

The Panel on Phytosanitary Measures considered that combining the other measures (visual inspection at the place of production, growing in screenhouses, treatment of the crop, treatment prior to export, visual inspection at export or at entry, packing methods) would not be sufficient to guarantee pest freedom of the consignment.

7.34 - Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

Level of uncertainty: low

The trade is thought to be very limited and disturbance would be minimal. The pathway is also already regulated to a certain extent in most countries of the PRA area.

7.35 - Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

Level of uncertainty: low

Measures would have costs linked to monitoring, establishment and maintenance of free places of production/pest free areas. However similar measures are applied against other pests. Production under protected conditions is a standard for the production of plants for planting.

Nevertheless the pest would be difficult to eradicate if introduced and could spread. The possible measures have a lower cost than attempting eradication or of bearing the costs of impacts caused by *K. lycopersicella* if it established.

7.36 - Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

yes

PFA

PFPP under screenhouses (with pheromone traps)

7.41 - Consider the relative importance of the pathways identified in the conclusion to the entry section of the pest risk assessment

The pathway considered are:

- Fruits of tomato and eggplant from areas where *K. lycopersicella* occurs
- Packaging (i.e. crates or boxes used for picking and packing tomato and eggplant fruits) from areas where *K. lycopersicella* occurs
- Plants for planting (except seeds) of tomato and eggplant from areas where *K. lycopersicella* occurs

Their relative importance is dealt with in 7.45 in the general conclusion.

7.42 - All the measures or combination of measures identified as being appropriate for each pathway or for the commodity can be considered for inclusion in phytosanitary regulations in order to offer a choice of different measures to trading partners. Data requirements for surveillance and monitoring to be provided by the exporting country should be specified.

7.43 - In addition to the measure(s) selected to be applied by the exporting country, a phytosanitary certificate (PC) may be required for certain commodities. The PC is an attestation by the exporting country that the requirements of the importing country have been fulfilled. In certain circumstances, an additional declaration on the PC may be needed (see EPPO Standard PM 1/1(2) Use of phytosanitary certificates).

7.44 - If there are no measures that reduce the risk for a pathway, or if the only effective measures unduly interfere with international trade (e.g. prohibition), are not cost-effective or have undesirable social or environmental consequences, the conclusion of the pest risk management stage may be that introduction cannot be prevented. In the case of pest with a high natural spread capacity, regional communication and collaboration is important.

7.45 - Summarize the conclusions of the Pest Risk Management stage.

List all potential management options and indicate their effectiveness.
Uncertainties should be identified.

Three pathways studied in this PRA present the highest risk of introducing *K. lycopersicella* to the PRA area from areas where it occurs:

- fruits of tomato and egglplant (especially tomato with vine attached, but also tomato without vine),
- packaging carrying tomato and eggplant fruit (or plants for planting), and
- plants for planting of tomato and eggplant.

For the latter, the risk is very low for countries where imports of such plants are prohibited (e.g. the EU).

Measures were identified which are aimed at preventing the introduction of *K. lycopersicella* from countries where it occurs to the PRA area. **Due to the uncertainties on the distribution of this pest in particular in Central and South America, the suggested requirements could be made for "where *K. lycopersicella* occurs" or in general - with an additional requirement that the consignment originates in a country known to be free from *K. lycopersicella*, or the measures below should be applied.**

Fruits of tomato and eggplant	PC and, if appropriate, RC -Pest-free Area for *K. lycopersicella* **OR** -Pest free place of production for *K. lycopersicella* (under screenhouses) **OR** -Systems approach: combination of measures at the place of production (mating disruption), growing under screenhouse, monitoring with pheromone

	traps, visual inspection at the place of production, handling and packing methods,use of new packaging, removal of green parts, visual inspection of the consignment
Packaging carrying tomato and eggplant fruit or plants for planting	All packaging should be new.
Plants for planting (except seeds) of tomato and eggplant	PC and, if appropriate, RC -Pest-free Area for *K. lycopersicella* **OR** -Pest-free place of production for *K. lycopersicella* (under screenhouses)

For all pathways, the risk is probably not very large as the volume on these pathways is currently small. However, the whole PRA area would be at risk of severe impacts in case of introduction of this pest, similar to what happened with the introduction of the related Gelechiidae species *T. absoluta*. Introduction of *K. lycopersicella* should therefore be prevented.

Two other pathways were considered in detail in a previous version of this PRA but were considered to pose a very low risk of entry and were not considered further: plants for planting of ornamental Solanaceae and soil (either as such or associated with potato tubers).

Regarding packaging, measures applied to packaging as part of a systems approach prior to export or after import would be needed. They should be combined with measures for fruit and plants for planting.

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ANNEX 1 – Tomato, eggplant, potato. Data on production and area in the PRA area

Table 1. Tomato (From FAOSTAT data 2005-2009)

tomato	Area harvested (ha)					Production (tonnes)				
country	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
Albania	6200	7385	6500	5050	5068	152000	164853	160000	162500	162376
Algeria	42354	31005	20079	19655	20789	1023445	796160	567313	559249	641034
Austria	184	189	198	185	172	35321	39105	44922	42109	41513
Azerbaijan	25171	26070	26444	26609	25333	437684	441951	432406	438419	392927
Belarus	8021	7733	7749	7602	7575	245893	241496	269640	274557	286984
Belgium	554	519	493	470		229610	238200	200000	200000	
Bosnia & Herzeg.	4048	3922	3825	3840	3685	30738	40700	33287	40722	46333
Bulgaria	5394	7022	4828	3474	3007	126462	212969	133188	134131	104234
Croatia	1192	1550	1682	1226	1229	28930	28400	48076	32358	37419
Cyprus	360	355	330	328	300	34106	30302	29386	23443	26490
Czech Republic	798	1456	1451	1202	1241	24232	35604	29771	27899	29441
Denmark	46	46	50	50	50	17639	17639	20000	20000	20000
Estonia	188	175	200	175	174	5183	6730	6800	5392	4699
Finland	118	117	117	116	114	37966	38743	38171	40467	38383
France	4984	4291	3941	4122	4500	790253	640582	575428	714635	725000
Germany	284	279	293	308	300	56121	53239	62599	65096	67000
Greece	34700	33881	33002	25000	25000	1713580	1568731	1464844	1338600	1350000
Hungary	3564	2873	2600	2275	2343	188415	204557	227600	205597	192810
Ireland	27	27	30	30		10000	10000	12000	12000	
Israel	5750	5270	5300	5200	5400	433225	438752	434297	418990	454761
Italy	138759	122192	125299	115477	117100	7187014	6351202	6530162	5976912	6382700
Jordan	9020	11265	10540	11752	12394	449490	545566	610246	600336	653693
Kazakhstan	25000	23200	22900	25100	25000	516000	510800	515190	549310	592000
Kyrgyzstan	9276	9451	9494	9957	10030	171199	172914	180331	187221	194161
Latvia	900	96	63	13	9	6770	371	261	41	30
Lithuania	364	311	374	200	293	2069	1430	1310	1300	701
Luxembourg	1	1	1	1	1	69	69	85	83	83
Malta	300	400	400	400	400	12680	16462	14841	15746	11566
Moldova	6146	8044	6157	7008	6100	84620	104355	46613	83802	68000
Morocco	22100	20833	23622	18600	18000	1205510	1245000	1237030	1312310	1300000
Netherlands	1396	1500	1500	1500		660000	680000	685000	720000	
Norway	33	34	34	31	32	13261	12018	15510	12017	10923
Poland	15571	15973	15909	14640	15278	600664	651567	689719	702546	709223
Portugal	13684	13014	14800	14297	16789	1085065	983191	1236235	1147600	1346702
Romania	46487	49967	45950	51460	48954	626960	834968	640785	814376	755596
Russian Federation	154210	151810	104200	112210	117000	2295900	2414860	1791007	1938710	2170390
Serbia		20947	20583	20309	19921		189222	152005	176501	189353
Slovakia	3349	3302	3181	2939	2922	61025	62952	55154	56585	51883
Slovenia	164	175	144	187	186	6629	4610	4400	4704	4344
Spain	72285	56690	53297	54868	62200	4810301	3800552	4081477	3922500	4749200

tomato	Area harvested (ha)					Production (tonnes)				
country	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
Sweden	46	51	50	50	50	17273	17400	16400	16200	16900
Switzerland	209	211	226	216	206	27072	26917	30630	33459	34450
Tunisia	26600	22600	26300	26000	27000	960000	855000	1000000	1170000	1200000
Turkey	270000	270000	270000	300000	300000	10050000	9854877	9945043	10985355	10745572
Ukraine	93800	92300	85400	80800	83800	1471800	1751000	1405400	1492100	2040800
UK	190	200	213	216		79540	84100	85600	88690	
Uzbekistan	55210	60470	61300	54000	60000	1317160	1583571	1680000	1930000	2110000

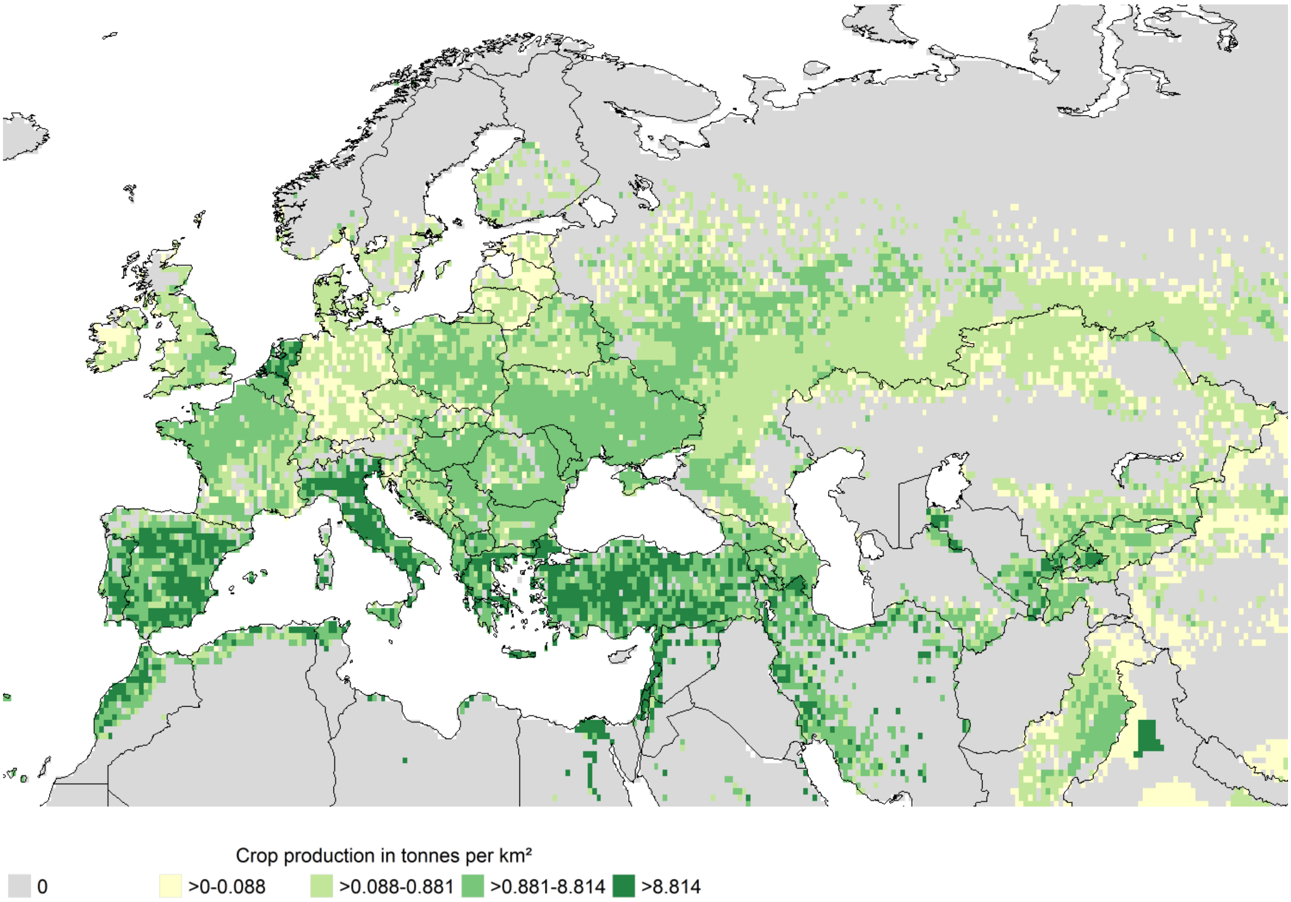
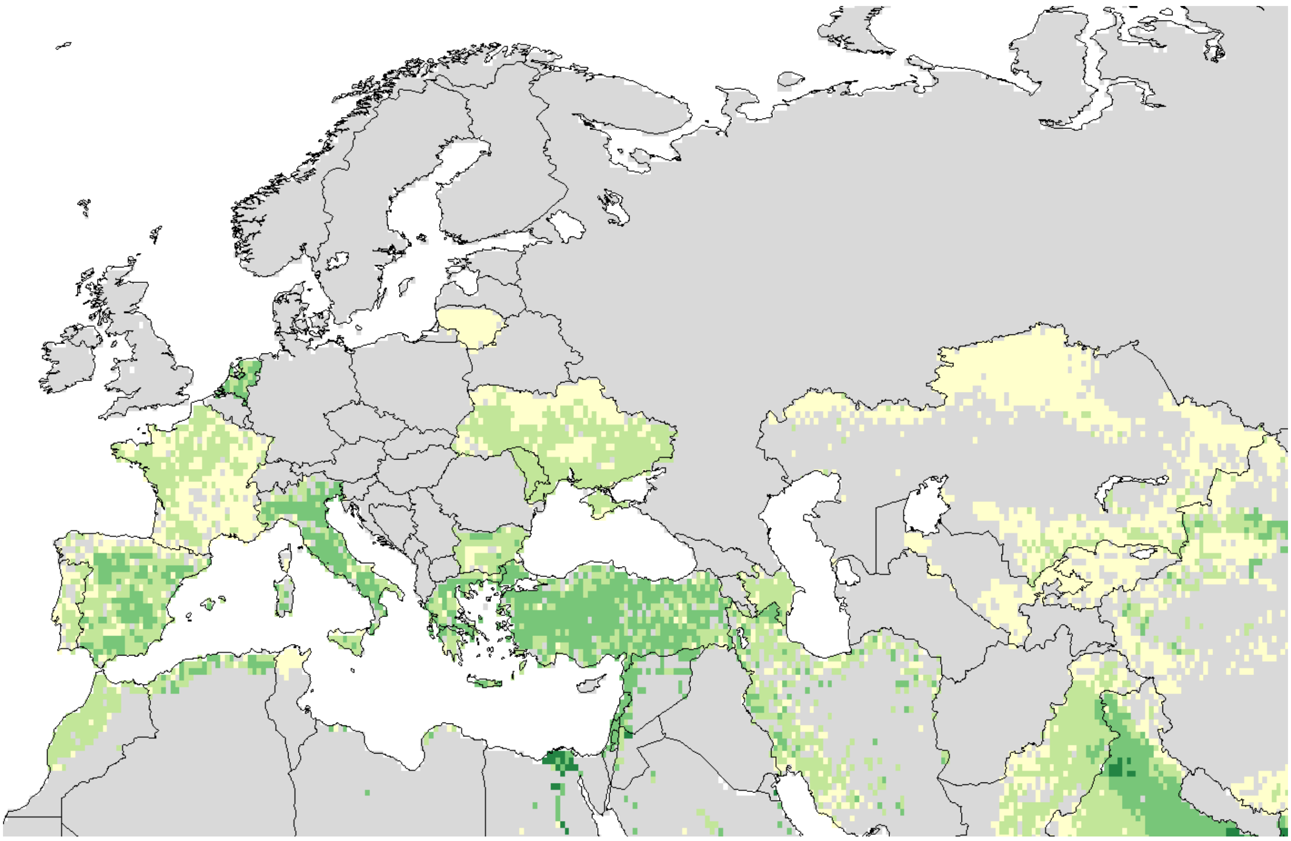


Fig 1. Tomato fruit production in tonnes per km² in the EPPO region**.** *Source: Monfreda et al. (2008)*

Table 2. Eggplant (From FAOSTAT data 2005-2009)

eggplant	area harvested (ha)					production (tonne)				
countrys	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
Albania	1100	766	900	920	1037	21100	17094	20000	17400	19579
Algeria	3445	3499	3764	3773	4133	43058	54438	58400	53762	76317
Austria	7	8	6	7	4	267	334	278	503	198
Azerbaijan	8600	8500	6000	4490	5695	37900	39100	50400	80472	102433
Belgium	12	11	15	11		4200	3900	4000	4000	
Bulgaria	467	303	354	260	695	10985	7782	8318	7062	16638
Cyprus	61	60	48	45	40	2816	2750	2690	2566	2680
France	429	407	411	417	425	18229	14402	14402	12860	13000

eggplant	area harvested (ha)					production (tonne)				
countrys	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
Greece	3186	3188	3121	2900	2900	68134	69341	67928	85300	85000
Hungary	28	65	100	100		682	1441	920	840	
Israel	640	660	650	530	660	44860	45994	44954	37205	46197
Italy	12169	11734	12991	10862	9400	338803	338361	334966	321795	245300
Jordan	2939	2610	2938	3753	2729	99240	95614	98138	99902	106793
Kazakhstan	3000	3400	2600	2500	2500	51000	58380	51130	44280	48000
Kyrgyzstan	100	100	200	100	100	100	100	300	100	100
Lithuania	0	600	1000	200	200	0	1500	2500	500	500
Malta	30	30	30	30	30	716	718	739	714	714
Moldova	680	804	735	589	500	7242	8553	4810	4697	4000
Morocco	2552	2405	1760	1745	1750	49973	56620	33715	34805	35000
Netherlands	90	100	100	100		42000	40000	41000	40000	
Portugal	250	250	300	300		5500	6000	6500	6500	
Romania	9511	11396	9701	10535	9927	124708	155919	114116	153677	168588
Serbia		100	100	100			1950	2000	2000	
Spain	3710	3435	3617	3596	3500	163783	167991	179826	175000	175000
Tunisia	16	16	16	16		220	220	230	230	
Turkey	36000	35000	33000	31000	31000	930000	924165	863737	813686	816134
Ukraine	6450	6500	5900	5800	6300	60600	65200	58700	61500	73000
Uzbekistan	200	250	300	200	300	2500	3000	3300	3700	4300



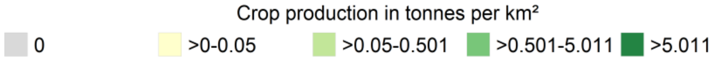


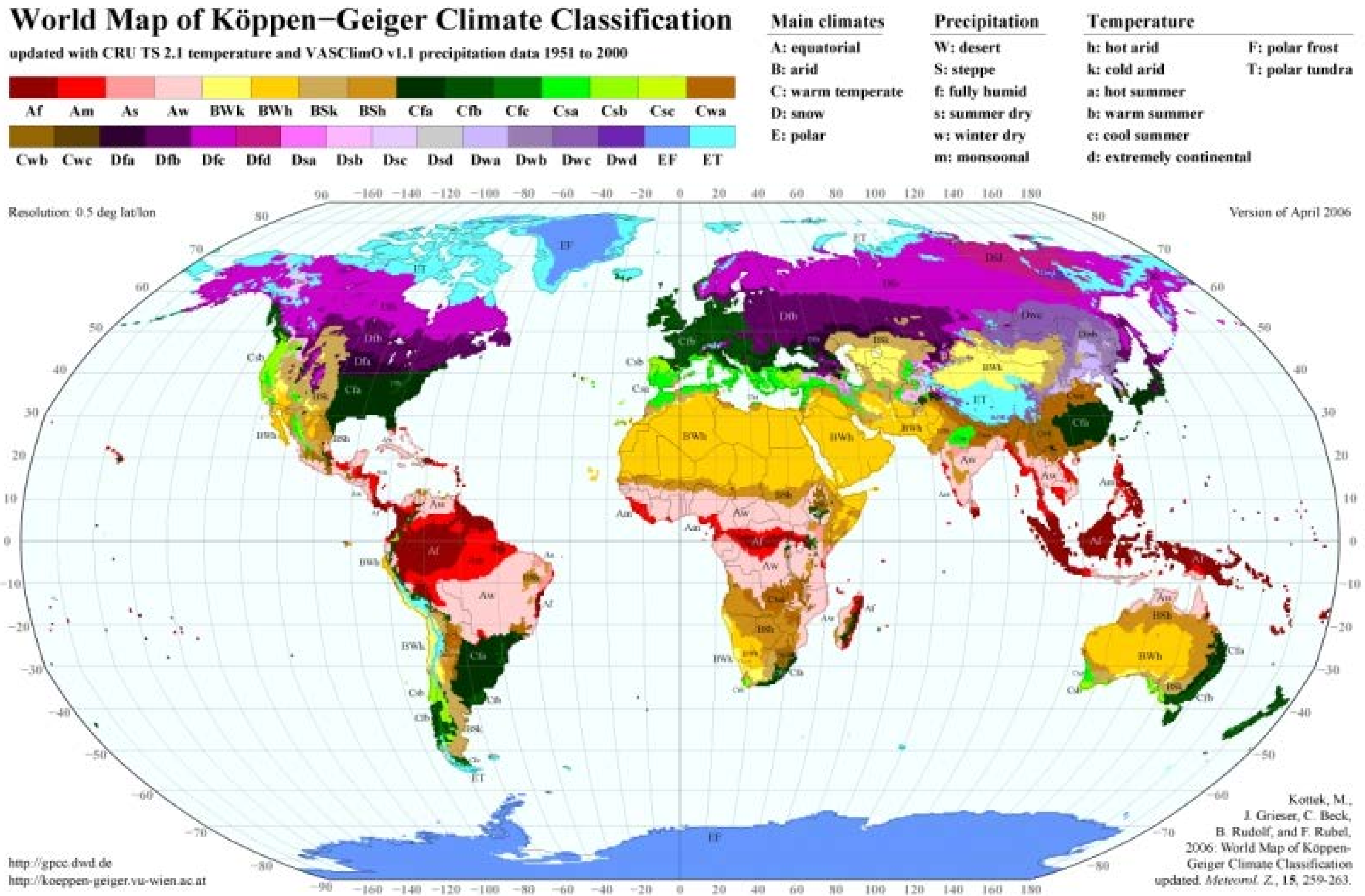
Fig2. Eggplant fruit production in tonnes per km² in the EPPO region**.** *Source: Monfreda et al. (2008)*

Table 3. Potato (From FAOSTAT data 2005-2009)

Tomato	area harvested (ha)					production (tonnes)					seed (tonnes)				
country	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
Albania	10134	9523	8200	9800	9100	169300	162600	154900	190000	200000	28569	24600	29400	27300	
Algeria	99717	98825	79339	91841	105121	2156550	2180961	1506859	2171058	2636057	105742	84892	98269	112479	
Austria	22186	21920	22675	22800	22222	763165	654621	668755	756945	722098	52608	54420	54720	53330	56000
Azerbaijan	70690	66847	67110	68856	65554	1083074	999343	1037317	1077110	982979	190100	207500	208300	213627	203670
Belarus	461646	433922	412553	396341	382981	8184953	8329412	8743976	8748630	7124981	1420000	1350000	1300000	1560000	1330000
Belgium	64953	67267	67942	63884	73700	2780865	2592820	3189817	2943205	3296400	63000	71000	72000	67000	
Bosnia &Herzeg.	41352	40670	41291	40412	36704	458615	410422	387239	428635	413658	50163	45206	42782	47170	45582
Bulgaria	23999	24471	22427	21648	14002	375459	386050	298722	353060	231745	36706	33640	32656	21750	21750
Croatia	18903	16759	17355	15000	14000	273409	274529	296302	255554	270251	25138	26032	22500	21000	
Cyprus	6190	4290	6290	5110	5300	152500	127500	155500	115000	131800	12042	15120	12279	12279	
Czech Republic	36071	30026	31908	29788	28374	1013000	692174	820515	769561		128000	100000	125000	125000	127000
Denmark	40000	38600	42152	40664	41000	1576400	1361200	1625580	1705403	1750000	100000	96533	103100	101660	100000
Estonia	13959	11510	11150	8800	9103	209772	152632	191754	125200	139050	30000	30060	29000	30000	30000
Finland	28900	28000	27300	26200	26400	742700	575700	701600	684400	755300	55600	52600	55600	53100	55000
France	156423	158315	158080	156200	163600	6604600	6362823	7183100	6808210	7164200	320000	309000	305000	319000	325000
Germany	276900	274300	274961	259800	263700	11624200	10030600	11643769	11369000	11617500	602000	602000	565000	559000	569000
Greece	44440	45446	46049	33500	33500	818727	901705	943196	848000	848000	102000	102000	93000	93000	93000
Hungary	25378	22583	25400	25424	22328	656721	564443	563100	683935	560615	78695	60000	56000	55000	50000
Ireland	11800	11500	11700	12000	12900	409200	382860	398960	371900	361300	20000	20000	37000	37000	
Israel	16780	15500	17000	18010	19000	593890	548182	618803	557917	608832	6000	6000	6000	6000	
Italy	69912	72451	69513	70578	70600	1753526	1782805	1781648	1603828	1753200	150000	150000	150000	150000	
Jordan	4848	5278	3543	5843	3800	172077	160028	97400	139787	118705	13195	8857	14607	9500	
Kazakhstan	167900	153500	155000	163100	172200	2520800	2361600	2414800	2354408	2755600	326600	313700	305400	310200	310000
Kyrgyzstan	75910	81101	86430	85000	87075	1141456	1254762	1373780	1334900	1393135	261400	278500	274000	270000	270000
Latvia	45100	45100	40300	37800	30000	658200	550900	642100	673400	525400	180000	160000	150000	119000	120000
Lithuania	73950	57800	52800	48400	46600	894700	457100	576100	716400	662500	246200	173900	158800	145000	140000

Tomato	area harvested (ha)					production (tonnes)					seed (tonnes)				
country	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
Luxembourg	608	595	627	604	604	19329	16449	19968	21756	20044	1500	2226	2426	2741	
Malta	820	820	700	700	700	19518	18450	14146	19000	10069	1066	910	910	910	
Moldova	35871	34437	35400	31247	28100	378223	376955	199400	271039	261000	62000	64000	60800	55000	60000
Morocco	62100	59600	57958	62800		1478540	1569100	1437215	1536560		101320	98528	106760	106760	
Netherlands	156000	155800	156900	151900	155200	6777000	6239600	6870400	6922700	7181000	267000	204000	309000	310000	310000
Norway	13700	14046	14466	14388	14400	316617	378301	329765	398400	332700	35500	36100	36000	36300	36000
Poland	588184	597230	549400	529500	488700	10369253	8981976	11791072	10462100	9702800	1480000	1395000	1360000	1220000	1360000
Portugal	41786	41386	41400	38900	36000	576304	611200	638900	566600	519300	65000	65000	65000	65000	
Romania	285312	283089	272548	259744	260317	3738594	4015899	3712410	3649020	4003980	862400	862400	1100796	1042331	
Russian Federation	3070510	2962420	2851660	2104000	2182400	37279820	38572640	36784200	28874230	31133960	8362500	8000000	7200000	6500000	7000000
Serbia		84434	81379	81172	78169		930305	743282	843545	898282		40689	40586	156338	156338
Slovakia	19101	18384	17769	14270	11620	301169	263083	287667	245277	216123	45000	43200	43200	43200	43200
Slovenia	6306	5918	5736	4427	4175	144714	106974	131050	100319	103425	11836	11472	8854	8350	8350
Spain	94998	87199	85728	81825	84600	2563464	2515001	2479582	2365500	2480800	140000	140000	140000	143000	148000
Sweden	30453	28001	28522	26900	26800	947300	777800	789000	853200	854300	51000	51000	51000	51000	51000
Switzerland	12510	12081	11768	11058	11215	485000	391000	491000	473000	517000	24973	24774	23439	24609	20000
Tunisia	25080	24900	24550	24800	25000	310000	365000	350000	370000	370000	24900	24550	24800	25000	
Turkey	154300	157908	152512	147812	142684	4090000	4397305	4246207	4196522	4397711	308600	316000	305000	296000	286000
Ukraine	1515900	1461500	1453300	1408900	1411800	19462400	19467100	19102000	19545400	19666100	4830000	4800000	4650000	4800000	4800000
United Kingdom	137400	141000	140200	144000	155000	5979000	5864000	5635000	5999000	6423000	389000	386000	335000	350000	360000
Uzbekistan	49810	52590	56008	59700	62000	924180	1020989	1188000	1398700	1524500	52590	56008	59700	62000	62000

ANNEX 2 – World Map of Köppen-Geiger Climate Classification



ANNEX 3 - Detailed assessment of the climatic suitability of the PRA area for establishment of *Keiferia lycopersicella* (prepared by R. Potting, PPS, NL)

1. Using climates in the current area of distribution to assess the climatic suitability of the PRA area

1.1 <u>What is the current area of distribution?</u>

The current area of distribution is mapped in Fig. 1. The distribution includes North America: Canada (Ontario), Mexico, USA (Arkansas, Arizona, California, Delaware, Florida, Georgia, Hawaii, Illinois, Mississippi, Missouri, North Carolina, Pennsylvania, Tennessee, Texas, Virginia).

Central America and the Caribbean: Bermuda, Costa Rica, Cuba, Dominican Republic, Haiti, Jamaica, Trinidad and Tobago (Trinidad).

South America: Bolivia, Colombia, Peru, Venezuela.

Fig. 1 Area of distribution of *K. lycopersicella*

NOTE: the presence of *K. lycopersicella* in Canada (Ontario) is in greenhouses only. This is also the case for the US states Georgia, Tenessee and North Carolina (Trumble, pers.comm. EWG 2011-09).

1.2 <u>What climates occur in the pest's current area of distribution?</u>

Köppen-Geiger climate zones

K. lycopersicella occurs in 7 Köppen-Geiger climate zones (see Table 1). These include equatorical climate zones in the Caribbean and South America and temperate climate zones in North America. The temperate climate zones (Csa, Csb and Cfb) correspond with the climate zones of the PRA area (see Fig 2).

Table 1 The Köppen-Geiger climate zones where *K. lycopersicella* occurs are indicated by asterisks.

Köppen-Geiger climate zones						
Code	**Main Climate**	**Precipitation**	**Temperatures**	**Caribbean & S. America**	**N. W. America**	**N. E. America**
Af	Equatorial	Fully Humid		**X**		
Am	Equatorial	Monsoonal		**X**		
Aw	Equatorial	Winter dry		**X**		
Cfa	Warm temperate	fully humid	hot summer			**X**
Cfb	Warm temperate	fully humid	warm summer			**X**
Csa	Warm temperate	dry summer	hot summer		**X**	
Csb	Warm temperate	Steppe	warm summer		**X**	
Cwa	Warm temperate	desert	hot summer			
Cwb	Warm temperate	desert	warm summer			
Dfb	Snow	fully humid	warm summer			
Dfc	Snow	fully humid	cool summer			
Dwa	Snow	desert	hot summer			
Dwb	Snow	desert	warm summer			

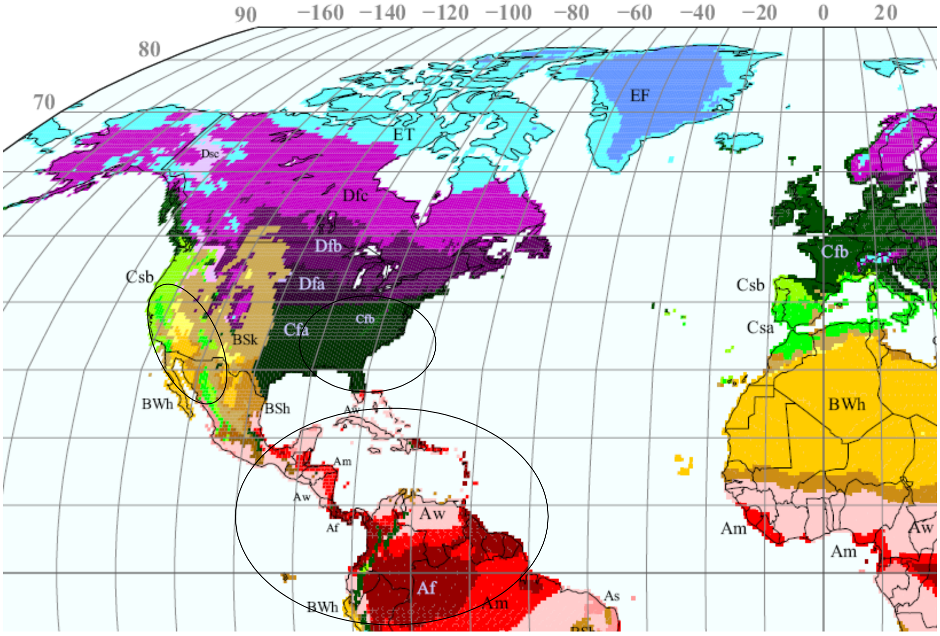


Fig. 2 Köppen-Geiger climate zones

The general geographical distribution of *K. lycopersicella* is indicated by the three circles for Caribbean/S.America; W-N America; E-N America.

Hardiness zones

To explore the relationship between the geographical distribution of *K. lycopersicella* and the severity of winter temperatures, maps of hardiness zones can be used. The United States Department of Agriculture National Arboretum (USDA-NA) hardiness zones are based on the average annual extreme minimum temperature (Magarey et al. 2008). The northernmost limits of the distribution of *K. lycopersicella* are in North-West United States and include the states of Illinois, Delaware, Pennsylvania, Virginia and North Carolina. The hardiness zones of these states are shown in figure 2. The coldest zones are 5a and 5b in Illinois and Pennsylvania, which correspond to winter temperatures between -23 to -29 °C.

It should be noted, that it is unknown if *K. lycopersicella* only occurs in greenhouses in Illinois, and Pennsylvania. This could have implications for the determination of the critical winter temperatures for the establishment of field populations.

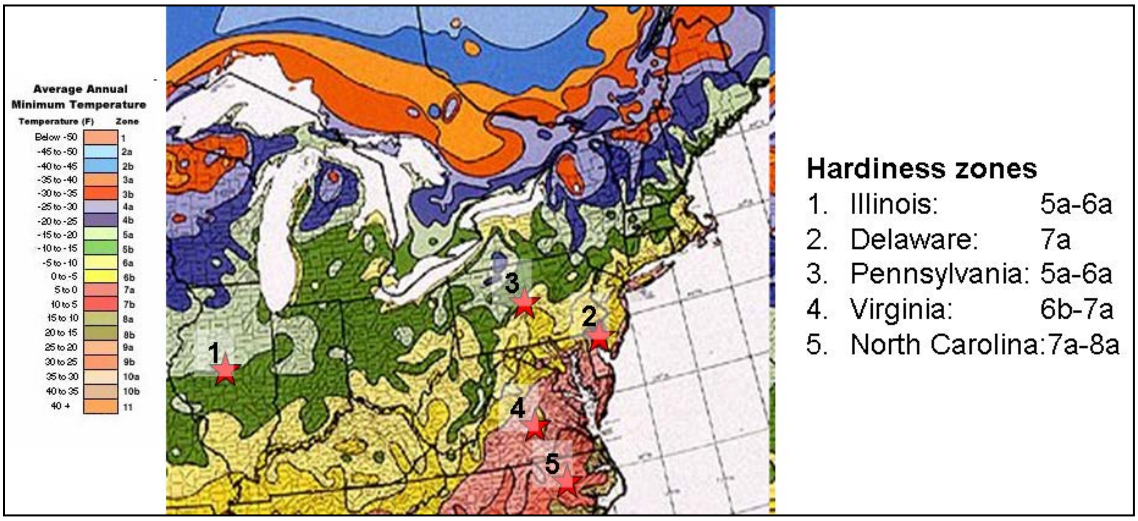


Fig. 3 Hardiness zones in North-West United states (obtained from http://www.usna.usda.gov/Hardzone/ushzmap.htm). US states where the presence of *K. lypersicella* is known are indicated by asterisks.

2. Using the known climate response data for *K. lycopersicella* to assess the climatic suitability of the PRA area

2.1 <u>The minimum threshold for development and degree day requirements</u>

A standard way to obtain the developmental threshold temperature is to plot the rate of development (1/number of days of development) against temperature. A linear regression equation (Y=aX-b) is used to calculate the critical temperature at which development stops (x-intercept of the linear equation=-b/a) and degree-day requirements (inverse of the slope= 1/a). The degree-day requirements are the accumulated degree-day units required to complete an insect's generation.

The egg to adult developmental data in Weinberg & Lange (1980) and Lin & Trumble (1985) were used to plot the data and to calculate the linear regression equation (see figure 4). Both data sets result in exactly the same slope (0.0022) of the linear equation, resulting in 454.4 degree-days for egg to adult development. The data sets differ in the equated critical temperature, which is 9.5˚C (Weinberg & Lange, 1980) and 10.3˚C Lin & Trumble (1985).

For the CLIMEX model for *K. lycopersicella* 455 DD and a threshold temperature of 10˚C was used.

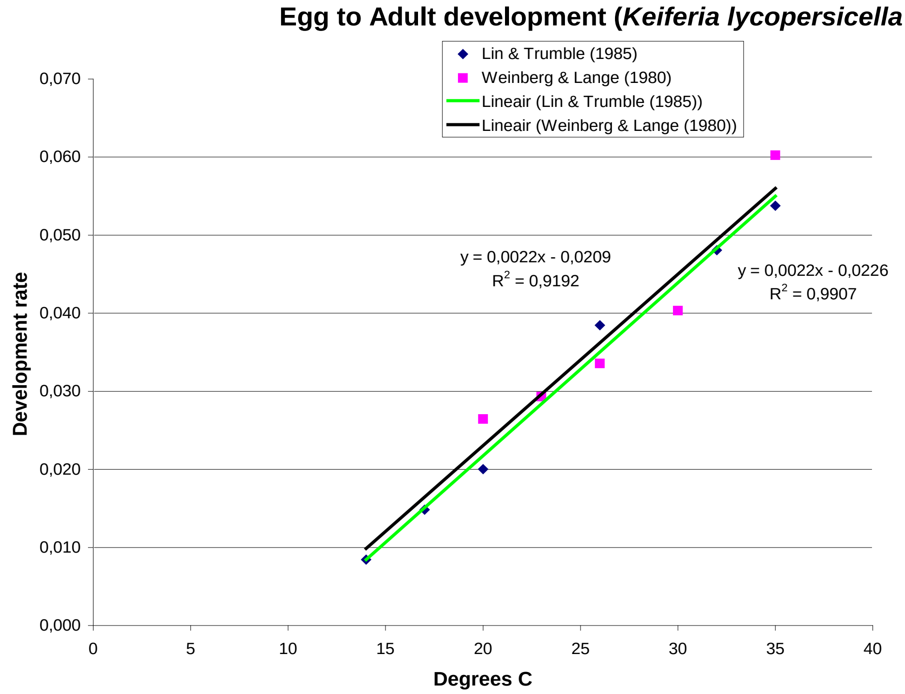


Fig. 4 Relation between temperature and development rate of *K. lycopersicella*

2.2 <u>CLIMEX modelling</u>

One of the factors determining the northerly limit of the organism in the PRA area is the amount of degree days available for development and reproduction.
A simple phenology model with a base temperature of 10 ºC and 455 degree days has been applied in CLIMEX (v3). The number of generations that *K. lycopersicella* can have in one year is presented for the PRA area, based on weather interpolated gridded data (figure 5).
In southern Europe and North Africa the number of expected generations is 3-8 and in Northern Europe 1-2 generations. It should be noted that transient field populations may occur in Northern Europe in the summer time. However, it is unclear if and how the organism can survive the winter conditions in this region.
More detailed information on the exact locations of field populations in North and South America is needed to build a CLIMEX model that can predict the zone in the PRA area where sustainable field populations can establish.

It should be noted that *K. lycopersicella* occurs in desert climates such as the tomato production regions in California (Bakersfield). Day time temperatures can be extreme in these regions and can reach 45°C. In Tunisia the distribution of *T. absoluta* seems to be limited by extreme daytime temperatures (Chermiti, pers. comm. EWG 2011-09). This could imply that *K. lycopersicella* can establish in larger parts in Northern Africa than is currently the case for *T. absoluta* (see Fig. 6).

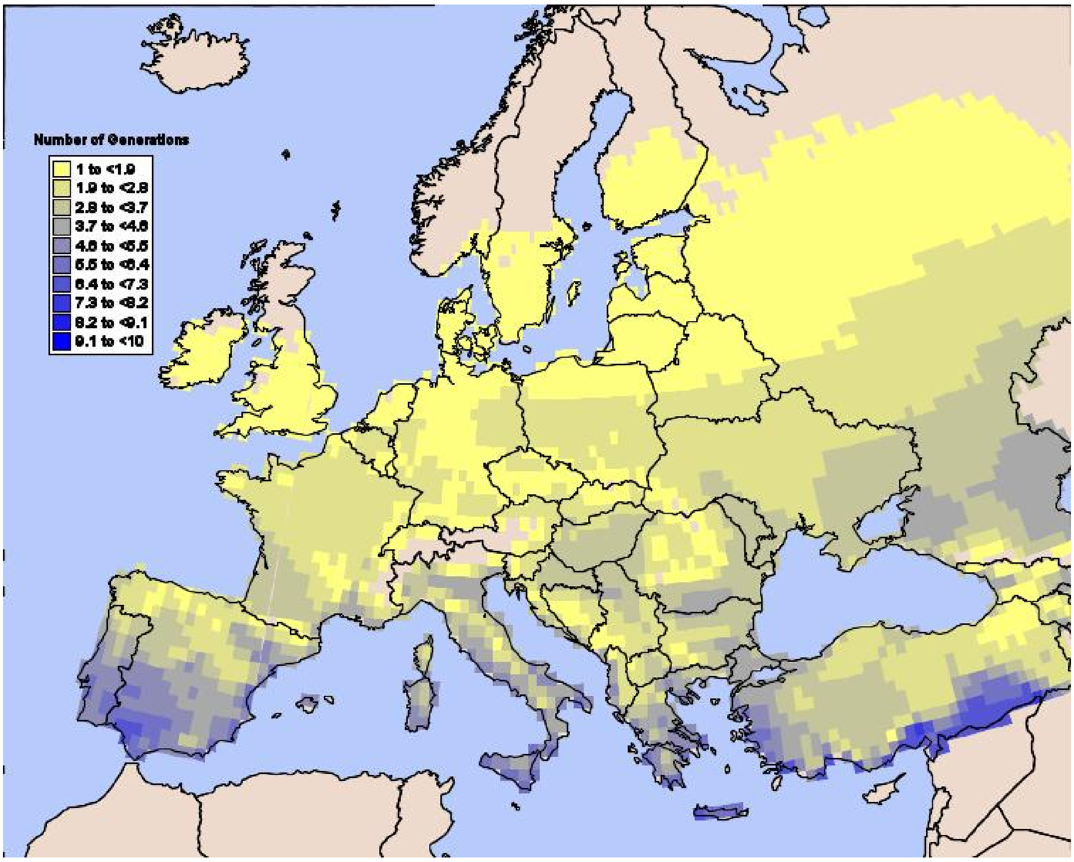


Fig. 5. Map showing the maximum number of expected generations of *K. lycopersicella* in the PRA area based on 455 degree day accumulation above a minimum temperature of 10° C, based on gridded interpolated dataset.

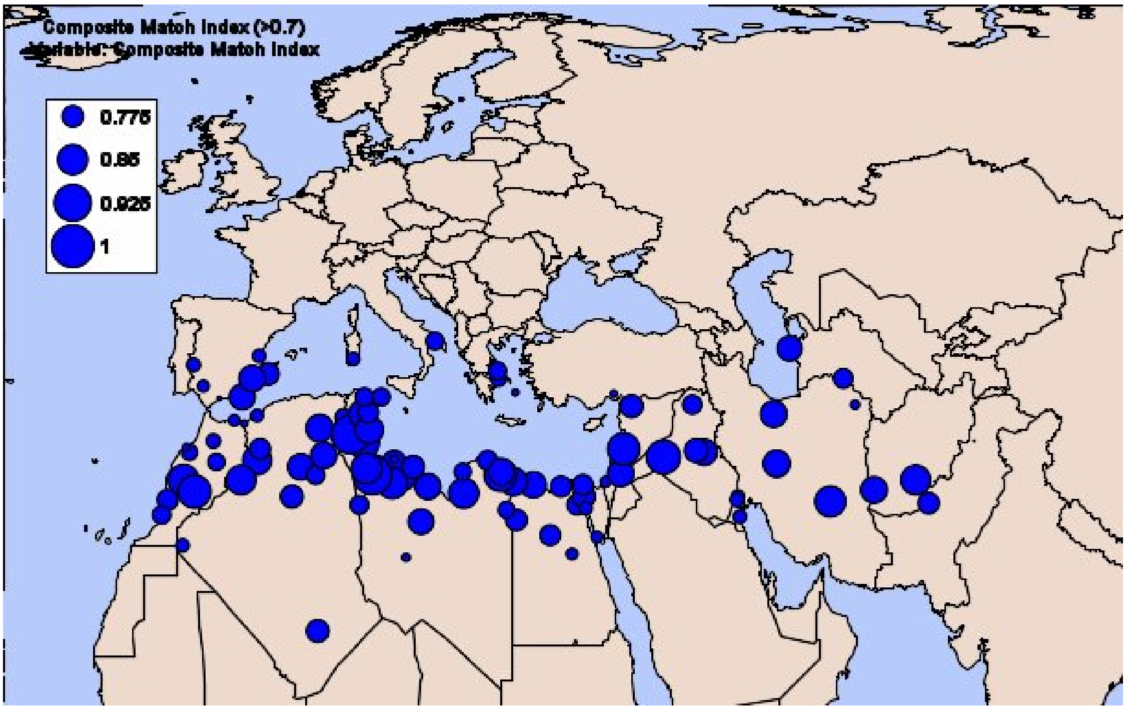


Fig. 6. Map showing the Climate match between Bakersfield (California) where the pest occurs, and the EPPO region. (Comparison taking into account, minimal temperature, maximal temperature, average temperature, total rainfall and rainfall pattern over 52 weeks a year)

Greenhouse conditions
Assuming that the mean temperature in a greenhouse is 20 ˚C, the expected time for one life cycle is: 455DD/(20-10)=45,5 days. In northern countries of the PRA area, the expected number of generations during the growing season (March-August) is 3-4 generations.

3. Conclusions

Rating: **largely similar** in the Mediterranean area
Level of uncertainty: **Low**

Visual examination of the Köppen-Geiger climate zones, hardiness zones and degree day maps shows that the climate in its current area of distribution is largely similar to that in the PRA area.
In northern areas of the PRA area only transient field populations are expected, but permanent populations may establish in greenhouses.

ANNEX 4 - Natural enemies of *Keiferia lycopersicella*

Note: synonymy has not been checked

Species (family)	**Reference**
Agathis sp. *(Braconidae)*	Oatman & Platner (1989), Pena & Waddill (1983)
Angitia blackburni	Elmore & Howland (1943, citing others)
Angitia ferrugineipes	Elmore & Howland (1943, citing others)
Apanteles (Xanthomicrogaster) digitus	Cock (1985)
Apanteles dignus (Braconidae)	Elmore & Howland (1943, citing others), Oatman & Platner (1989)
Apanteles epinotiae	Elmore & Howland (1943, citing others)
Apanteles gelechiidivoris	CABI, 2007
Apanteles scutellaris	Alvarado-Rodríguez, 1988;Cock, 1985; CABI, 2007; Elmore & Howland (1943, citing others), Oatman & Platner (1989)
Bacillus thuringiensis kurstaki	CABI, 2007
Bacillus thuringiensis thuringiensis	CABI, 2007
Bracon spp. *(Braconidae)*	Oatman & Platner (1989)
Bracon gelechiae (Braconidae)	Oatman & Platner (1989)
Campoplex n. sp. *(Ichneumonidae)*	Oatman & Platner (1989)
Campoplex phthorimaeae (Ichneumonidae)	Oatman & Platner (1989), Elmore & Howland (1943, citing others), CABI, 2007
Campoplex sp.*n.*	Cock (1985)
Catolactus aeneoviridis	Elmore & Howland (1943, citing others)
Chelonus blackburni	
Chelonus blackburni (Braconidae)	Oatman & Platner (1989), Cock (1985)
Chelonus phthorimaeae (Braconidae)	Oatman & Platner (1989), Elmore & Howland (1943, citing others), CABI, 2007
Chrysocharis spp.	Elmore & Howland (1943, citing others)
Elasmus nigripes (Eulophidae)	Oatman & Platner (1989)
Goniozus sp. *(near Plalynotae) (Bethylidae)*	Oatman & Platner (1989)
Hormius pallidipes	Elmore & Howland (1943, citing others)
Microbracon junicola	Elmore & Howland (1943, citing others)
Microchelonus blackburni	CABI, 2007
Orgilus spp. (Braconidae)	Oatman & Platner (1989)
Parahormius pallidipes (Braconidae)	Oatman & Platner (1989), CABI, 2007; Cock (1985)
Pristomerus hawaiiensis (Ichneumonidae)	Oatman & Platner (1989)
Pristomerus spinator (Ichneumonidae)	Oatman & Platner (1989)
Pseudapanteles dignus	CABI, 2007; Alvarado-Rodríguez, 1988
Sympiesis stigmatipennis (Eulophidae)	Oatman & Platner (1989), Pena & Waddill (1983), Elmore & Howland (1943, citing others), CABI, 2007
Temelucha spp.	Pena & Waddill (1983)
Tetrastichus sp.	Elmore & Howland (1943, citing others)
Trathala flavoorbilalis (Ichneumonidae)	Oatman & Platner (1989)
Trichogramma pretiosum (Trichogrammatidae)	Oatman & Platner (1989), Pena & Waddill (1983), CABI, 2007
Zatropis (near Tortricidis) (Pteromalidae)	Oatman & Platner (1989), Elmore & Howland (1943, citing others)