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Pest Risk Analysis for

Neoleucinodes elegantalis

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This risk assessment follows the EPPO Standard PM PM 5/5(1) *Decision-Support Scheme for an Express Pest Risk Analysis* (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 the Panel on Phytosanitary Measures and if relevant other EPPO bodies.

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Photo: *Neoleucinodes elegantalis* adult Dr M. Alma Solis, Systematic Entomology Laboratory, USDA-ARS, Beltsville (US)

Pest Risk Analysis for *Neoleucinodes elegantalis* (Guenée), 1854

This PRA follows EPPO Standard PM 5/5 *Decision-Support Scheme for an Express Pest Risk Analysis*.

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Core members (Ms Dimitrova, Mr Guitian Castrillon, Ms Levi, Ms Petter; Mr Pfeilstetter, Mr Steffek, Ms Ustun, Mr van der Gaag) reviewed the draft PRA between August and September 2013.
The risk management part was reviewed by the Panel on Phytosanitary Measures on 2014-03-06.

Content

Summary of the Express Pest Risk Analysis for ***Neoleucinodes elegantalis***			
PRA area: EPPO region			
Describe the endangered area: Glasshouses and other protected conditions (screen houses/ polytunnels) throughout the PRA area. Outdoor host crops in the Mediterranean region, Portugal and in the Near East.			
Main conclusions *Overall assessment of risk:* The likelihood of entry is considered as low, although it might increase if trade volumes of host commodities from the Americas and Carribean would increase. The likelihood of establishment is considered moderate outdoors and under protected conditions in the Mediterranean region, Portugal and in the Near East. Establishment in the rest of the EPPO region is considered very unlikely and unlikely outdoors and under protected conditions, respectively. Where it is introduced, the pest is likely to cause losses, at least until control methods are added to the current integrated management programmes in the crops concerned. The pest is expected to have a moderate impact e.g. on fruit production, exports and possibly on seed production. Long-distance spread will be via human-assisted pathways, especially fruit. *Phytosanitary Measures to reduce the probability of entry:* for fruit and plants for planting: PFA, Pest free place of production, systems approach. In the two later cases, only new packaging should be used at origin, and packaging should be destroyed or safely disposed of at import.			
Phytosanitary risk for the *<u>endangered area</u>* *(Individual ratings for likelihood of entry and establishment, and for magnitude of spread and impact are provided in the document)*	High ☐	**Moderate** ☒	Low ☐
Level of uncertainty of assessment (see Q 17 for the justification of the rating. Individual ratings of uncertainty of entry, establishment, spread and impact are provided in the document)	High ☐	**Moderate** ☒	Low ☐
Other recommendations: It would be important to lower the uncertainty of the assessment by • obtaining more data on the temperature thresholds for the pest, • clarifying whether the distribution records at origin correspond to *N. elegantalis*, and why differences are reported on its behaviour and its host plants between different places where the pest occurs.			

Stage 1. Initiation

Reason for performing the PRA:

Neoleucinodes elegantalis is a Lepidopteran fruit-borer which is currently present in some countries of South, Central and North America, and the Caribbean. In several countries, including Argentina, Bolivia, Brazil, Colombia, Ecuador, Honduras (due to rejections at export), Suriname and Venezuela, it has been reported as a major pest of several solanaceous fruit crops. The pest is absent from the EPPO region, where several of its cultivated hosts are extensively grown for fruit: tomato (*Solanum lycopersicum*), eggplant (syn. aubergine; *S. melongena*) and sweet pepper (*Capsicum annuum*). Although no introduction is reported outside of the Americas and the Caribbean, *N. elegantalis* is known to be associated with international trade. There are many records of interception from the USA (Molet, 2012), and the pest has been intercepted 31 times by the Netherlands on fruit of eggplant from Suriname in baggage at Schiphol airport (NVWA, 2012).

In 2012, the EPPO Panel on Phytosanitary Measures added *N. elegantalis* to the EPPO Alert List of pests possibly presenting a risk to the EPPO region and selected it as a priority for PRA. The Panel also suggested that the recently-adopted PM 5/5 *Decision-Support Scheme for an Express Pest Risk Analysis* could be used.

The present PRA uses and refers to elements in other recent PRAs, especially those for three Lepidopteran pests of tomato or eggplant: the related-species *Leucinodes orbonalis* (EPPO 2012a; van der Gaag *et al*., 2005), as well as *Keiferia lycopersicella* (EPPO, 2012b) and *Tuta absoluta* (Potting *et al.*, 2010).

Note: In order to be consistent with other previous PRAs, this PRA use 5 rating levels (e.g. very low, low, moderate, high, very high) even if PM 5/5(1) uses only 3 levels.

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

Stage 2. Pest risk assessment

1. Taxonomy

Taxonomic classification. Order: Lepidoptera; Superfamily: Pyraloidea; Family: Crambidae; Subfamily: Spilomelinae; Tribe: Spinomelini; Genus: *Neoleucinodes*; Species: *elegantalis* (Guenée), 1854.

Capps (1948) proposed the new genus *Neoleucinodes* and included in it several species previously included in the genus *Leucinodes*. Diaz (2010b) indicate that there are five species of *Neoleucinodes* in Colombia, some being present in other South American countries, and gives some information on the distribution and hosts of these five *Neoleucinodes* spp. in South America. One of these, the recently-described *N. silvaniae* (with limited distribution in Colombia and *Solanum lancefolium* as host), is morphologically very similar to *N. elegantalis* (Diaz & Solis, 2007; Molet, 2012). *N. elegantalis* is also morphologically very similar to several other species of Crambidae that occur in Central and South America (genera *Neoleucinodes*, *Euleucinodes*, *Proleucinodes*) but which are not considered as pests. The identification of these species requires the examination of the genitalia. It is possible that some older records of *N. elegantalis* were misidentified, as in some cases these records are not supported by any recent evidence of presence of the pest.

Synonyms. *Leucinodes elegantalis* Guenée (Capps, 1948).

In Colombia, *N. elegantalis* is found in different life zones (according to the Holdridge classification of climate zones), some being separated from each other by physical barriers, and it is envisaged that a speciation process of these distinct populations has led or could lead to biotypes or host races. The presence of different biotypes was demonstrated in Colombia (Diaz-Montilla *et al.* 2013b; Baena- Bejarano *et al.* 2013).

Common names

- *English.* tomato fruit borer, eggplant moth, cocona fruit borer, small tomato borer (EPPO, 2012c; Molet, 2012).

- *Spanish***.** perforador del fruto, pasador del fruto de lulo/del tomate, gusano rosado, barrenador del fruto del tomate, gusano perforador, gusano del tomate de árbol, gusano perforador menor del fruto (Gallego, 1960; ALAE, 1968; Sánchez, 1973; Posada *et al.*, 1981; Fernández and Salas, 1985; Gallego & Velez, 1992; Serrano *et al.* 1992; Carmona *et al.*, 2006; EDA, 2007; GAD-DSA, 2010; EPPO, 2012c).
- *Portuguese.* broca pequena do fruto, do tomateiro (Badji *et al.*, 2003; EEACG, 2010; EPPO, 2012c).
- *French*. petit foreur de la tomate (DAFGuyane, 2006).

2. Pest overview

2.1 Biology of the pest

The main elements relevant for this PRA are summarized below and in Appendix 1 (references are specified only in the Appendix 1 to keep the text here short). See also the datasheet (Diaz-Montilla, in press)

Life stages

Table 1. Morphology of the life stages of *N. elegantalis*

Stage	***Colour/shape***	***Size***
Eggs	White to orange/reddish close to eclosion	Oval, 0.5x0.3 mm
Mature larvae	Whitish to pinkish with brown head	15-20 mm
Pupae	Light to dark brown	12-15 mm
Adults	White wings with brown and dark dots	15-33 mm (wingspan)

Eggs are laid singly or in groups of 2-3 eggs, and mostly on young fruits, under the calyx or on fruit stalks but may also be laid on flowers, leaves or buds in case of high infestation levels. The average number of eggs per female seems to be around 30-50.
There are 4 or 5 larval instars. At egg eclosion, larvae penetrate quickly (about 1 hour) into the fruit. The entry holes are very small. Larvae feed within the fruit throughout their development. Mature larvae exit the fruit through a bigger exit hole.
Pupae are protected by a delicate sticky cocoon (Carneiro *et al.*, 1998). Pupae are usually formed on enfolded leaves on the plant or on leaves on the ground, but the pest may also pupate in plant debris or on plastic mulch on the ground at the base of the plant.
Adults are nocturnal. They mate within 48 to 72 h of eclosion and shortly thereafter begin depositing eggs.

Life cycle

Several generations per year are observed. The pest may develop both on crops and on wild hosts. In some areas, the pest is present throughout the year in the crops and generations overlap (Barbosa *et al.*, 2010). At temperatures around 20-25°C, the life cycle lasts 30-60 days.

Temperature and relative humidity thresholds and preferences

Marcano *et al.* (1991a, b) report no oviposition at 14.7 °C, no eclosion of egg at 30.2 °C, and no development to the adult stage at 34.5 °C.
According to Marcano (1991a&b), development is favoured by a relative humidity above 65% and a maximum temperature of 25ºC. Populations of *N. elegantalis* are reported to increase during the rainy season (EDA, 2007).

Detection

Signs and symptoms of infestation include entry holes, exit holes, slight change of colour of fruit, fruit falling on the ground, excrements on the fruit (especially on *S. quitoense* and *S. betaceum*).
Visual detection is difficult as many life stages are hidden.

Detection methods (see Appendix 1 for details).
The pest can be detected by pheromone traps (Cabrera *et al.*, 2001; Badji, 2003; Jaffe *et al.*, 2007), but the pheromone blend used in practice is not attractive for all populations (e.g. in Ecuador and Brazil, see Appendix 1). Careful visual examination may also detect eggs, pupae, and signs of presence of larvae (especially exit holes). *N. elegantalis* is morphologically very similar to several other species of Crambidae that occur in Central and South America.

3. Is the pest a vector? Yes ☐ No ✓

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

5. Regulatory status of the pest

N. elegantalis is not listed as a quarantine pest by any EPPO country according to the EPPO collection of phytosanitary regulations and summaries (www.eppo.int). *N. elegantalis* is on the EPPO Alert List.
In other regions, *N. elegantalis* is listed as a quarantine pest for at least (this is not an exhaustive list): Chile, New Zealand and the Caribbean Plant Protection Commission (Diaz *et al.*, 2010, citing others; EPPO, 2012c; MPI, 2012). It is an actionable pest for the USA, and subject to monitoring (CAPS, 2012).

N. elegantalis was mentioned in the literature as a quarantine pest for the following countries, but is not listed as a quarantine pest anymore in 2013, which may indicate an introduction:

- Argentina: mentioned in EPPO (2012c) based on information from 1995, but the pest is no longer on the list of regulated pests for Argentina published in 2009 (www.ippc.int).
- Peru: listed in 2007[1], mentioned in Diaz *et al.* (2010), but the pest is no longer on the list of regulated pests for Peru published in 2012 (www.ippc.int).

6. Distribution

N. elegantalis is reported as present in a number of countries. However, it is not considered as a pest everywhere. This is summarized in the column '*comments on the pest status'* and more details are given below the table as well as in section 12.

Continent	*Distribution*	*Comments on the pest status* (*see explanation below*)	*Reference*
America	**Present in North America**		
	• Mexico	No specific record as a pest found. Details in the draft data sheet (distribution checked by Diaz-Montilla, Corpoica, Colombia - Solis, USDA pers. comm. 2013)	Capps, 1948
	Present in Central America and Caribbean		
	• Costa Rica	No specific record as a pest found	Capps, 1948; CRBio, 2012
	• Cuba	No specific record as a pest found	Capps, 1948; Núñez Águila, 2004
	• Grenada	No specific record as a pest found	Capps, 1948
	• Guatemala	No specific record as a pest found	Capps, 1948; Lightfield, 1996 (citing Saunders *et al.*, 1983, Chawkat, 1995)
	• Honduras	Recorded as a pest (due to rejections at export)	EDA, 2007; Espinoza, 2008; Miller *et al.*, 2012
	• Jamaica	No specific record as a pest found	Capps, 1948
	• Panama	No specific record as a pest found	Capps, 1948; Lightfield, 1996 (citing Saunders *et al.*, 1983, Chawkat, 1995)
	• Puerto Rico	No specific record as a pest found	Capps, 1948; Lightfield, 1996 (citing Saunders *et al.*, 1983, Chawkat, 1995)
	• Trinidad and Tobago	No specific record as a pest found	Trinidad, Capps, 1948
	Present in South America		
	• Argentina	Recorded as a pest (details in draft data sheet)	Capps, 1948; Olckers *et al.*, 2002; INTA, 2011, Puch and Mollinedo, 2009
	• Bolivia	Restricted distribution (Gobierno Departamental Autónomo Santa Cruz). No indication found of further spread. Recorded as pest. First damage observed in 2008.	GDA-DSA, 2010
	• Brazil	First recorded in 1922. Important pest. Details in the data sheet (in press).	Capps, 1948; Badji *et al.*,

[1] http://www.senasa.gob.pe/RepositorioAPS/0/2/JER/NOTIFICACON_CUARENT/lpc_may_2007%5B1%5D.pdf

Continent	*Distribution*	*Comments on the pest status* (*see explanation below*)	*Reference*
			2003, citing Toledo, 1948; Costa Lima, 1950
	• Colombia	First recorded in 1945 on *S. betaceum*. Important pest. Details in the draft data sheet (distribution checked by Diaz-Montilla, Corpoica, 2013)	Capps, 1948; Diaz & Solis, 2007
	• Ecuador	Restricted distribution. Province Pastaza (Amazone region) (PQR, 2012d). Current distribution (Fontagro project): Provinces: Napo, Carchi, Pichincha, Tungurahua, Morona Santiago, Chimborazo, Pastaza, Galapagos Details in the draft data sheet (distribution checked by Diaz-Montilla, Corpoica, 2013 – Soria, Fontagro project, pers. comm.). Introduced into the Galapagos [in 2002] (Santa Cruz Island) (Roque-Álbelo and Landry, 2011, accidental introduction). Recorded as a pest. Important pest on *S. quitoense* and *S. betaceum*.	Capps, 1948; Casas Leal 2008 (citing Jijon 1982); Asaquibay *et al.*, 2009; Paredes *et al.*, 2010; Causton *et al.*, 2006; Roque-Álbelo and Landry, 2011.
	• Guyana	No specific record as a pest found	Capps, 1948
	• Paraguay	No specific record as a pest found	Capps, 1948; Medal *et al.*, 1996
	• Peru	Restricted distribution (EPPO, 2012d). Province Leoncio Prado (department Huanuco). No indication found of further spread	Capps, 1948; Anteparra *et al.*, 2010
	• Suriname	Introduced in 2003 according to Parbode (2010). AAAAG (2008) mentions that it was first observed in 2006. Important pest	AAAAG, 2008; Parbode, 2010
	• Uruguay	Collected from aubergine, tomato and *Solanum sisymbriifolium.* No specific record as a pest found. After specific surveys, Diaz-Montilla (Corpoica, pers. comm. 2013) considered that the species is not present in crops in Urugay.	EPPO, 2012d, based on Biezanko *et al.*, 1974
	• Venezuela	First recorded in 1934 (Marcano, 1991a, citing others). Important pest.	Capps, 1948; Salas *et al.*, 1991 ; Marcano, 1991 a &b
Africa	Absent		
Asia	Absent		
Europe	Absent		
Oceania	Absent		

Comments on the distribution:

N. elegantalis seems to be native to South America because it was shown to be first associated with solanaceous plants native in that region. In some countries of South America, Central America, or the Caribbean, information shows that it was recently introduced (e.g. Suriname, Galapagos within Ecuador). In others, even for recent records, it is difficult to know if the pest was previously there and unnoticed, before damage was observed (e.g. Bolivia).

Damage is not observed throughout the distribution of the pest (Capps, 1948; Diaz-Montilla, Corpoica, Colombia, pers. comm., 2013), nor on all host plants. Country records may be grouped as follows:

- **Argentina, Bolivia, Brazil, Colombia, Ecuador, Honduras, Peru, Suriname, Venezuela.** There are indications on the situation of the pest and records of damage on fruit crops. The pest is recorded as an important pest mostly from Brazil, Colombia and Venezuela, and there is abundant literature for these countries. For Peru, there is an uncertainty on whether the pest was recently introduced or detected: Capps (1948) mentions Peru, but Anteparra *et al.* (2010) note that *N. elegantalis* had not been observed on any crops in this country prior to its detection on *S. sessiliflorum* in 2008.
- **Costa Rica, Cuba, Mexico, Paraguay, Uruguay**. The records in the table above (additional to Capps (1948) for Cuba, Mexico and Paraguay) relate to collection data or lists of species. For Mexico, the pest was collected in light traps but is not recorded as a pest (Solis, USDA, pers. comm., 2013). For Costa Rica, Cuba, Paraguay and Uruguay, no publication was found on the presence of the pest in crops and whether it causes damage.

Doubtful and unreliable records

- **Grenada, Guatemala, Guyana, Jamaica, Panama, Trinidad and Tobago, doubtful record.** The only record is from Capps (1948), and no other record of *N. elegantalis* was found in the literature. Note: Guatemala, Panama, Puerto Rico are also mentioned in Lightfield (1996), with reference to Chawkat

(1995) and Saunders et al. (1983). However, Chawkat (1995) was not available for verifying the original source/details of the records but it is a short datasheet. Saunders et al. (1983) does not seem relevant as it is a general publication on Central America, which does not give details on distribution. These records seem doubtful as no other record was found.

- **Puerto Rico:** Molet (2012) reports that M. A. Solis, a pyraloid moth expert at the Systematic Entomology Laboratory (SEL), Agricultural Research Service (ARS), concluded that it is likely a misidentification that has been perpetuated in literature.
- **French Guiana, unreliable record.** Capps (1948) (and other publications citing it) mention the presence of *N. elegantalis* in French Guiana. However, this pest was considered as absent and alert was given to growers in 2006 (DAF Guyane, 2006) due to the recent introduction of this new pest in the neighbouring country Suriname. This territory was still considered at threat in 2008 (AAAAG, 2008). The record of French Guiana is therefore considered unreliable (EPPO, 2012c).
- **Nicaragua, El Salvador, doubtful record.** Anteparra *et al.* (2010), which is about the situation in Peru, include Nicaragua and El Salvador in a distribution list of the pest. However, this seems to originate from Lightfield *et al.* (1996), which is a PRA from the USA for eggplants from El Salvador and Nicaragua. Lightfield *et al.* (1996) give distribution records for pests, but for *N. elegantalis* only refer to Costa Rica, Guatemala, Panama and Puerto Rico, and not Nicaragua and El Salvador (although they add *N. elegantalis* to the list of quarantine pests). These countries are not included in the distribution list above.

7. Host plants and their distribution in the PRA area

The hosts of *N. elegantalis* are cultivated, wild and weed species in the family Solanaceae. The host plants that are widely cultivated in the EPPO region are in bold.

Host scientific name (common name)	**Presence in PRA area** (see 9.1)	**Comments**	**Reference (for host status)**
Cultivated species proved to be hosts (listed in this category if cultivated at least in some countries at origin)			
***Capsicum annuum* (sweet pepper)**	Yes	Sweet pepper. Widely cultivated for fruit, at origin and in the EPPO region.	Anteparra, 2010, citing others; Barbosa *et al.*, 2010 citing others
Solanum lycopersicum	Yes	Tomato. Widely cultivated for fruit at origin and in the EPPO region.	Capps, 1948
***Solanum melongena* (incl. synonym *S. ovigerum*)**	Yes	Eggplant (syn. aubergine). Widely cultivated for fruit at origin and in the EPPO region.	Capps, 1948; Barbosa *et al.*, 2010 citing others; Benvenga 2009 citing Picanço *et al.* (1997)
Solanum betaceum (=Cyphomandra betacea)	Yes	Tamarillo, tomate de árbol. Cultivated for fruit at origin. Only limited production in the EPPO region.	Capps, 1948; Barbosa *et al.*, 2010 citing others; Diaz & Solis, 2007
Solanum pseudolulo	?	Lulo del pacific or luloeperro. Cultivated for fruit at origin. Crop found infested in Colombia	Diaz, 2009
Solanum quitoense	?	Lulo, naranjilla. Cultivated for fruit at origin. Possibly ornamental in the EPPO region?	Asaquibay *et al.*, 2009 (abstract), Barbosa *et al.*, 2010 citing others
Solanum sessiliflorum	?	Cocona, tupiro, popiro, cubui, Indian tomato, peach tomato, apple or peach of the Orinoco. Cultivated for fruit in some countries at origin, wild in others. Tropical species. Possibly ornamental in the EPPO region?	Anteparra *et al.*, 2010; Diaz 2010b citing Diaz & Anteparra unpublished
Unconfirmed records of cultivated hosts (see explanation below)			
Solanum gilo (=S. aethiopicum)	?	Jiló. Widely grown for fruit in Brazil. Not known to be cultivated in the EPPO region.	Picanço *et al.*, 1997; Diaz 2010b citing Picanço *et al.*, 2007; Benvenga, 2009
Solanum lycocarpum	?	Manzana del lobo. Traditional fruit crop in at least a part of Brazil, wild in some other countries at origin. Possibly ornamental in the EPPO region?	Diniz and Morais, 2002
Solanum sisymbriifolium	?	Fruit and ornamental. Also used as trap crop for potato cyst nematode. Possibly used as ornamental or trap crop in the EPPO region?	Capps, 1948; Barbosa *et al.*, 2010 citing others; Gama 2011 citing Benvenga 2009

Wild plants, weeds			
Solanum acerifolium	No?	In EPPO region, not present according to Flora Europeae (2011) and Solanaceae Source (2013)	Diaz, 2010b
Solanum arboreum	No?	In Ecuador. In EPPO region, not present according to Flora Europeae (2011) and Solanaceae Source (2013)	Unpublished data (Diaz-Montilla, Corpoica, Colombia, pers. comm., 2013)
Solanum atropurpureum	No?	In EPPO region, not present according to Flora Europeae (2011) and Solanaceae Source (2013)	Diaz, 2010b
Solanum crinitum	No?	In EPPO region, not present according to Flora Europeae (2011), and Solanaceae Source (2013)	Diaz, 2010b
Solanum hirtum	No?	In EPPO region, not present according to Flora Europeae (2011) and Solanaceae Source (2013)	Anteparra, 2010, find other; Diaz, 2010b
Solanum torvum	Yes	In the PRA area, used as rootstock for *S. melongena*.	Diaz, 2010b
Solanum umbellatum	No?	In Colombia. In EPPO region, not present according to Flora Europeae (2011) and Solanaceae Source (2013)	Unpublished data (Diaz-Montilla, Colombia, pers. comm., 2013)

Comments on hosts

- In its current distribution, *N. elegantalis* does not seem to attack all hosts in all places. For example, in Ecuador it is reported to cause damage only on *S. quitoense* and not on tomato, eggplant or sweet pepper (Paredes *et al.*, 2010). In Colombia on the Caribbean coast (Northern part) the pest is only found on wild hosts even if *Capsicum annuum* and *Solanum melongena* are grown there commercially (Diaz *et al.*, 2011), and it is a pest of concern for sweet pepper and eggplants in other parts of Colombia.
- Although some records for cultivated host species are not totally confirmed because of the difficulty of identification of the pest, these hosts have been kept in pathways as a precautionary step: *S. gilo*, *S. lycocarpum*, *S. sisymbriifolium*.
- All hosts of *N. elegantalis* are Solanaceae, but not all Solanaceae have been recorded as hosts. In particular potato (*Solanum tuberosum*) is not a host.

Unconfirmed host records

- .
- ARS (2012) mentions *Sechium edule* in a host list relating to interceptions, which is identical to that in Solis (2006), which gives identification keys for intercepted species. However, the original source of this record is not known, and *S. edule* is a Cucurbitaceae. It is not clear whether this record relates to an interception. In addition, Robinson *et al.* (2010) mention that *N. elegantalis* was intercepted on *Cereus* spp. (Cactaceae). All hosts of *N. elegantalis* in the literature directly related to this pest are Solanaceae, and *Sechium edule* and *Cereus* spp. were not considered as hosts in this PRA.
- The record of *Solanum mauritianum* mentioned in Olckers *et al.* (2002, citing Neser *et al.*, 1990) refers only to collection of adult specimens (Diaz-Montilla, Corpoica, Colombia, pers. comm., 2013).
- A number of wild plants are reported as hosts, but the original source does not mention the study of genitalia (which allows differentiating *N. elegantalis* from other species of *Neoleucinodes*, *Euleucinodes*, *Proleucinodes*). These species are:
  - *Solanum capsicoides (= Solanum ciliatum),* Barbosa *et al.*, 2010 citing others; Benvenga, 2009,
  - *Solanum granulosum-leprosum,* Cordo *et al.,* 2004
  - *Solanum palinacanthum,* Carneiro *et al.*, 1998
  - *Solanum paniculatum,* Barbosa *et al.*, 2010 citing others
  - *Solanum reflexum* (= *S. aculeatissimum*), Barbosa *et al.*, 2010 citing others; Benvenga, 2009 citing others
  - *Solanum robustum,* Carneiro *et al.*, 1998, Barbosa *et al.*, 2010 citing others; Benvenga, 2009 citing others
  - *Solanum viarum,* Medal *et al.*, 1996; Olckers *et al.*, 2002.

  None of these species are present in the EPPO region according to Flora Europeae (2011) and Solanaceae Source (2013)

Uncertainties on hosts

- *Capsicum frutescens* (chilli). The literature seems to refer to sweet pepper (i.e. *Capsicum annuum*) and not to chilli when referring to the hosts of the pest. Solis (2006), which gives identification keys for intercepted Lepidoptera mentions both *Capsicum* sp. and *Capsicum annuum*, but it is not clear what it refers to. The same article mentions "cayenne pepper" as a host (but identifies it to *Capsicum annuum*).
- Molet (2012) mentions *S. racemiflorum* in a list of minor hosts, referring to Aponte *et al.* (2005) and EPPO (2012d). These publications do not mention this species, and no other reference was found in the literature. In addition, it seems to be a synonym of *S. aethiopicum* (Bisby *et al.*, 2009). As Molet already referred to *S. aethiopicum*, it is not clear what was meant with *S. racemiflorum*. *S. racemiflorum* was not retained as a host in this PRA.

8. Pathways for entry

Host fruit is the only pathway mentioned in the literature in relation to the spread of *N. elegantalis*, together with natural spread by moths flying within and between tomato fields. In addition, unlike for *K. lycopersicella*, movement of the pest by infested seedlings, picking and packing boxes carrying life stages are not mentioned. However, taking account of its biology, it is considered here that it could also be transported on plants for planting, soil and packaging.
For the purpose of assessing entry, the hosts that are cultivated at origin (see table in section 7) are considered for the commodity pathways: *Capsicum annuum, Solanum lycopersicum, Solanum melongena*. Information related to the life-cycle of the pest relevant for the pathways of entry is given in section 2.1. Notable differences between *N. elegantalis* and *K. lycopersicella* regarding pathways are that larvae of *N. elegantalis* are present only on fruit; their presence on other plant parts (e.g. calyx) is limited to the short period needed to find a suitable site on a fruit. Indications related to oviposition also seem to indicate that females oviposit only on plants carrying flowers or young fruits. Therefore it is considered that seedlings (e.g. young plants of tomato, eggplant or sweet pepper) would not carry any life stages.

There are a number of records of interception of *N. elegantalis* in the USA and the Netherlands. In the Netherlands, *N. elegantalis* was intercepted 31 times on fruit of *S. melongena* from Suriname from 2006 to 2013. In the USA, most interceptions were made on fruit. A small proportion of interceptions seem to have been on other commodities (Molet, 2012), but no detail is available. Regarding the host species concerned, Robinson *et al.* (2010) report that the pest was intercepted in the USA on *Capsicum* spp., *Solanum* spp., *S. lycopersicum, S. melongena, S. quitoense, S. torvum* as well as on *Cereus* spp. (see under section 7 regarding the uncertainty linked to *Cereus* spp.). Molet (2012) notes that the pest had been intercepted 1175 times at points of entry in the USA as of April 2012, all specified interceptions being on host material, originating from Brazil (610), Venezuela (157), Ecuador (102) and Peru (59).

Possible pathways *(in order of importance)*

Fruit of cultivated host species from where the pest occurs Pathway prohibited in the PRA area?: No Pathway subject to a plant health inspection at import?: Yes for eggplant, No for others (in the EU) Pest already intercepted on the pathway?: Yes, numerous (USA, NL)
This pathway includes fruit with or without green parts associated. The calyx would always be associated to eggplant and sweet pepper, while not for tomato. The situation for other host fruits is not known. Fruit is known to be a pathway (introduction into Suriname, see section 6; interceptions, see above - Capps, 1948; Lightfield, 1996; Parbode, 2010; Molet, 2012; NVWA, 2012). **Biological considerations.** The pest may be associated with consignments of host fruits, at any time of the year, with or without green parts attached. Larvae are the most likely life stage to be associated with fruit. Pupae are not likely to be associated with the fruit at harvest or packing, but if mature larvae exit the fruit during transport and storage, pupae may be formed on packages. Pupae have been detected at import (EDA, 2007; Espinoza, 2008). The numerous interceptions of *N. elegantalis* in the Netherlands and the USA in fruit from South America show that the pest can survive transport to the PRA area. Multiplication in transport and storage is unlikely as transport time would not be long enough and not at suitable temperatures to allow emergence of adults, reproduction and egg laying. Interception records also show that it is possible to detect the pest at import although visual detection at early

stage is difficult since larvae are within the fruit. However, host fruit is not subject to specific phytosanitary import requirements against *N. elegantalis* in most EPPO countries, and may be at most subject to some general inspection or targeted inspections against other pests; it is not certain that *N. elegantalis* would be detected. However the fact that fruit of *S. melongena* imported into the EU should be inspected to detect *Thrips palmi* allowed the detection of *N. elegantalis* in eggplant fruit from Suriname in the Netherlands.

Hosts are widespread in the EPPO region (especially tomato, eggplant, sweet pepper), but host fruit are imported for consumption or processing. Transfer with fruit directly provided to the consumer or used for processing is considered unlikely (the pest will be destroyed during processing or discarded by the final consumer). An exception would be if fruit arrive in areas close to production facilities. The risk is therefore higher where imported fruit are stored or repacked close to growing facilities, as for *Keiferia lycopersicella* (EPPO, 2012b). The risk of entry would be higher for the part of the PRA area where the pest could survive outdoors (see 9.2). Late stage or fully grown larvae close to pupation were intercepted in the Netherlands, and would need only a few days to leave the fruit and find a pupation place outside the fruit in the packing station.

Consequently, transfer to a host is considered moderately likely, only if packing and handling facilities are located near production areas of the main hosts. This is a known situation for tomato, chili pepper and eggplants (as reported respectively in the PRAs for *Tuta absoluta* (Potting *et al*., 2010), *Anthonomus eugenii* (Baker *et al.*, 2012; van der Gaag & Loomans, 2013), *Leucinodes orbonalis* (van der Gaag *et al*., 2005) and according to Guitan-Castrillon in Almeria, Murcia and Valencia Regions in Spain, pers. comm., 2013). Information is lacking for other host fruits.

Trade

Appendix 2 indicates imports of small volumes of tomato, eggplant and sweet pepper fruit from countries where the pest occurs, although very limited volumes from countries where it is recorded as a pest causing damage in those crops (especially Brazil, Venezuela, Colombia). There is no import of fruit of the three species from many countries where the pest occurs. However, there are a few instances of regular trade between one country of the EPPO region and one country where the pest occurs. No data was found for other host fruit, but volumes are supposed to be lower than for tomato, eggplant and sweet pepper. Small import volumes allowed the entry of *T. absoluta* within the PRA area some years ago. The risk of successful transfer is higher for countries where the pest is likely to establish outdoors.

Conclusion

The volume of trade of host fruit from countries where *N. elegantalis* occurs into the PRA area is low and the pest is very unlikely to multiply in transport. Other parameters (e.g. association, survival, probability of detection) are favourable to entry, and *N. elegantalis* has been intercepted on this pathway, and is reported to have entered Suriname on tomato fruit. However the key factor is the probability of transfer: it is considered moderately likely if packing and handling facilities for imported fruit are situated close to production areas and very unlikely elsewhere.

Likelihood of entry on the pathway: - moderate, if imported close to production sites. - low in other situations.	**Uncertainty**: moderate in all cases. It is uncertain how much imported host fruits are sorted and packed close to production areas, whether some Solanaceae weeds could serve as hosts in the EPPO region.

Fruit packaging originating from where the pest occurs

Pathway prohibited in the PRA area?: No

Pest already intercepted on the pathway?: No

This covers crates or boxes used for picking and packing host fruits. Packaging carrying fruit is not mentioned in the literature as a possible pathway for *N. elegantalis* but interceptions records are for pupae, which would be formed in the packaging (Espinosa, 2008). Packaging is considered to be a pathway of spread of *T. absoluta* within the EPPO region (Potting *et al.*, 2010), and such association was also considered for *K. lycopersicella*. There is no biological difference allowing the EWG to discard this pathway.

Biological consideration. The life stage which is most likely to be associated with packaging is pupae. Pupae are normally formed on leaves. However, emerging mature larvae transforming to pupae in packing material may pupate at the surface of the crate or between fruit. It is not known whether packing material such as crates would be subjected to any management measures. Packaging used to carry host fruit may be used for other produce while still carrying life stages of the pest.

Transport of fruit takes place within a few days, and stages may survive on crates. The pupal stage lasts up to 40 days (averages closer to 7-15 days). Adults may also survive for several days. The pest would be even more likely to remain undetected than on fruit, as inspection (if any) would mostly target the commodity itself. However, the pest has been intercepted through the presence of pupae. Pupae might be able to complete their development, emergence may take place, and mated adults find a suitable host depending upon where the packaging material is held. Crates used for infested fruit (e.g. tomato) might be reused for harvesting the same fruit, 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, or sweet pepper, weeds, etc. depending upon the location). **Conclusion**: The volume of trade is low (see fruit pathway) and the pest is very unlikely to multiply in transport, and may be detected at entry. Although transfer would be more difficult than from plants, it has been shown to still be possible for *T. absoluta* in the case of a high volume trade to have a sufficient population of adults so that mating takes place (Potting *et al.* 2010). The probability of entry is rated as moderate if crates are destined to facilities where hosts are grown, and very low in other cases.

Likelihood of entry on the pathway: - moderate if imported into a facility where hosts are grown - very low in other cases.	**Uncertainty**: moderate. Whether the pest would remain associated with crates for enough time to facilitate entry with another commodity.

Plants for planting of cultivated host species (see list above) originating from where the pest occurs. Pathway prohibited in the PRA area?: Yes, in some countries (e.g. the EU) Pest already intercepted on the pathway?: No.
Seedlings are not likely to carry any life stage of the pest. This pathway covers larger plants for planting that may be traded for ornamental purposes, with or without associated soil and growing medium. Plants for planting are not specifically mentioned in the literature as a means of spread of the pest (e.g. it is not known whether some of the few interceptions not related to fruit in the USA were made on plants for planting.) **Biological considerations.** Plants for planting would normally be traded without fruit, which implies that larvae would not be present, except for ornamental plants traded with fruit. Pupae may be associated to folded leaves on older plants for planting which have had fruit. Eggs may be laid on leaves but only in the case of high infestation If life stages are associated with the plants for planting, they are likely to survive transport and storage, and may continue their development. The pest is not likely to multiply in transport and storage as this will be short in comparison with its life cycle. Transport is also likely to occur under favourable temperature conditions as these have to be favourable for the hosts. Plants for planting will be planted in favourable conditions for their development, which are likely to be alsosuitable for pest development. Transfer to another host will depend where the plants will be used. Ornamental plants (especially tropical species) may be used indoors in ornamental glasshouses, and transfer is less likely in areas where the pest cannot survive outdoors. **Trade**: No detailed data is available for the trade of host plants, as Solanaceae or individual species are not detailed in the trade statistics of Eurostat or FAO. However, several elements tend to indicate a minor volume of trade: - This pathway is heavily regulated in the EPPO region. 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). - Not all countries in the PRA area have specific requirements on imports of host plants for planting (EPPO, 2012b). Trade to these countries is not known, but it is supposed that if ornamentals are imported, they would mostly come from within the PRA area. **Conclusion**. Plants for planting (ornamentals) with fruit are considered as a favourable pathway for the entry of the pest, but the volumes of imports from areas where the pest occurs are presumed very low. Consequently the likelihood of entry is considered to be low (with a moderate uncertainty). Where imports of Solanaceae are prohibited (e.g. EU), the likelihood of entry is very low (with low uncertainty).

Likelihood of entry on the pathway: low (very low	**Uncertainty**: moderate (low for the EU). Whether

to the EU)	there is trade into countries of the PRA area where solanaceous plants are not prohibited
Travellers carrying fruits or plants for planting of main hosts from where *N. elegantalis* occurs Pathway prohibited in the PRA area?: No Pest already intercepted on the pathway?: Yes (e.g. in NL)	
N. elegantalis was intercepted in the Netherlands during control of passenger baggage at Schiphol airport (NVWA, 2012a). No regular inspections of travellers or their luggage is carried out in the EPPO region. The number of travellers from where *N. elegantalis* occurs could increase as international travel develops. However, entry on fruit transported by travellers is unlikely as such fruit are likely to be intended for consumption, which limits the possibilities for transfer of the pest to a host (see the pathway fruit above). Transport of plants for planting with travellers is possible (despite the fact that Solanaceae are not major ornamental plants, travellers may carry ornamentals or crops to plant for example in their gardens), but for entry to be successful, it would have to occur in an area where the pest could survive outdoors, preferably close to production areas, and the presence of the pest would depend on the age and presence of fruit on the plants. This seems to lower the likelihood of entry on such material. The risk of introducing this pest supports considerations to put in place better prevention against the introduction of pests on fruits or plants carried by travellers. This would require a general approach for plants and plant products carried by travellers, including raising awareness and carrying out inspection (EPPO, 2012a). However, this is beyond the scope of this PRA, and this pathway was not considered further.	
Likelihood of entry on the pathway: low	**Uncertainty**: moderate

Pathways considered unlikely (likelihood very low) and not considered further in the PRA.
The pest has never been intercepted on these pathways.

- **Soil or growing media from areas where *N. elegantalis* occurs.** Only pupae may be associated with soil but they are generally formed in plant debris on the soil, not directly in the soil. The importation of soil inro the EU from countries where the pest occurs is forbidden. **Uncertainty***:* low
- **Hitch-hiking of adults on containers, machinery and conveyances.** Adults fly and may become associated to means of transport. For *N. elegantalis*, attraction by light is reported in some publications, but is not considered consistent (see under section 2.2). In addition, the life span of the adult is low (a few days) and unlikely to allow entry from the Americas. This pathway is considered very minor in comparison with the possibility of entry on fruit. **Uncertainty***:* low
- **Natural spread from where the pest occurs.** *N. elegantalis* is reported only in the Americas and the Caribbean. Adults fly, but this is not considered as a possible means of entry into the EPPO region. Natural spread will be an important parameter in case of introduction into the EPPO region. Details on spread are given in section 11. **Uncertainty***:* low
- **Movement of individuals, e.g. traded by collectors.** *N. elegantalis* may circulate between plant collectors and hobbyist entomologists, but in the latter case is most likely to be traded once dead. Fresh material for study may be circulated but is likely to be used in laboratories. **Uncertainty**: high (no data)

Pathways commonly considered for other pests but not considered relevant for this pest:

- **Tissue culture of hosts.** Solanaceae may be exchanged as tissue culture for the purpose of breeding. However, no life stage of *N. elegantalis* could be associated with tissue cultures of its hosts.
- **Processed commodities made from fruit of the hosts (e.g. dried fruit, pulp, canned preparations etc.)**. Such commodities would be processed to a degree that would not allow survival of life stages of *N. elegantalis*. Larvae are small and may survive pulping or cutting processes, but they are not likely to complete their development.
- **Seeds of host plants.** Life stages of *N. elegantalis* are not associated with seeds.
- **Weed hosts**. *N. elegantalis* has a number of weed hosts (see section 2). 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 the table above. Hitch-hiking on other commodities is not considered likely.

The likelihood of entry is considered as low given the current volume of trade for the pathways considered and the fact that the transfer from fruit or packaging is possible only if they are imported to places of production. The likelihood of entry will increase if volumes increase.

Rating of the likelihood of entry	*Low* ✓	*Moderate* ☐	*High* ☐
Rating of uncertainty	*Low* ☐	*Moderate* ✓	*High* ☐

9. Likelihood of establishment outdoors in the PRA area

9.1 Host plants in the EPPO region

Tomato, eggplant and sweet pepper are widely grown in the EPPO region, commercially in the field or under protected conditions (glasshouse, tunnels, plastic, EPPO, 2012e), as well as in gardens. Tomato is cultivated throughout the PRA area, whilst sweet pepper and eggplant have a more southern and eastern distribution. See Appendix 3 for details and maps of distribution.

The abundance of plants and the type of plants will influence the suitability of the area for establishement (e.g. all-year tomato crops, mixed eggplant-tomato areas, solely eggplant, volunteer plants). Particularly in North Africa, tomato may be grown outdoors 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 (EPPO, 2012b). EPPO (2012a, citing pers. comm.) mentions that eggplant is grown both under protected conditions and outdoors. In Italy, the main growing area is situated in the south (Campania and Sicily being the most important producing regions); during the summer, the crop is grown in open field or under tunnels, while in winter-early spring the crop is grown only in protected conditions. Similar growing conditions occur in other Mediterranean countries such as Morocco or Spain, for instance.

Tamarillo is cultivated in Madeira, Portugal for the local market (EPPO 2012e). It is also cultivated in gardens in Portugal (incl. continental). No data have been found on cultivation in other Mediterranean countries in the PRA area, but it is sold as a garden plant.
Regarding other host species that are cultivated at origin, *S. sisymbrifolium* has been investigated in the UK as a trap crop for potato cyst nematodes (FERA, 2010). It is also listed in Flora Europea (2011) as occurring in Europe (no details). No data was found regarding other species that are cultivated at origin (*S. gilo*, *S. quitoense*, *S. sessiliflorum*, *S. lycocarpum*). EPPO (2012a) mentions that *S. aethiopicum* and *S. torvum* are not usually grown in the EPPO region. However, *S. torvum* is used as rootstock for *S. melongena*. The other wild/weed host species at origin are not mentioned in Flora Europea (2011).

9.2 Climatic conditions

In the current area of distribution, *N. elegantalis* occurs in 5-6 climate zones. The majority of the distribution area in South America is (sub)tropical, but the organism is also present at high altitudes which have a more temperate climate, comparable to climate zones present in parts of the EPPO area. An assessment of the climatic suitability of the PRA area for the establishment of *N. elegantalis* is presented in Appendix 4. The CLIMEX model includes both a 'heat strees' and a 'dry stress' factors to take into the fact that the pest seems to prefer humid and not too hot conditions. However, it should be noted that *N. elegantalis* occurs in dry regions of Argentina with a mean monthly rainfall of 608 mm (similar to the annual rainfall in Mediterranean climate).
The minimum development threshold temperature has been estimated to be 10.5˚C and the number of Degree-Days for development from egg to adult is 526. One generation is possible in northern Europe and transient populations may occur in summertime. In North Africa and the Near East, up to 7 generations are predicted based on the model. It is also expected that the pest may be able to establish in the field in other countries around the Mediterranean Basin and in Portugal.
There is no evidence that *N. elegantalis* has a diapause phase but it can be envisaged that development is very slow in periods of low temperatures. In Colombia, there are very few areas where the minimum temperature drops below 10˚C. Temperature accumulation above the minimum developmental threshold and the availability of suitable (fruiting) hosts is the main factor controlling *N. elegantalis* establishment and distribution. Preliminary results show that different haplotypes may be adapted to different climatic conditions (Diaz-Montilla *et al.*, 2013b).

There is a low uncertainty that the organism can establish in part of the EPPO region. The main uncertainties (moderate-high) of the climatic suitability are the exact border of establishment of field populations in the EPPO region (based on winter temperatures in the north and maximum temperatures in the south) and uncertainties on the humidity requirements of the organism, such as effect of irrigation in hot, dry areas in the south of the EPPO region.

9.3 Managed environment

Tomato, eggplant and sweet pepper are grown outdoors in the field and in gardens, and other host fruit crops may have a limited cultivation. 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, and overlapping generations. It is not clear whether wild or weed hosts are present in the EPPO region. Where host plants are not present all year round (e.g. crop free periods in glasshouses), the probability of establishment is unlikely.

As for *K. lycopersicella*, it is not considered likely that the existing management practices in the field will prevent establishment because the application of pest management practice will not necessarily target pests in fruit, and the timing will not necessarily be suitable to control *N. elegantalis*. Details of the management practices for tomato and eggplant are given in EPPO (2012b).

9.4 Biological considerations

Descriptions of the life cycle, and its duration are broadly similar in the various literature reviews of the pest (see Appendix 1). The pest has several generations per year, and may be present all year round. Generations overlap and all stages are available all the time after the first generation. This complicates control.

Details are missing on some aspects of the biology, i.e. the survival of pupae or adults when conditions are not favourable for normal continuation of the life cycle (which is reported for *K. lycopersicella*). It is not known whether populations are sustainable where no fruit are available for an extended period. However, it can be envisaged that development is very slow in periods with low temperatures coinciding with the period with a low availability of fruiting hosts.

N. elegantalis has a host range limited to the family Solanaceae, including wild species. There is only one reported case of introduction, to Suriname, although there are many interceptions e.g. by the USA and also in the Netherlands. There is no information available regarding resistance to insecticides.

There is uncertainty whether *N. elegantalis* would be adaptable to new conditions (e.g. plant species outside the host range), as observed for Gelechiidae such as *Tuta absoluta* (EPPO, 2012b). A preliminary study indicates that different haplotypes may be adapted to different conditions and on different hosts (Diaz-Montilla *et al.*, 2013b; Baena- Bejarano *et al*, 2013).

The following factors, normally evaluated when assessing establishment, are considered either not relevant or not likely to have an effect on the establishment of *N. elegantalis*:

- Alternate hosts and other essential species: *N. elegantalis* does not need an alternate host or another species to complete its life cycle. However, wild, weed or volunteer Solanaceae may help its maintenance in the wild.
- Other abiotic factors: no such factor that could have an impact on establishment was identified.
- Competition and natural enemies. Although some natural enemies are present, and competition may also occur, it is not considered that this would be sufficient to prevent establishment.

Uncertainty: Moderate (Adaptability to climate outdoors in different areas of the EPPO region, importance of humidity, adaptability to new hosts).

Around the Mediterranean Basin and Portugal:

Rating of the likelihood of establishment outdoors	*Low* ☐	*Moderate* ✓	*High* ☐
Rating of uncertainty	*Low* ☐	*Moderate* ✓	*High* ☐

Rest of the EPPO region

Rating of the likelihood of establishment outdoors	*Low* ✓	*Moderate* ☐	*High* ☐
Rating of uncertainty	*Low* ✓	*Moderate* ☐	*High* ☐

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

Areas where hosts (e.g. tomato, aubergine, peppers) are grown under protected cultivation in the EPPO area are likely to be at risk. The management of temperatures in glasshouses maintains average temperatures between 20 and 35°C, which are suitable for the pest. However, in the Mediterranean area, it is possible that much higher temperatures occur in glasshouses in summer. This may have a negative influence on the survival of the pest (but it should be also considered that larvae are in the fruits in which the temperature may be lower, e.g. if they are located in lower and/or shaded parts of the plants). There is also an uncertainty on whether the pest would survive during periods when there is no crop in the glasshouse, especially for the northern and central parts of the EPPO region. In such conditions, there may be a period of several weeks without fruit. Therefore, during this period, female may not lay eggs and larvae may not develop (contrary to for example *T. absoluta* for which larvae can mine leaves). Adults are not expected to live long enough to merge the gap without fruit, in particular because no diapause phase is observed in the area of origin. In the Southern part of the region, the presence of wild hosts may facilitate reintroductions into glasshouses.

A study in Argentina on damage by *Tuta absoluta* and *Neoleucinodes elegantalis* on tomato in glasshouses during one month showed that *T. absoluta* caused more damage than *N. elegantalis* (Puch and Mollinedo, 2009). There is an uncertainty on whether *N. elegantalis* is as well adapted to growing conditions in glasshouses, such as temperature, as *T. absoluta*.

In the EPPO region, tomato, eggplant and sweet pepper are widely grown under protected conditions (plastic, tunnel, glasshouse). Indications on protected conditions in the EPPO region were provided for tomato and eggplant in the PRA on *K. lycopersicella* (EPPO, 2012b).

Establishment in protected conditions around the Mediterranean Basin and Portugal is considered moderately likely, while it is very unlikely that the pest establishes permanently in protected conditions in areas of the EPPO region where it can not survive outdoors.

Uncertainty: Moderate (Whether it could adapt to glasshouse conditions, especially to periods without fruit and high temperatures).

Around the Mediterranean Basin and Portugal:

Rating of the likelihood of establishment indoors	*Low* ☐	*Moderate* ✓	*High* ☐
Rating of uncertainty	*Low* ☐	*Moderate* ✓	*High* ☐

Rest of the EPPO region

Rating of the likelihood of establishment indoors	*Low* ✓	*Moderate* ☐	*High* ☐
Rating of uncertainty	*Low* ☐	*Moderate* ✓	*High* ☐

11. Spread in the PRA area

N. elegantalis is likely to spread naturally and through human-assisted pathways.

11.1 Natural spread

There is no evidence that the pest is migratory, but adults can move between tomato fields (Eiras, 2000). No precise data was found in the literature regarding distances of flight, or whether this pest may also be transported by wind/storms (as shown in the USA for *K. lycopersicella*, EPPO, 2012b).

11.2 Human-assisted pathways

Human-assisted pathways have been shown to transport the pest (see under section 8), especially trade of fruit. Within the EPPO region, the pest could move with fruit and conveyances (especially crates which have carried infested tomatoes), and possibly with plants for planting with fruit. Transport of infested fruit may result in multiple introductions. There is a massive movement of tomato, eggplant and sweet pepper fruits between countries of the EPPO region (CIRAD, 2012a&b). Crates which have been used to transport tomatoes have been identified as sources of movement of *T. absoluta* within the EPPO region in the UK and the Netherlands, and a similar situation could occur for *N. elegantalis* if it was to establish (see section 8).

11.3 Estimates of spread and expected spread within the EPPO region

The rate of spread would be high in the absence of control of movement of host plants and plant products, and packaging material which could carry infested consignments. The Lepidopteran species *T. absoluta* (same main host and similar management practices) has spread rapidly since its introduction to the PRA area in 2006. It has not established in some countries where eradication has been possible at each finding because the pest entered under protected conditions , but it could have established if measures had not been taken (and it is considered as established some countries where host crops are only under protected conditions, such as in the Netherlands). It is assumed, as for *T. absoluta* and *K. lycopersicella,* that it will be possible to prevent the spread of *N. elegantalis* under protected conditions in some areas of production. There is a moderate uncertainty on whether *N. elegantalis* would spread in a similar manner, especially as there are fewer stages associated with green parts of plants (and it will not be transported with seedlings unlike *T. absoluta*). However, a fast rate of spread throughout the area of potential establishment could be expected if *N. elegantalis* is introduced in an area where its hosts are extensively grown outdoors in suitable conditions. The rate of spread would also depend on the time of introduction, and whether host plants are most susceptible to pest attack (green young fruit). Where hosts are grown only under protected conditions, the spread would be slower. Multiple introductions in different areas would allow spread to be more rapid within the PRA area.

The spread will depend on where the pest is first introduced in the PRA area, i.e. whether it is able to survive outdoors and whether there is a trade of host fruit from that area to other countries of the EPPO region. A worst case scenario is if the pest is introduced into an area where it can survive outdoors and from which host fruit is traded. In that case the magnitude of spread could be high. In other situations, it will be lower.

Uncertainty: whether the pest would spread in a similar manner as T. absoluta.

In case of introduction into an area where it can survive outdoors and from which host fruit is traded:

Rating of the magnitude of spread	*Low* ☐	*Moderate* ☐	*High* ✓
Rating of uncertainty	*Low* ✓	*Moderate* ☐	*High* ☐

12. Impact in the current area of distribution

12.1 Nature of the damage

The damage is caused by larvae that feed inside the fruit, causing in some cases premature fruit fall (EPPO, 2012c). The presence of one larva in the fruit causes damage, and this density is considered as the economic injury level by some authors (Benvenga 2009 citing others). The fruit attacked cannot be sold and the production is also seriously affected (Badji *et al.*, 2003). The infested fruits are unfit for trade and industrial processing, as the pulp is destroyed and often also infected by pathogens that colonize from exit holes (Benvenga 2009 citing others). Direct damage to fruit lead to loss of production and quality, rejection of crops for exports to due the low (or nul) tolerance for larvae in fruits, secondary contamination by fungi and bacteria. An effect on the viability of seed has also been shown. Details on the different impacts are given below.

12.2 Direct and indirect impacts on the production

Fruit losses

N. elegantalis is considered as a major pest due to yield losses in several countries such as Argentina, Bolivia, Brazil, Colombia, Ecuador, Suriname and Venezuela. The pest is reported to cause up to 90% losses (Carneiro *et al.*, 1998, Blackmer *et al.*, 2001; Benvenga *et al.*, 2010, citing others), and a few detailed figures are available in the literature as follows:

- 40-90 % in Suriname depending on farms [presumably on tomato] (AAAAG, 2008).
- 30-40% on tomato and sweet pepper in Venezuela (Salas, 2008; Mercano, 1990).
- In Colombia, losses in tomato reach 60.3%, 76.9% in Brazil, 40.7% in Venezuela during the rainy season (August) and lower (5.09%) in the dry season (in March and April) (Perez Rosero, 2010, citing others).
- In *S. quitoense* in Ecuador, Paredes *et al.* (2010) reports occasional losses of 60% (especially in areas of high rainfall), but no special damage reported on other hosts, and Revelo *et al.* (2010) reports 90% losses with control measures.
- In Peru, percentages of infestation of *S. sessiliflorum* fruit were 4-5 % and the pest caused the destruction of fruits (Anteparra *et al.*, 2010).

- In Colombia, 80 % losses in tomato, *S. quitoense*, *S. betaceum* (Carmona *et al.*, 2006).
- In Argentina, 12 % losses on glasshouse tomato (Puch and Mollinedo, 2009).
- In Honduras, 1% losses in eggplants (Dias & Brochero, 2012 citing SENASA 2008) but with consequences on exports to the USA.

The pest is more problematic during the rainy season. For exemple, in experiments conducted on tomato by Nunes and Leal (2001) in Brazil, fruit losses due to the pest are between 4.65 and 10.74 % during the dry season, and between 19.92 and 33% during the rainy season depending on the treatment applied.

Other than yield losses, data is lacking on its economic impact. In some countries the pest is present without any published reports of severe damage (see section 6). There therefore seems to be variation in the damage potential in different areas and on different hosts.

Secondary infections by other insects or pathogens
The pest contributes to a higher incidence of the bacterium *Erwinia carotovora* (Picanço *et al.*, 2007). This is understood to be the same mechanisms as mentioned by other authors, i.e. facilitating the entry of the pathogens in the fruit through holes made by the larvae.

Impact on export markets
In some countries, *N. elegantalis* is not considered as a serious direct pest, but it may have major impact on exports. Espinoza (2008) reports that this pest is not a problem in Honduras in the field and that levels of populations are very low (less than 1% infestation in eggplant), but that it has negative effects on exports due the absence of tolerance for larvae in fruit at import, leading to rejection of eggplants from Honduras at import into the USA.

Detection of pupae in consignments leads to interceptions and possibly rejection of consignments (EDA, 2007; Espinoza, 2008). The larvae are not readily detectable in packed fruit as they are inside the fruit, but it may complete its development during transport and be detected at import as pupae (EDA, 2007).

Impact on seed production
On tomatoes, it has been observed that the viability of seeds from fruits attacked by *N. elegantalis* could be reduced by 30-100% and had a lower germination when compared with that of seeds from undamaged fruits (Benvenga 2009 citing, Reis *et al.*, 1989; EPPO, 2012c).

12.3 Environmental impact
Traditionally, control relies on the frequent application of plant protection products, leading to effects on the environment and on beneficial organisms (Badji *et al.*, 2003, EEACG 2010, citing others).

12.4 Social damage
Control methods relying only on the application of plant protection products led to effects on human health (Badji *et al.*, 2003, citing others). Insecticide residues may be present in fruit for consumption. No other mention of social damage at origin was found in the literature, but as *N. elegantalis* can completely destroy host crops, it must compromise production and income locally.

12.5 Possible options for control
In the past, control measures relied on the use of calendar applications of plant protection products. This could lead to large numbers of applications (2-3 applications per week from the beginning of the flowering period (Badji *et al.*, 2003); in extreme cases 36 applications per crop (EEAG, 2010, citing Picanço *et al.*, 2007), leading to costs, resistance, killing of beneficial organisms, effects on human health and the environment (Badji *et al.*, 2003, citing others). Current management methods rely on integrated measures, combining chemical control based on the results of monitoring, biological control and cultural practices. EDA (2007) note that control allows reducing infestation and the number of fruit with holes, but does not prevent damage completely.

Monitoring
In IPM programmes, the timing of applications is based on the results of monitoring. Currently monitoring seems to be performed mostly using pheromone traps with visual inspection for eggs and fruit sampling being used to time pesticide applications.

Pheromone trapping. Pheromone traps are used commercially in several countries, including Colombia, Brazil, Ecuador and Venezuela (Cabrera *et al.*, 2001; Jaffe *et al.*, 2007; Guillén *et al.*, 2008). The pheromone blend used has not been effective in all places and crops. The use of at least 20 traps per hectare is recommended (Silva, 2008). Traps must be installed before the flowering stage, and control should be performed about eight days after an average of 0.24 adult per trap per day is found in summer (0.23 in winter) (threshold corresponding to that for egg below) (Benvenga *et al.*, 2010).

Eggs. Benvenga *et al.* (2010) note that Gravena & Benvenga (2003) recommend dividing culture in one acre (about 4000 m^2) plots with 60 plants inspection on 12 points at random, twice a week, with visual inspection of the upper third bunches containing fruits in early development. This method has the advantage of ease of observation postures on the surface of fruits. However, this requires appropriate training for inspection, detection and identification of the various pests that may occur. The threshold for action based on detection of eggs is 5% of plants with eggs in the early stage of fruit development (Benvenga *et al.*, 2010). Information on egg distribution could be used to develop a monitoring program, and limiting searching efforts to the fruit and under the calyx of the first four basal fruits on fruit clusters with fruits 1-3 cm diameter (Blackmer *et al.*, 2001).

Fruit sampling for larvae. SENESA-HN (2012) mentions thresholds for action of 5% fruits with signs of damage (entry holes) or 1% fruits with exit holes among 250-500 fruit/ha (50-100 fruits/sampling locations).

Chemical control
The biology of the pest complicates control as many life stages are hidden and the pest is protected during the phase of the cycle when it causes damage (Badji *et al.*, 2003). Eggs may be under the calyx (Barbosa *et al.*, 2010); young larvae are present on fruits for a very short duration in the first hours of the morning before entering the fruit where they stay until they emerge to form pupae; pupae are protected from sprays as they develop within leaves folded by the sticky pupal coat; where leaves are not available, pupae can be formed in debris making them difficult to observe; and adults emerge in the evening/night and are entirely nocturnal. Several life stages may be present at the same time because of overlapping generations, which also hamper control as different active substances should be used against e.g. eggs and larvae.

Plant protection products seem to mostly be applied as sprays. A few publications mention other forms of applications: França *et al.* (2009a) obtained promising experimental results with toxic baits associated to a plant protection product (carbaryl, cartap, deltamethrin, fenpropathrin, indoxacarb, lambda-cyhalothrin, lufenuron) with honey.

The timing of applications needs to be adjusted to the life stage targeted, as eggs, young larvae and adults are accessible only for limited time periods. To target young larvae before they enter the fruit, Espinoza (2008) recommends applications in the early morning. Diaz (2010b) mentions applications in the late afternoon targeting small fruits. To control adults, Carmona *et al.* (2006) recommend nocturnal applications. GAD-DSA (2010) recommends ovicidal sprays from the start of fructification. Benvenga (2009, citing others) mentions ovicidal applications on fruit against eggs, with better cover ensured with vegetable oil.

Traditionally organophosphates (e.g. metamidophos, monocrotophos), carbamates (carbofuran) or pyrethroids were widely used (Asaquibay *et al.*, 2009; Diaz, 2010a). Many active substances are mentioned in the literature, as listed below. The ones already advised in the PRA against *K. lycopersicella* as likely to have an impact based upon the experience with *T. absoluta* in the PRA area are marked with *, with additional notes from EPPO (2012b).
The table below indicates whether active substances are registered or not in at least some EU countries (from EU, 2013; http://ec.europa.eu/sanco_pesticides/public/index.cfm). They may not be registered for use in the host fruit crops, and even if registered for certain uses, they may need to be registered for specific use against *N. elegantalis*. In the UK, abamectin, *Bacillus thuringiensis* subsp. *kurstaki*, indoxacarb, spinosad are approved for use in tomato and eggplant (EPPO, 2012b).

Finally, França *et al.* (2009b) observed a deterrent effect of azadirachtin to oviposition by *N. elegantalis*. Azadirachtin is registered in some countries of the PRA area against *T. absoluta* (e.g. Turkey) and it is authorized in organic production.

Active substance	**Reference**	**Remark**	**Approved in EU?**	***IRAC MoA**
abamectin*	Picanço *et al.* 1998; Nunes and Leal, 2001; Asaquibay *et al.*, 2009; Benvenga, 2009, citing others	(also used in eggplant production in Turkey) (EPPO, 2012b)	Yes	**6** Avermectins
Bacillus thuringiensis subsp. *kurstaki** and *Bacillus thuringiensis*	Nunes and Leal, 2001; Carmona *et al.*, 2006; Jaramillo *et al.*, 2007; Asaquibay *et al.*, 2009; Diaz, 2010b; EAAG, 2010; SENESA-HN, 2012	Authorized in organic production. registered in Turkey, Greece against *T. absoluta* on tomato. (EPPO, 2012b)	Yes	**11.A**
Beauveria bassiana	GAD-DSA, 2010		1 strain approved, 2 pending	
cartap	Benvenga, 2009, citing others		no	**14** Nereistoxin analogues
chlorfluorazon (chlorfluazuron?)	Nunes and Leal, 2001		no	**15** Benzoylureas
chlorantraniliprole	Diaz-Montilla, 2013	Used in EU against *T. absoluta*	Yes	**28** Diamides
deltamethrin*	Nunes and Leal, 2001	not compatible with IPM (EPPO, 2012b)	Yes	**3A** Pyrethroids Pyrethrins
diflubenzuron	EDA, 2007; GAD-DSA, 2010		yes	**15** Benzoylureas
emamectin benzoate*	Diaz, 2010b; GAD-DSA, 2010	Authorized temporally at national level (BE, CY, EL, FR, HU, IT, NL, PL, PT, RO, SI) but not yet registered at the EU level. Registered in Turkey against *Heliothis armigera, H. viriplaca* on tomato, and *Spodoptera littoralis* on eggplant. (EPPO, 2012b)	Pending	**6** Avermectins
endosulfan	EDA, 2007		no	**2A** Cyclodiene organochlorin
etofenprox	Benvenga 2009, citing others		yes	**3A** Pyrethroids Pyrethrins
flubendiamid	Diaz-Montilla, 2013 unpublished data	Authorized temporally in Spain at national level. Under registration in the EU	No (under reg.)	**28** Diamides
indoxacarb*	Martinelli *et al.*, 2003	(also used in eggplant production in Turkey) (EPPO, 2012b)	Yes	**22A** Indoxacarb
lambda-cyhalothrin*	EDA, 2007; GAD-DSA, 2010; SATA, 2011	not compatible with IPM (EPPO, 2012b)	Yes	**3A** Pyrethroids Pyrethrins
lufenuron	EDA, 2007; GAD-DSA, 2010 (+difenzoquat metilsulfate)		yes	**15** Benzoylureas
Metharrizium anisopliae	GAD-DSA, 2010		1 strain approved	
methomyl*	Benvenga 2009, citing others; SATA, 2011		yes	**1A** Carbamates
methoxyfenozide	EDA, 2007; GAD-DSA, 2010		yes	**18** Diacylhydrazines
spinosad*	EDA, 2007	authorized in organic production (also used in eggplant production in	yes	**5** Spinosyns

Active substance	Reference	Remark	Approved in EU?	*IRAC MoA
		Turkey) (EPPO, 2012b)		
spinetoram	Diaz-Montilla, 2013 unpublished data		pending	**5** Spinosyns
teflubenzuron	Nunes and Leal, 2001; Carmona *et al.*, 2006; SATA, 2011		yes	**15** Benzoylureas
thiametoxam	EDA, 2007		yes	**4A** Neonicotinoids
tiocyclam-hidrogéno-oxalato (thiocyclam?)	Carmona *et al.*, 2006		no	**1A** A nereistoxin analogue insecticide.
tolfenpyrad	Diaz-Montilla, 2014		no	**21A** METI acaricides and insecticides
triflumuron	Asaquibay *et al.*, 2009; EDA, 2007		yes	**15** Benzoylureas
Verticillium lecanii	GAD-DSA, 2010		?	

*According to the IRAC Mode of Action Classification Scheme (IRAC, 2012). To prevent or delay the evolution of resistance to insecticides, successive generations of the pest should not be treated with compounds from the same MoA group.

Use of pheromone traps for control (mating disruption)

Pheromone traps, sometimes associated with insecticides, are used for mating disruption (Cabrera *et al.*, 2001; Carmona *et al.*, 2006; França *et al.*, 2013) but research is still needed to improve traps and find suitable pheromone for all populations / biotypes (see Detection methods in section 2).

Biological control

The range of natural enemies varies according to the host plant. Different biological control agents have been identified on different hosts, including: *Apanteles* sp., *Bracon* sp., *Chelonus* sp., *Pimpla sanguinipes*, *Lymeon* sp., *Neotheronia* sp., *Brachymeria* sp., *Trichospilus diatraea* in *Solanum quitoense*; *Trichogramma exigum*, *Trichogramma minutum*, *Trichogramma pretiosum*, *Trichogramma* sp. on tomato; *Lixophaga* sp. on *S. quitoense*), *Copidosoma* sp. on *S. quitoense* and *S. betaceum*); *Beauveria* spp. and *Chrysoperla externa* host not extracted) (Carneiro *et al.*, 1998; Diaz & Brochero, 2012; Carmona *et al.*, 2006, Blackmer *et al.*, 2001, citing others; Diaz, 2010b; SENESA-HN, 2012). Diaz & Brochero (2012) notes a greater abundance and diversity of natural enemies in *S. quitoense* compared with other hosts. Although *Trichogramma* was mentioned as effective by some, other records did not find parasitoids associated with eggplant or sweet pepper (Diaz & Brochero, 2012).

Some biological control agents are mass-reared for inundative releases, and the following are mentioned in the literature: *Trichogramma pretiosum*, *Trichogramma exiguum*, *Trichogramma minutum*, *Trichogramma* sp. (Carneiro *et al.*, 1998; Jaramillo *et al.*, 2007; Silva, 2008, GAD-DSA, 2010; SENESA-HN, 2012).

Finally pathogens are being investigated such as *Paenibacillus polymyxa*, *Aspergillus* sp., virus NeelV1-NeelV2 (Sosa, 2009).

Cultural practices

The following management practices are used where the pest occurs:

- removal and destruction of fallen fruit, infested fruits and discarded fruit in the field, selection areas and packaging areas (Carneiro *et al.*, 1998; Blackmer *et al.*, 2001, citing Gallo *et al.*, 1998; Carmona *et al.*, 2006; EDA, 2007; Espinoza, 2008; GAD-DSA, 2010). EDA (2007) recommends removing fruit that are not eligible for export from the plant, and after harvest also destroying fruit that cannot be exported or those rejected at packing. INIAP (2003) note that fallen fruits should be collected within 4-5 days of falling in order to prevent that mature larvae leave the fruit and pupate. EDA (2007) recommends that fruit should be destroyed by chopping and burying it, covered with lime to a depth of at least 30 cm to prevent adult survival for those that emerge from pupae. Senesa-HN (2012) recommends burying fruit and covering it with lime and soil, keeping the entire area covered in plastic to prevent adults escaping;
- elimination of wild solanaceous hosts and of host weeds within and around the crop (Carneiro *et al.*, 1998; Blackmer *et al.*, 2001, citing Gallo *et al.*, 1998; Carmona *et al.*, 2006; Souza *et al.*, 2010; Espinoza, 2008);

- physical protection with nets to prevent entry of adults into the crop (Carmona *et al.*, 2006);
- not cultivating other host plants close to tomato crops (Carneiro *et al.*, 1998);
- elimination of crop residues after harvest and of abandoned plantations (Souza *et al.*, 2010; SENESA-HN, 2012);
- avoiding planting throughout the year, crop rotation with non-hosts (Souza *et al.*, 2010; SENESA-HN, 2012; GAD-DSA, 2010) or periods without the crop (2-3 months for eggplant) in case of high population levels (Espinoza, 2008);
- avoid planting during seasons with higher populations, and at sites of high infestations (SENESA-HN, 2012);
- removal and destruction of mature leaves to reduce the number of pupae (Jaramillo *et al.*, 2007).

The following have been researched, but are not mentioned among methods used in practice:
- growing other species as "barriers" around the crop: sorghum (Diaz, 2010a citing Paula *et al.*, 2004));
- bagging of flowers and young fruits to avoid infestation (Diaz, 2010a citing Rodrigues Filho *et al.*, 2001; Jordão and Nakano, 2000 & 2002; Diaz *et al.*, 2003). This is not cost-effective;
- nocturnal illumination of tomato fields was investigated (Souza *et al.*, 2010), and the results indicated absence of larvae (while 85% infestation in the control). However, further research was recommended.

Use of resistant cultivars
There does not seem to be resistant cultivars at the moment, although resistance has been investigated. In a study on 19 tomato cultivars in 1998, the susceptibility ranged between 11 and 36% of fruit damaged (Lyra Netto & Freitas Lima, 1998). Restrepo Salazar *et al.* (2008) investigated crosses of tomato and *S. habrochaites* var. *glabratum*. Barbosa *et al.* (2010) tested eight cultivars of tomato, but did not find significant differences in number of eggs and larvae nor survival of larvae, although one cultivar was less attractive. Pérez Rosero (2010) mentions that there are currently no commercial varieties of tomato with resistance. França *et al.* (2009 citing others) report that in Colombia, research on genetic resistance through gene introgression from wild grown tomato materials have begun, and that, in Brazil, selections were made to identify tomato materials that are resistant and susceptible to *N. elegantalis.*

N. elegantalis is recognized as a major pest in some countries, and the impact is presumably high in these countries. In some others, it is not identified as a pest, or does not cause heavy damage, and the impact is therefore low. Giving a rating for the whole area where the pest occurs is therefore difficult. In addition, there are uncertainties as to why *N. elegantalis* is not recorded as a pest in some countries.

Rating of the magnitude of impact in the current area of distribution	*Low* ☐	*Moderate* ☐	*High* ✓
Rating of uncertainty	*Low* ☐	*Moderate* ☐	*High* ✓

13. Potential impact in the PRA area

Will impacts be largely the same as in the current area of distribution? **No**

N. elegantalis seem to cause bigger fruit losses in a warm rainy climate than in drier or more temperate climates, and t is not known whether it will find such conditions in the PRA area outdoors (see under section 9.2). It is expected that there will be fewer generations in the PRA area than in the area of origin (see Appendix 4) and thus less damage.

Due to the life cycle of the pest (i.e. the limited time at which larvae are sensitive to sprays), some measures applied against other pests (such as *T. absoluta in* tomato crops) may have an effect on *N. elegantalis,* but it is likely that their timing would not be adequate to control *N. elegantalis* and avoid damage. Specific control measures will have to be implemented, which will increase production costs. 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, and it will take several years before control of *N. elegantalis* may be included in IPM programmes in the PRA area.

Economic impact (without environmental impact)
Loss of fruit harvest: Losses will depend on the type of crop, as well as on the pests already present and how they are managed. It is not known whether the timing of applications against other pests would be suitable for, hence effective against, *N. elegantalis*. The impact may be major in the first years before new control techniques are developed. The time taken to register necessary plant protection products/pheromones could contribute to limitations on control options.

Increase in production costs: Effective pesticides are already registered against other lepidopteran pests. However, monitoring with pheromone traps and additional sprays will increase production costs.

Disruption of existing IPM programmes: Broad range insecticides mentioned for control in South America are not used in IPM systems in the EPPO region. It is unlikely that existing IPM programmes will control *N. elegantalis*, particularly in crops where no Lepidoptera pests occurs currently (e.g. in aubergine). Integrating *N. elegantilis* into IPM programmes will take time. Pollination and biological control in IPM programmes will be disrupted in the meantime.

Impact on internal and external markets: It is likely that the presence of *N. elegantalis* will have an impact on internal markets and on exports. There is a large trade of tomato, eggplant and sweet pepper fruits within the EPPO region (see fruit pathway under 8), and the major exporters probably export also to outside the EPPO region. There is a zero tolerance for the presence of larvae or pest body parts in fresh or canned fruit within the EU and for export to some other countries (e.g. Japan). In addition, due to the need for more applications of pesticides in addition to those already applied against other pests, the MRL (maximum residue limits) may be exceeded. The presence of the pest may have a high impact on major exporters, but the effect is rated as moderate for the entire region.

Environmental impacts
The main environmental impact is expected to be due to the use of pesticides.

Social impact: minor overall, but may be locally high
Social impact might be high locally in areas where widespread damage occurs, at least in the short term after its introduction. This has been observed in some countries of the EPPO region when *T. absoluta* was introduced (EPPO, 2012b). However, it is unlikely that *N. elegantalis* would make the production of fruit of tomato, eggplant and sweet pepper uneconomic. Other aspects are considered in EPPO (2012b).

Costs likely to be incurred by the introduction of *N. elegantalis* (other than direct costs linked to the impacts above)

- General costs: surveillance and monitoring, eradication and containment efforts.
- Sanitation practices, phytosanitary measures for export, sorting of fruit.
- Initial costs of shifting to producing alternative species.
- Research: natural enemies, effective pheromone blend, use of pheromone traps for mating disruption or mass trapping, mass rearing and insect sterile techniques, economic thresholds, host resistance, cultural controls, role of wild hosts.

Rating of the magnitude of impact in the area of potential establishment	*Low* ☐	*Moderate* ✓	*High* ☐
Rating of uncertainty	*Low* ☐	*Moderate* ✓	*High* ☐

Note: The impact in the current area of distribution is assessed as high with a high uncertainty because in some countries N. elegantalis is not reported as a pest. This may be explained by differences of populations. The uncertainty for impact in the EPPO region is lower as it is considered that only population behaving as pest in the area of origin could be imported with trade. The magnitude of impact is considered lower than in Colombia or Brazil because the climatic conditions may not be as favourable to the pest development.

14. Identification of the endangered area
The pest has the potential to establish in glasshouses and other protected conditions (screenhouses/ polytunnels) throughout the PRA area. Information from CLIMEX modelling (Appendix 4) suggests that it is

most likely to establish outdoors in the Mediterranean region, Portugal and in the Near East. Hosts grown in these areas are at risk of economic impact.

15. Overall assessment of risk

Summary of ratings and uncertainty

	Rating level	***Uncertainty***
Entry	low	*moderate*
Establishment (Mediterrean Basin and Portugal)	moderate	*moderate*
Establishment (glasshouses/protected conditions in the rest of the EPPO region)	low	*low*
Spread (In case of introduction into an area where it can survive outdoors and from which host fruit is traded)	high	*low*
Impact	moderate	*moderate*

The likelihood of entry is considered as low, although it will increase if trade volumes of hosts from the Americas and Carribean increase. The likelihood of establishment is considered moderate outdoors and under protected conditions around the Mediterranean Basin and Portugal, and low under protected conditions in the rest of the EPPO region. Establishment outdoors in the rest of the EPPO region is considered very unlikely. The endangered area is considered to be the Mediterranean Basin and Portugal, as well as under protected conditions in the rest of the EPPO region (as it may cause damage even it is does not establish permanently). Where it is introduced, the pest is likely to cause some losses, at least until control methods are added to the current integrated management programmes in the crops concerned. The pest is expected to have a moderate impact e.g. on fruit production, exports and possibly on seed production. Long-distance spread will be via human-assisted pathways, especially fruit. Where *N. elegantalis* is introduced, it will have moderate impact overall, but eradication or containment will be difficult and costly, and unlikely to be successful other than in glasshouses. Phytosanitary measures have therefore been considered for the commodity pathways identified.

Stage 3. Pest risk management

16. Phytosanitary measures

The entry section (section 8) identified fruit as a major pathway, and management measures were considered for it. In addition, although the likelihood of entry on plants for planting of host plants (plants carrying fruit) was rated as low, measures are considered here as this pathway would be more likely if the volumes traded increased or the current prohibitions on imports of solanaceous plants were lifted. Finally, measures for packaging were added to the fruit and the plants for planting pathways.

- For fruit, measures were considered for all hosts that are cultivated at origin, although the volume of tropical fruit hosts is estimated as very low. In addition, there is an uncertainty on whether some species such as *S. lycocarpum*, *S. pseudolulo* and *S. sessiliflorum* would be traded as fruit.
- For plants for planting, measures were considered for all hosts that are cultivated at origin.

The risk of entry with travellers carrying host fruit and plants from countries where the pest occurs could be addressed by raising awareness and inspection.

Appendix 5 summarizes the consideration of measures.

The risk of entry associated with the other pathways identified in section 8 is low, and measures were not considered necessary.

Possible pathways ***(in order of importance)***	**Measures identified**
Fruit of cultivated host species* from areas where *N. elegantalis* is present	- PFA (based on survey and trapping with pheromone traps) or - Pest free place of production (in screened glasshouses with trapping with pheromone traps). or - Systems approach (on the basis of bilateral agreement) : Growing under screenhouse + monitoring and treatment at the place of production + good agricultural practices (e.g. changing plastic or substrate) + inspection and sorting at packing + visual inspection of the consignment + separation of trade and production flows and surveillance systems (incl. trapping at packing stations) in the importing country. For Pest-free places of production and systems approach, only new packaging should be used at origin, and packaging should be destroyed or safely disposed of at import.
Packaging	Combined with the fruit and plants for planting pathways
Plants for planting of cultivated host species* from areas where *N. elegantalis* is present	- PFA (based on survey and trapping with pheromone traps) or - Plants that have never borne fruit (e.g. seedlings). or - Pest free place of production e.g. under screened glasshouses with the use of pheromone traps. In addition, handling and packing should be done within the pest-free place of production, and avoiding infestation during transport In all cases, plants and containers should be free from plant debris.
Travellers carrying fruits or plants for planting of main hosts from where *N. elegantalis* occurs	Raising awareness and inspection of luggages

* i.e. *Capsicum annuum, Solanum betaceum, Solanum gilo, Solanum lycopersicum, Solanum melongena, Solanum pseudolulo, Solanum quitoense, Solanum sessiliflorum, Solanum lycocarpum, Solanum sisymbriifolium*

Eradication and containment

No attempt of eradication of *N. elegantalis* is known. As for *Keiferia lycopersicella* (EPPO, 2012b), it is considered that the likelihood for eradication would depend on the conditions of the introduction:

- Very likely in the case of an introduction outdoors (field or garden) in an area where *N. elegantalis* cannot survive outdoors (in this case the likelihood is not due to eradication but to the impossibility to overwinter).
- Likely in the case of an introduction under protected conditions in an area where *N. elegantalis* cannot survive outdoors
- Unlikely in the case of an introduction under protected conditions in an area where *N. elegantalis* can also survive outdoors.
- Very unlikely in the case of an introduction outdoors (field or garden) in an area where *N. elegantalis* can survive outdoors.

Eradication would rely on early detection of the pest and application of measures. Early detection requires trapping, and monitoring of crops to detect larval signs (see section 12.5). It also requires identification capabilities. Stringent measures should be applied, including application of plant protection products and appropriate sanitation of places of production.

Containment would be difficult in areas where the pest can survive outdoors, as it may find other hosts.

17. Uncertainty

The main uncertainties are as follows:

- biotypes/haplotypes and how they behave on different crops
- biology (environmental conditions that are lethal to the insect, interaction and importance of relative humidity with temperatures for the development of the pest, possibility for diapause, survival without host fruit, life cycle in the PRA area, minimum threshold temperature for mating)
- adaptability of IPM programmes
- current distribution of the pest at origin (and whether all records relate to *N. elegantalis*)
- host range (is it limited to Solanaceae?)
- capacity for natural spread.

18. Remarks

The EWG recommends a careful monitoring of trade volumes and origins of the host fruit in order to reevaluate the risk as necessary. The highest risk is when trade of imported fruit and production flows are not separated.

It would be important to lower the uncertainty of the assessment by research on:
- obtaining more data on the temperature thresholds for the pest to survive and ability to adapt and overwinter;
- clarifying whether the distribution records at origin correspond to N. elegantalis or other species that have been misindentified, and investigate the differences between haplotypes in e.g. behaviour, host plants.

Research would also be useful on:
- whether different cultivars are used in the EPPO region and at origin, and if so investigate the resistance/tolerance of cultivars in the EPPO region.
- developing an effective pheromone blend.

19. References

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Appendix 1. Details on the biology of *Neoleucinodes elegantalis* relevant for Pest Risk Analysis

Morphological descriptions and illustrations

Capps (1948) provides a description of the larvae, adults and pupae, drawings of morphological characters, and a key to *Neoleucinodes* species. Diaz & Solis (2007). Diaz (2009) provides descriptions of several new species that occur in Colombia (including illustrations of characters). Pictures can be found, among others in: Carneiro *et al.* (1998), Espinoza (2008), Diaz (2010b) and Paredes *et al.* (2010).

Life stages

Eggs

Eggs are laid singly or in groups of 2-3 eggs (Blackmer *et al.*, 2001; Eiras and Blackmer, 2003, citing others). Places of oviposition vary according to the crop and observations.

- On tomato, eggs are mostly laid on young fruits, under the calyx or on fruit stalks (Salas *et al.*, 1991; Marcano, 1991a, Blackmer *et al.*, 2001; Rodrigues Filho *et al.*, 2003; Salinas, 1993; Jaramillo *et al.*, 2007). A large proportion of eggs are laid on small fruits of 1-3 cm diameter (Blackmer *et al.*, 2001; Carneiro *et al.*, 1998; Eiras *et al.*, 2003; Rodrigues Filho *et al.*, 2003), and most on the first four basal fruits in a cluster (Blackmer *et al.*, 2001). Carneiro *et al.* (1998) note that eggs are laid on flowers, calyx and green fruits, but also on leaves in case of high infestation levels. Buds are also mentioned (Viáfara *et al.*, 1999).
- On eggplant, Espinoza (1998) notes that oviposition patterns are similar to tomato, and that eggs are mostly laid on the calyx or directly on the fruit and below the sepals (Espinoza, 2008; Serrano *et al.* 1992).
- On *S. quitoense*, eggs are laid on small fruits of 19 mm diameter (approximately, 45 to 60 days of development). Eggs are laid in groups of 2-4, near the calyx or fruit surface on the base or middle of the trichomes or hairs (Serrano *et al.* 1992; Asaquibay *et al.*, 2009; Paredes *et al.*, 2010).
- On tamarillo, eggs are located either on different areas of the fruit, as well as on the binding of the fruit with the peduncle. The female prefers to lay eggs in green fruits (small, medium and large) of 1 to 140 days of development with 0.7-4.86 cm diameter (Diaz-Montilla *et al.*, 2013a).

There is a great variation in the number of eggs per female reported in the literature (see table 2 below). The highest numbers reported in the literature are around 160-200 eggs (Fernandez and Salas, 1985; Marcano, 1991a; Serrano *et al.* 1992; Carmona *et al.*, 2006), but the average number of eggs per female seem to be around 30-50. Marcano (1991b) notes that the fecundity seems much lower than that of the related species *L. orbonalis*. Fernandez and Salas (1985) found 74.96 % fertility (percentage of eggs eclosed).

Table 1. Number of eggs per female

Reference	Average number of eggs per female (°C, where indicated)	Range
Fernandez and Salas, 1985 [and citing others]	35 eggs (27.48°C) [17.60]	1-196 [0-120]
Marcano (1991a) (tomato as food)	52 eggs at 20°C 26 eggs at 25°C 27 eggs at 30.2°C	19-77 2-54 1-84
Marcano (1991b) (eggplant as food) [and citing Clavijo]	75.5 eggs at 25°C 60 eggs at 30.2°C [26 eggs at 25°C]	3-133 4-159 -
Serrano *et al.* (1992) (*S. quitoense*)	93 eggs at 24ºC	

Larvae

There are four or five larval instars depending on situations. Marcano *et al.* (1991b) obtained different numbers of instars depending on the temperature: five instars at 14.7 and 30.2°C, and four at 20 and 25°C. Studies on eclosion and larval behaviour on tomato found that over 90% of eggs hatch within the first two hours of light (Eiras and Blackmer, 2003). At egg eclosion, larvae penetrate quickly into the fruit. Eiras and Blackmer (2003) found that larvae spent around 50 minutes at the surface of the fruit, and needed an additional 20 minutes to completely enter the fruit once a suitable site was identified. The location of entry holes vary according to authors. On tomato, Salas *et al.* (1991) noted that entry holes were located mostly in the lower half of the fruit, while Eiras and Blackmer (2003) found them under the calyx (32%), on the upper surface of the fruit (10%), middle surface (18%) or lower surface (40%). The entry holes are very small; the scar is almost imperceptible (Espinoza, 2008), and is a depressed area with a necrotic spot of about 0.5 mm.

There are usually one or a few larvae per fruit, but as many as 18 (Capps, 1948). Depending on fruit size, fruit of *S. quitoense* can support around 1 to 14 larvae, fruit of *S. betaceum* between 1 to 9 larvae, tomato fruit between 1 to 34 larvae (Serrano *et al*. 1992). Larvae feed within the fruit throughout their development. They feed only on fruit and are not known to feed on other parts of the plant (unlike *Leucinodes orbonalis*). At high population levels, eggs may be laid on other parts of the plant, but larvae are not known to successfully develop in the absence of fruit (Diaz-Montilla, Corpoica, Colombia, pers. comm. 2013).

Mature larvae exit the fruit through a bigger exit hole. The exit holes favour the entry of other insects, fungi and bacteria (Perez Rosero, 2010; Paredes *et al.*, 2010) (see also under 12).

Pupae
Mature larvae develop into pupae, which are protected by a delicate sticky cocoon (Carneiro *et al.*, 1998). The place of formation of the pupae depends on the morphology of the host plant and the material that the larvae encounters when exiting the fruit: in some plants such as tomato, pupae are formed on enfolded leaves on the plant; they can still develop after the leaves fall on the ground; in tamarillo, pupae are formed on leaves on the ground; in *S. quitoense*, pupae are formed on leaves and dry flower buds in the aerial part of the plant, but also pupate in the spaces between the fruits of a cluster (Viáfara *et al.*, 1999) and in plant debris accumulated in the axils of the plants (Serrano *et al.*, 1992); in sweet pepper, pupae may be formed on plastic mulch on the ground at the base of the plant (Capps, 1948; Salas *et al.*, 1991; Marcano 1991a; EDA, 2007; Asaquibay *et al.*, 2009; Viáfara *et al.*, 1999; picture in Diaz, 2010b; Salas *et al.*, 1991, citing others; Diaz-Montilla, Corpoica, Colombia, personal communication). In any case, it does not seem that the larva is exposed for a long time before it becomes a pupa.

Adults
Adults are nocturnal. They emerge from the pupae within 1-7 h of the beginning of darkness falling, mate within 48 to 72 h of eclosion (Eiras, 2000), and shortly thereafter begin depositing eggs. Mating and oviposition also occur during the night (Marcano *et al.*, 1991a). During the day, adults hide and do not move (Marcano *et al.*, 1991a) unless disturbed.

Life cycle
Several generations per year are observed in countries where *N. elegantalis* occurs. No precise number of generations was found, and in particular no mention was found of high numbers of generations as for *Tuta absoluta*. Costa Lima (1950) mentions 2 generations per year, but this may have referred to two cropping periods. The pest may develop both on crops and on wild hosts. In some areas, the pest is present throughout the year in the crops and generations overlap (Barbosa *et al.*, 2010). In Colombia the number of generations of *N. elegantalis* has not been determined but there are multiple generations (Diaz-Montilla, Corpoica, Colombia, pers. comm. 2013). In tropical conditions, solanaceous plants are cultivated throughout the year.

The duration of the cycle varies with temperature and to a lesser extent to host plants on which the pest develop. Most authors, at temperatures around 20-25°C, report life cycles of 30-60 days.

Table 2. Duration of the life stages of *N. elegantalis*

Host plant, conditions	**Duration of life stages** ***in average number of days (or range of number of days if specifically indicated in the references)***					**Reference (type of study) (country)**
Tomato	**Eggs**	**Larvae**	**Pupae**	**Adults**	**Total**	
14.7°C / 79.5% RH 20°C / 93% RH 25°C / 65.7% RH 30.2°C / 75.4% RH 34.5°C / 40% RH	14.7°C: no ovipositi. 20°C: 7.1 25°C: 5.1 30.2°C : no eclosion 34.5°C: no dev.	14.7°C: 64 20°C: 22.7 25°C: 15.7 30.2°C: 12.7 34.5°C: 17.1	14.7°C: 41.5 20°C: 13.9 25°C: 9.3 30.2°C: 8 34.5°C: no dev.	Pre-ovi. 2-3 d Longevity 14.7°C: 9.4 20°C: 7.2 25°C: 4.6 34.5°C: no dev.	14.7°C: 114.9* 20°C: 50.9 25°C: 34.7 30.2°C: 85.6* *without egg phase	Marcano *et al.*, 1991a(specific study o life cycle) (Venezuela)
27ºC and 68%	5.5	16.4	8-12	Pre-oviposition: 4 d (up to 16) Oviposition 1-6 Longevity 4.3 (3-8)	34	Fernandez and Salas, 1985 (specific study o life cycle) (Venezuela)

Eggplant	Eggs	Larvae	Pupae	Adults	Total	
14.7°C / 79.5% RH 20°C / 93% RH 25°C / 65.7% RH 30.2°C / 75.4% RH 34.5°C / 40% RH	14.7&20°C: no oviposition 25°C: 5.3 d 30.2°C: oviposition, no egg hatching 34.5°C: no devt to adult	5 instars: 14.7&30.2°C 4 instars: 20&25°C 14.7°C: 63.9 d 20°C: 31.4 d 25°C: 18.3 d 30.2°C: 15.3 d 34.5°C: no dev.	14.7°C: 36.2 d 20°C: 13.3 d 25°C: 9.47 d 30.2°C: 7.8 d	14.7°C: 10.5 d 20°C: 7 d 25°C: 6 d 30.2°C: 4.5 d Preovi. 25/30.2°C: 2.75/2.5 d Ovip. 3/2.83 d	14.7°C: 110.6* 20°C: 51.7* 25°C: 39.16d 30.2°C: 27.6* *without egg stage	Marcano *et al.*, 1991b (specific study on life cycle) (Venezuela)
S. quitoense	**Eggs**	**Larvae**	**Pupae**	**Adults**	**Total**	
24ºC 74% H R	5.9	5 instars 22.2 d Prepupa: 2.4 d	12.3 d	6.8 d female 4 d male Preoviposition: 3 d	43 d	Serrano *et al.* 1992

One important feature of the life cycle of *N. elegantalis*, in particular in relation to control, is that many life stages are hidden: eggs may be under the calyx; young larvae are present on fruits for a very short duration in the first hours of light before entering the fruit for their entire life; pupae are enclosed in a cocoon attached to leaves and in debris making them difficult to observe; and adults emerge in the evening/night and are entirely nocturnal.

Temperature and relative humidity thresholds and preferences

This is considered here as it is important for the establishment of the pest in the EPPO region (see section 9.2). A few elements are available in the literature in studies on the biology and life cycle of the pest.
Regarding temperature thresholds, Marcano *et al.* (1991a, with tomato as food) did not obtain oviposition at 14.7 °C and no eclosion at 30.2 °C; at 34.5 °C, there was no development to the adult stage. Marcano (1991b) with eggplant as food, obtained similar results, with no oviposition at 14.7 and 20 °C, no eclosion of the eggs at 30.2 °C, and no development to the adult phase at 34.5 °C. It is probable that there is a temperature threshold for mating, but no precise data is available.

Relative humidity seems important for the life cycle (Benvenga *et al.*, 2010, citing others). Marcano *et al.* (1991a), expecting a lower development time as temperature increases, noted that this did not occur at 34.5 °C (where the larval stage was longer than at 30.2 °C). Marcano (1991b), with eggplant as food found no complete development of the larvae at 34.5 °C and makes the hypothesis that the relative humidity of 40% at high temperature (34.5 °C) may have been the reason that larvae did not develop. Populations of *N. elegantalis* are reported to increase during the rainy season (EDA, 2007). Fernández *et al.* (1988) regarding the higher incidence of the pest in periods of higher rainfall, emphasizing the importance of relative humidity for the life cycle of the pest.

According to Marcano (1991a&b), the viability of the life cycle is dependent on the combination of climatic factors, and is favoured by a relative humidity above 65% and a maximum temperature of 25º C.

2.2 Detection

Detection is mentioned here as it is relevant especially in relation to spread (section 11) and phytosanitary measures (section 16).

Signs and symptoms of infestation

- Entry holes. The scar of the entry hole is almost imperceptible (Espinoza, 2008), and is a depressed area with a necrotic spot of about 0.5 mm.
- Exit holes
- The fruit takes a slight change of colour
- Fruits fall on the ground
- Excrements on the fruit (especially on *S. quitoense* and *S. betaceum*)

Visual detection is difficult. Eggs are very small, larvae enter the fruit shortly after eclosion, through an entry hole that is very small and may be hidden under the calyx, pupae are mostly in folded leaves that hide them, and adults are nocturnal. The initial damage may be recognized by the presence of pimples or orifices on the skin of the fruit, once the larva finishes its life cycle within the fruit, it exits the damaged fruit to pupate

(Viáfara *et al*., 1999). However, damage may be first observed at harvest of the first fruit (Carneiro *et al.*, 1998). Infested fruit may fall on the ground and be observed at the base of the plants (Asaquibay *et al.*, 2009). Damaged fruits of *S. quitoense* and *S. betaceaum* before they fall to the ground can be recognized by the presence of excrements of the last instar larvae that left the fruit to pupate (Diaz-Montilla *et al.,* 2013a). Finally, in the Netherlands, the pest was intercepted on eggplant from Suriname based on the presence of larvae (e.g. detection of exit holes).

Detection methods

Trapping

Trapping is available and relies on a sex pheromone. The components of the sexual pheromone of *N. elegantalis* were analysed, and E11-16:OH was effective (Cabrera *et al.*, 2001; Badji *et al.*, 2003). A synthetic mixture of *E*11–16 :OH and *Z*3,*Z*6,*Z*9–23 :Hy as a trap bait was shown effective (Cabrera *et al.*, 2001). In Venezuela, a synthetic pheromone blend has been available commercially since 2001 (Silva, 2008) and has been used in several countries (e.g. Colombia, Brazil, Ecuador and Venezuela; Jaffe *et al.*, 2007). In Colombia this pheromone was first evaluated in tomato in 2001 (Diaz-Montilla, Corpoica, Colombia, 2013, personal communication). In the USA, the lure recommended for monitoring of this quarantine pest (under the name "Neoleucinodes elegantalis Lure") is effective for 30 days (Molet, 2012; CAPS, 2012). Research has been done regarding the use of pheromone traps for mating disruption and mass trapping (see 12.5).

The commercial pheromone blend used in South America appears to be attractive only to some biotypes. In Venezuela it attracts the pest in sweet pepper, tomato and *S. betaceaum* (Mirás *et al*. 1997; Arnal *et al*. 2005) in Colombia captures were made in tomato, *S. quitoense* and *S. betaceum* (Kuratomi 2001, Colorado *et al*. 2010), but no evaluation was made in sweet pepper and eggplant. In Brazil, captures were made on tomato in the state of Sao Paulo (Benvenga *et al*. 2010), but apparently not in all the states of this country (Jaffe, personal communication). In Honduras there were no captures on eggplant (Jaffe personal communication). In Ecuador there was no capture in *S. quitoense* or *S. betaceum* (Soria, personal communication, Fontagro project). For this reason, work is being conducted in Colombia to determine the genetic structure of the population of this insect in Central and South America, using two molecular markers Co1 and S18.

It seems that several trap types or forms may be used. Salas (2008) found no difference between the water pan traps and Delta traps, although Miras *et al.* (1997), comparing four models of traps for catching *N. elegantalis*, showed that the water pan trap with water and baited with virgin female, captured significantly more males. The large plastic delta trap (noting that the trap colour - orange, red, white - does not affect the efficacy) is recommended in the USA in combination with the lure for the capture of possible introduced adults (Molet, 2012; CAPS, 2012).

Details on use of pheromone traps are given in section 12.5.

Visual inspection. The signs and symptoms of infestation described above may be observed, but are not conspicuous at early stages of colonization. EDA (2007) mentions detection in the field by examining fruit for exit holes, and searching for pupae under the plants or between rows. The pest leaves the fruit to pupate and the presence of pupae is detected at import inspection (EDA, 2007; Espinoza, 2008). Detection of eggs seems to be used to determine the timing of sprays of plants protection products (see in section 12) (Diaz 2010a, citing Serrano *et al*., 1992; Benvenga *et al.*, 2010).

Positive identification of *N. elegantalis* is required to confirm the presence of the pest. *N. elegantalis* is morphologically very similar to several other species of Crambidae that occur in Central and South America, and in particular *N. elegantalis* is almost identical externally to the newly described species *N. silvaniae* (Diaz & Solis, 2007). Keys are available in Diaz & Solis (2007). It is not known whether some species that are present in the EPPO region are very similar morphologically to *N. elegantalis.*

Appendix 2. Trade of tomato, eggplant and sweet pepper fruit from countries where *N. elegantalis* occurs

Tables 1. Tomato

Table 1a. Exports of tomato fruit in 2006-2010 from countries where the pest occurs to EPPO countries (in tonnes) (from FAOstat). Countries for which there was no export (at origin) or no import (in the EPPO region) are not indicated in the table.

From / date	2006	2007	2008	2009	2010
Argentina			Spain 1		
Brazil		France 12 Netherlands 6	France 15	France 22	France 20
Colombia	France 168	France 127	France 93	France 55	France 33
Costa Rica	France 5	France 34		UK 101	UK 14
Ecuador	Netherlands 1 Spain 1	Germany 1	Germany 0		
Guatemala	France 3				Slovakia 14
Guyana					France 1
Mexico					Netherlands 13
Peru		France 1 Spain 12	Germany 0		Spain 9
Suriname		UK 5			France 18
Uruguay					
Venezuela	France 12 Netherlands 2	France 2	Malta 3	Czech Republic 3	

Table 1b. Imports into the EU of tomato in 100kg from countries where the pest occurs (from Eurostat). Countries without imports or exports are not listed below. In particular, there was no import from Venezuela, where the pest is a serious pest of eggplant.

	Brazil				Colombia				Costa Rica		Cuba	Ecua-dor	Mex-ico	Panama			Peru				Suriname	
	08	09	10	11	08	09	10	11	10	11	10	10	08	09	10	11	08	09	10	11	10	11
Germany	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	0	4	0	:	:
Denmark	:	34	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Spain	:	:	:	:	:	:	:	:	:	:	:	5	:	:	:	:	:	:	38	:	:	:
France	48	136	229	286	1.211	292	648	91	195	89	0	:	:	101	156	15	2	:	:	:	22	74
Italy	:	:	:	:	:	:	:	:	:	:	:	:	1	:	:	:	:	:	:	:	:	:
Luxembourg	:	:	:	:	:	11	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Netherlands	:	:	:	:	:	4	14	2	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Portugal	:	:	2	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:

Tables 2. Eggplant

Table 2a. Exports of eggplant fruit in 2006-2010 from countries where the pest occurs to EPPO countries (in tonnes) (from FAOstat). Countries for which there was no export (at origin) or no import (in the EPPO region) are not indicated in the table

From / date	2006	2007	2008	2009	2010
Argentina	Italy 21				
Brazil		Italy 0			
Costa Rica		France 4			
Guyana	France 1				
Honduras			Finland 16	Italy 2	
Mexico					Netherlands 2
Suriname					France 15

Table 2b. Imports into the EU of eggplants in 100kg from countries where the pest occurs (from Eurostat). Countries without imports or exports are not listed below. In particular, there was no import from Venezuela, where the pest is a serious pest of eggplant.

Partner	Brazil	Colombia	Cuba	Ecuador	Guatemala		Peru		Suriname			
	2009	2009	2008	2008	2009	2010	2008	2011	2008	2009	2010	2011
Belgium	:	10	:	:	:	:	:	:	:	:	:	:
France	:	:	:	:	:	:	:	:	:	:	10	8
United kingdom	:	:	:	:	:	:	27	10	:	:	:	:
Netherlands	0	:	1	13	3	7	:	:	459	611	1.551	1.480

Tables 3. Sweet pepper

Table 3a. Exports of chillies and pepper (green) in 2006-2010 from countries where the pest occurs to EPPO countries (in tonnes) (from FAOstat). Note: FAOstat does not have a separate categopry for sweet pepper only. Countries for which there was no export (at origin) or no import (in the EPPO region) are not indicated in the table

From / date	2006		2007		2008		2009		2010	
Argentina	Spain	5	Spain	2						
Bolivia	Spain	1					Spain	1	Spain	4
Brazil	France Italy Netherlands Portugal Spain UK	144 22 27 8 33 15	Belgium France Italy Netherlands Portugal Spain UK	1 150 28 22 5 3 7	Belgium France Italy Netherlands Portugal UK	36 79 18 2 5 1	France Germany Italy Netherlands Portugal UK	11 6 10 24 0 8	France Italy Netherlands Spain	4 25 18 1
Colombia					France Germany	2 1	France	1		
Costa Rica	Netherlands	6	France	7						
Ecuador	Belgium Netherlands	0 2	Belgium Germany Netherlands Spain Sweden UK	12 19 0 1 6 20	Germany	0	Spain UK	2 20	Spain	1
Grenada	UK	16								
Guatemala									UK	23
Honduras			Germany Netherlands UK	83 83 350	Germany UK	67 183	Germany Netherlands UK	59 20 162		
Jamaica			UK	1	UK	5	UK	3	UK	4
Mexico	Italy Netherlands	10 57	Italy Netherlands	19 38	Italy Netherlands Slovakia UK	10 16 0 1	Italy Spain UK	6 1 1	Netherlands Spain	6 1
Panama							Italy Netherlands	6 2		
Peru	Italy Netherlands Spain	79 0 38	France Italy Spain Sweden Switzerland UK	1 114 41 5 1 1	France Italy Spain Switzerland UK	47 121 36 1 31	France Italy Netherlands Spain Switzerland UK	2 134 23 25 2 185	Italy Netherlands Spain Switzerland UK	145 6 58 2 1
Trinidad and Tobago	UK	7	UK	0						
Uruguay			UK	0						
Venezuela	Netherlands	1			Malta	1				

Table 3b. Imports of chilli and sweet peppers in 100kg from countries where the pest occurs (from Eurostat)

07096010: Fresh or chilled sweet peppers

07096099: Fresh or chilled fruits of genus Capsicum or Pimenta (excl. for industrial manufacture of capsicin or capsicum oleoresin dyes, for industrial manufacture of essential oils or resinoids, and sweet peppers). Note: this category seems to exclude sweet pepper

		Bolivia		**Brazil**				**Colombia**				**Cuba**			
		2010	2011	2008	2009	2010	2011	2008	2009	2010	2011	2008	2009	2010	2011
07096010	Spain	:	18	:	:	:	:	:	:	:	:	:	:	:	:
07096010	France	:	:	:	:	27	29	:	12	:	:	:	:	6	:
07096010	Italy	:	:	57	:	:	:	:	:	:	:	:	:	:	:
07096099	Germany	:	:	:	3	:	:	6	0	0	1	5	:	:	:
07096099	Spain	21	70	:	:	10	:	:	:	:	:	:	:	:	:
07096099	France	:	:	9	36	37	:	:	:	:	:	:	:	:	:
07096099	UK	:	:	10	15	:	:	:	:	:	:	:	:	:	:
07096099	Italy	:	:	32	:	:	:	:	:	:	:	:	:	:	:
07096099	Luxembourg	:	:	:	:	:	:	:	0	:	:	:	:	:	:
07096099	Netherlands	:	:	24	226	209	:	:	:	:	0	73	66	2	3
07096099	Portugal	:	:	41	0	0	0	:	:	:	:	:	:	:	:

		Ecuador			**Grenada**			**Honduras**		**Jamaica**				**Mexico**			
		09	10	11	08	09	10	10	11	08	09	10	11	08	09	10	11
07096010	Spain	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	6
07096010	UK	:	:	:	:	:	:	:	:	:	:	:	2	:	:	:	:
07096010	Italy	:	:	:	:	:	:	:	:	:	:	:	:	85	:	:	:
07096099	Belgium	9	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
07096099	Spain	:	8	15	:	:	:	88	35	:	:	:	:	1.207	976	1.270	818
07096099	Finland	:	:	:	:	:	:	:	:	:	:	:	:	:	:	2	:
07096099	France	:	0	:	:	:	:	:	:	:	:	:	:	:	:	:	0
07096099	UK	:	:	:	493	247	130	:	:	948	647	234	91	:	891	750	1.383
07096099	Netherlands	:	1	0	:	:	:	:	:	:	:	:	:	22	16	20	43

		Nicaragua				**Panama**		**Peru**				**Suriname**				**Trinid. &Tob.**	**Venezuela**
		08	09	10	11	09	10	08	09	10	11	08	09	10	11	08	08
07096010	Germany	:	:	:	:	:	:	:	0	:	:	:	:	:	:	:	:
07096010	France	:	:	:	:	:	7	:	:	:	0	:	:	:	:	:	:
07096010	UK	:	:	:	:	:	:	:	5	16	14	:	:	:	:	:	:
07096010	Italy	:	:	:	:	:	:	2	:	:	:	:	:	:	:	:	:
07096010	Netherlands	:	:	:	:	:	:	:	:	:	880	:	:	0	:	:	:
07096010	Portugal	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	2
07096099	Belgium	:	:	:	:	:	:	:	1	0	:	:	:	:	:	:	:
07096099	Germany	:	:	:	:	:	:	:	:	0	:	:	:	:	:	:	:
07096099	Spain	1.495	1.714	846	2.097	:	14	:	6	:	58	:	:	:	:	:	:
07096099	UK	:	:	:	:	:	:	3	:	8	:	:	:	:	:	3	:
07096099	Netherlands	:	:	:	:	58	46	0	1	4	184	586	219	555	208	:	:

Appendix 3. Areas cultivated in tomato, eggplant and sweet pepper in EPPO countries

The total areas of cultivation for tomato, eggplant and sweet pepper in the EPPO region in 2011 were as follows according to FAOStat:

- tomato: 1 045 743 ha
- eggplant: 84 362 ha
- sweet pepper and chilli: 281 621 ha.

- 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. From EPPO (2012b). FAOStat in Appendix 3 also indicates large areas cultivated in the Azerbaijan, Algeria, Russian Federation, Ukraine, Uzbekistan and Kazakhstan.
- 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. From EPPO (2012b). FAOStat in Appendix 3 also indicate large areas cultivated in Algeria, Kazakhstan, Morocco, Ukraine.
- Sweet pepper. According to the data of Faostat (Appendix 3), capsicum (including sweet pepper and chilli) are cultivated in the southern part of the PRA area (especially Turkey, but also Algeria, Spain, Tunisia, Italy) and in south-eastern part of the region, and in Central Asia (Ukraine, Serbia, Romania, Kazakhstan). Production in gardens is expected to be as for eggplants, mostly in southern areas.

Fig. 1. Tomato production in the EPPO region in 2000 (Source Monfreda *et al.*, 2008)

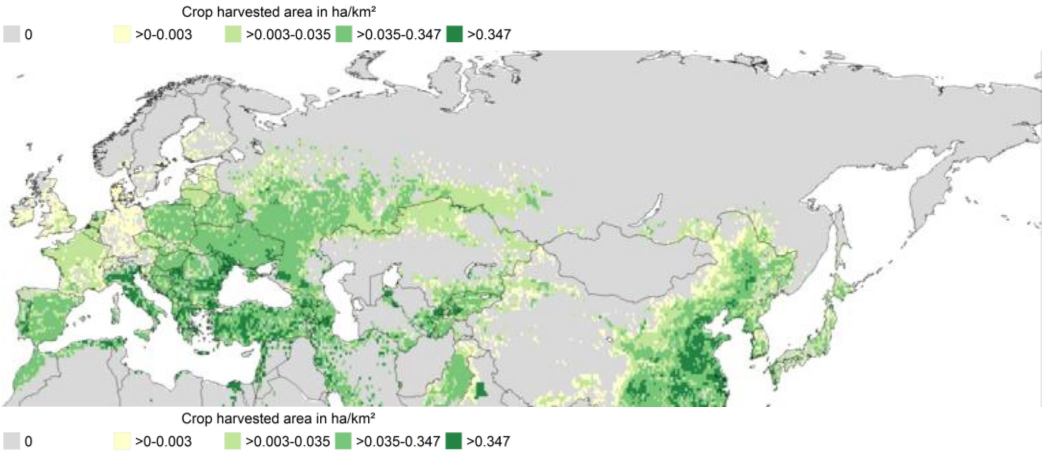


Table 1. Tomato. Areas cultivated (in ha) in EPPO countries in 2011. From FAOStat (countries without production were deleted from the table).

Country	ha	Country	ha	Country	ha
Albania	6300	Germany	321	Poland	13441
Algeria	23500	Greece	19800	Portugal	16744
Armenia	6837	Hungary	1975	Republic of Moldova	5847
Azerbaijan	26613	Ireland	32	Romania	51745
Belarus	5777	Israel	5002	Russian Federation	117000
Belgium	474	Italy	103858	Serbia	20229
Bosnia and Herzegovina	3589	Jordan	12954	Slovakia	3835
Bulgaria	3860	Kazakhstan	27000	Slovenia	201
Croatia	1054	Kyrgyzstan	9181	Spain	49913
Cyprus	132	Latvia	1000	Sweden	48
Czech Republic	409	Lithuania	346	Switzerland	206
Denmark	40	Luxembourg	1	Tajikistan	11799
Estonia	167	Malta	350	FYR Macedonia	5632
Finland	114	Morocco	18160	Tunisia	32200
France	6111	Netherlands	1702	Turkey	269584
Georgia	6933	Norway	31	Turkmenistan	9580

Country	ha
Ukraine	85900
United Kingdom	216
Uzbekistan	58000
Total	**1045743**

Fig. 2. Eggplant production in the EPPO region in 2000 (Source Monfreda *et al.*, 2008)

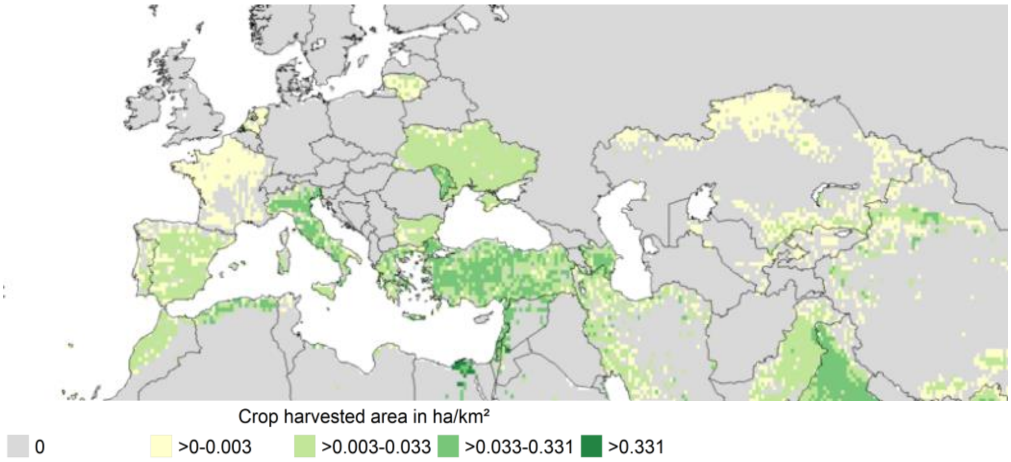


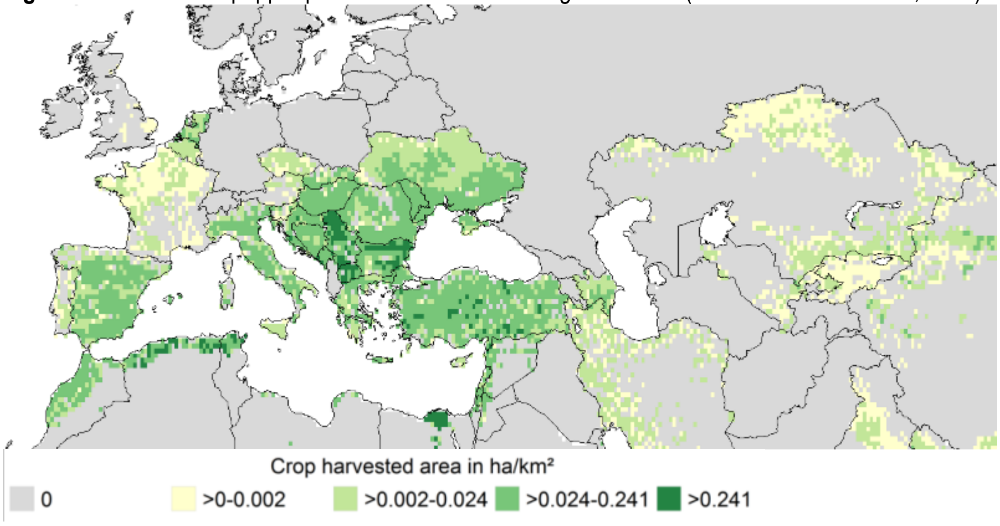
Table 2. Eggplant. Areas cultivated (in ha) in EPPO countries in 2011. From FAOStat (countries without production were deleted from the table).

Country	ha
Albania	1000
Algeria	5400
Azerbaijan	5924
Belgium	22
Bulgaria	347
Cyprus	21
France	711
Georgia	1490
Greece	2500
Hungary	52
Israel	650
Italy	9423
Jordan	2395
Kazakhstan	3200
Kyrgyzstan	200
Lithuania	996
Malta	24
Morocco	2382
Netherlands	101
Portugal	349
Republic of Moldova	656
Romania	10020
Serbia	98
Spain	3268
FYR Macedonia	47
Tunisia	31
Turkey	25355
Ukraine	7500
Uzbekistan	200
Total	**84362**

Table 3. Sweet pepper and chilli. Areas cultivated (in ha) in EPPO countries in 2011. From FAOStat (countries without production were deleted from the table)

countries	ha
Albania	3100
Algeria	27000
Azerbaijan	4388
Belgium	87
Bosnia and Herzegovina	3431
Bulgaria	4620
Croatia	1530
Cyprus	21
Czech Republic	263
Finland	6
France	624
Georgia	600
Germany	43
Greece	3600
Hungary	2668
Israel	5500
Italy	10327
Jordan	1305
Kazakhstan	7000
Kyrgyzstan	300
Morocco	6129
Netherlands	1357
Portugal	239
Republic of Moldova	2648
Romania	20001
Serbia	17888
Slovakia	1740
Slovenia	139
Spain	16887
Switzerland	17
FYR Macedonia	8465
Tunisia	18000
Turkey	93826
Ukraine	17100
United Kingdom	72
Uzbekistan	700
Total	**281621**

Fig. 3. Chilli and sweet pepper production in the EPPO region in 2000 (Source Monfreda *et al.*, 2008)



Appendix 4. Detailed assessment of the climatic suitability of the PRA area for the establishment of *Neoleucinodes elegantalis*

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

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

Köppen-Geiger climate zones

N. elegantalis occurs in at least 5 Köppen-Geiger climate zones (see Fig. 1 and Table 1). These include equatorical and temperate climate zones. The temperate climate zones (Cfa and Cfb) correspond with the climate zones of the PRA area (see Fig 1).

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

Köppen-Geiger climate zones				
Code	**Main Climate**	**Precipitation**	**Temperatures**	**South 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	
Csb	Warm temperate	Steppe	warm summer	
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	

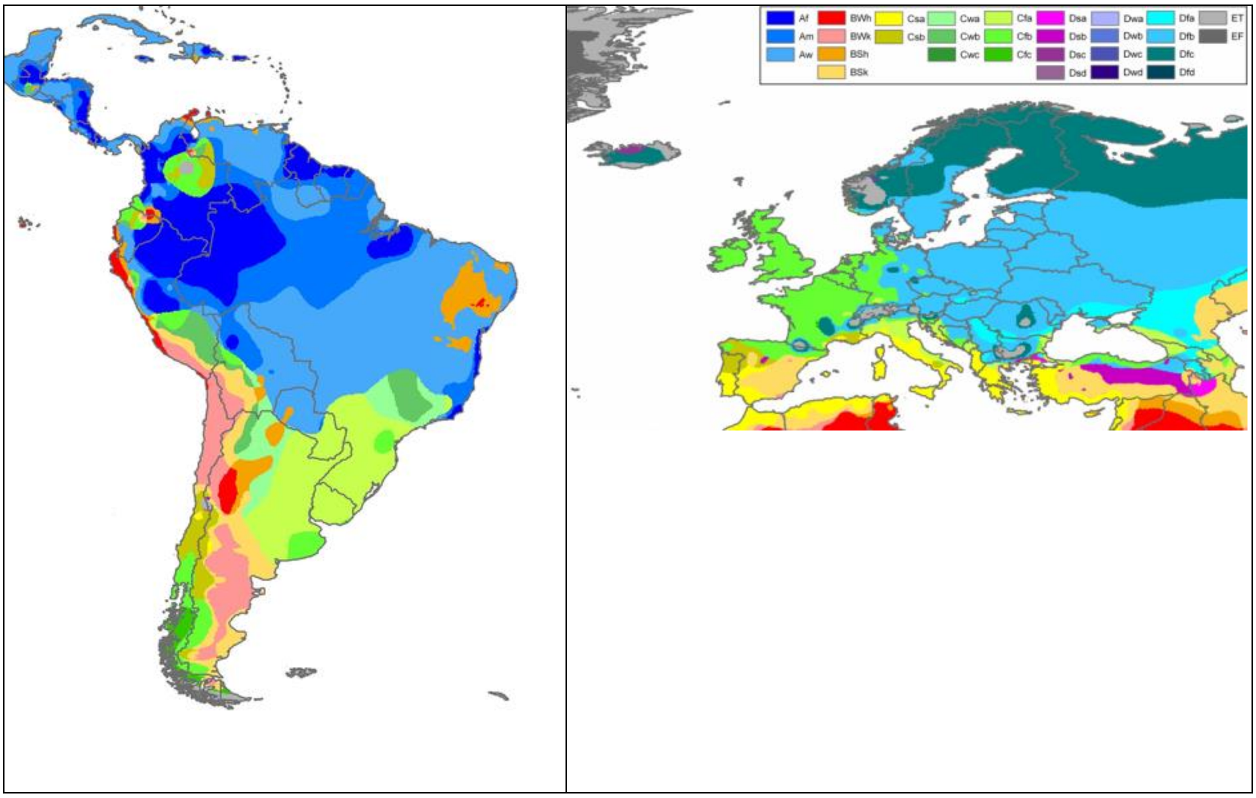


Figure 1 Köppen-Geiger climate zones in South America and Europe

Holdridge Life zones

Diaz *et al*, 2011 investigated the geographic distribution of *N. elegantalis* in Colombia. According to the Holdridge classification of climate zones, *N. elegantalis* is present in six zones, corresponding to tropical dry forest (bs-T), montane dry forest (bs-PM), montane rain forest (bh-PM), very humid forest (bmh-PM), lower montane wet forest (bh-MB) and lower montane wet forest (bmh-MB).

2. Using the known climate response data for *N. elegantalis* 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.

Marcano (1991) investigated the relation between temperature and development for *N. elegantalis* on tomato in the laboratory. The egg to adult developmental data in Marcano (1991) were used to plot the data and to calculate the linear regression equation (see table 2 & figure 2).

The linear equation results in 526 degree-days for egg to adult development and a critical temperature of 10.5˚C where development stops.

Table 2 Development of the different life stages of *N. elegantalis* at different temperatures (adapted from Marcano, 1991)

Temp.	Egg	Larva	Pupa	Total
14.7 ˚C	9.22	64	41.5	115 days
20˚C	7.1	22.7	13.9	44 days
25˚C	5.1	15.7	9.3	30 days
30.2˚C				26 days

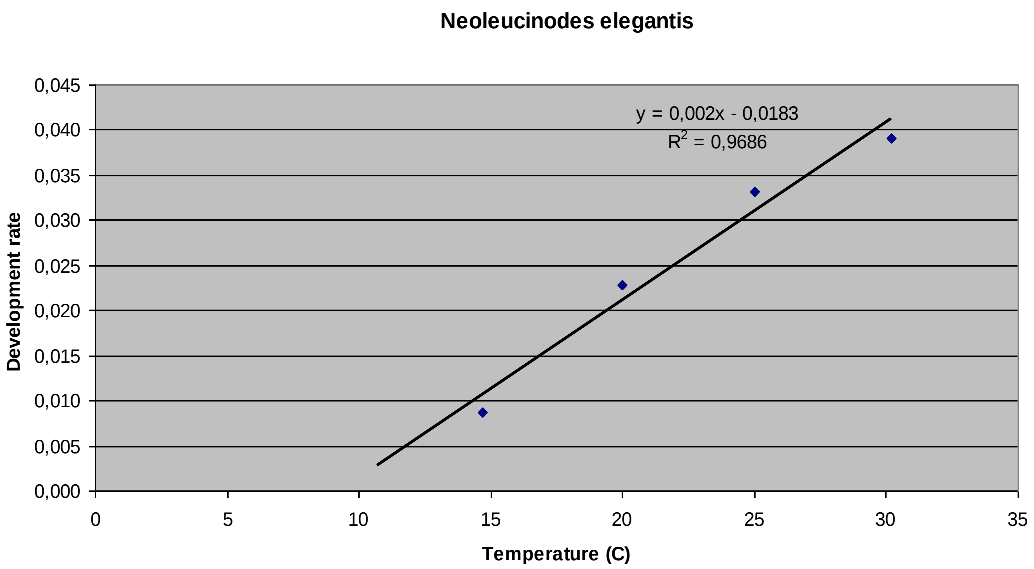


Figure 2 Relation between temperature and development rate

2.2 <u>CLIMEX modelling</u>

There is no specific information available on the number of lifecycles/generations that *N. elegantalis* can have in a year. It is unknown how the organism survives if temperatures are low or when suitable hosts are absent. The extensive detailed dataset of Diaz *et al.* (2011) on the presence of *N. elegantalis* at 119 Colombian locations was used to estimate the number of generations of *N. elegantalis*, using climate data from Colombian weather stations (CLIMEX (v3) meteorological database).

CLIMEX includes data for 49 weather stations in Colombia. To estimate the maximum number of generations at these locations, a simple development model with a base temperature of 10.5 ºC and 526 degree-days was applied in CLIMEX (v3). The results are presented in Fig. 3.

Within Colombia there is a large variation in the possible number of generations (0-12) over a year. One of the possible reasons of this large variation (in the number of degree-days available for development at a particular location) is the large variation of altitudes in Colombia, which ranges from very low in the Pacific region (10 m) to very high in the Andes region (>2000m).

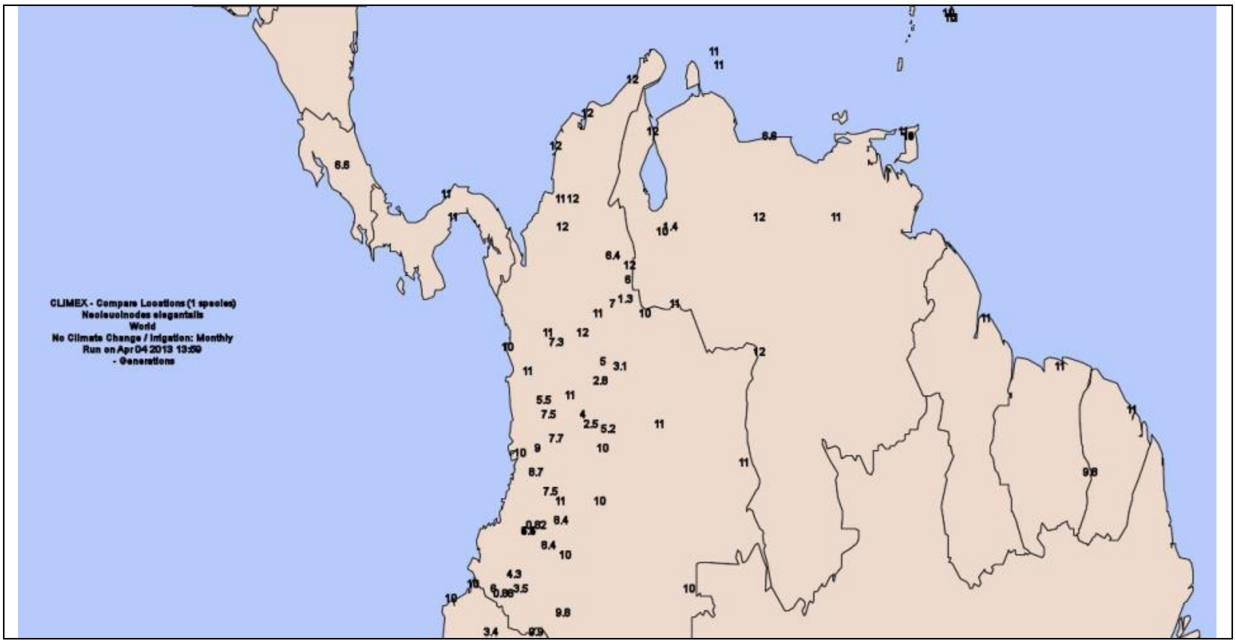


Figure 3. Map showing the maximum number of expected generations of *N. elegantalis* at locations with weather stations in Colombia, based on 526 degree-day accumulation above a minimum temperature of 10.5 ºC (CLIMEX v3).

An attempt was made to find the weather stations that are near locations where *N. elegantalis* was shown to occur in Colombia (data from Diaz *et al*., 2011). For example, in the department Huila, *N. elegantalis* was present in Garzon, Gigante and Algeciras. The nearest weather stations for which climate data are available are Altamira and Algeciras (see Fig. 4). Based on the weather station data, it is expected to have approximately 8 generations per year. However, the field locations in Garzon, Gigante and Algeciras where *N. elegantalis* was shown to be present are at different altitudes than the weather stations. The field locations were at altitudes ranging from 932-2250m, whereas the weather stations were at altitude of 1020 and 1155m. Thus, the number of estimated generations at the field sites can only be derived with caution from data from nearby weather stations.

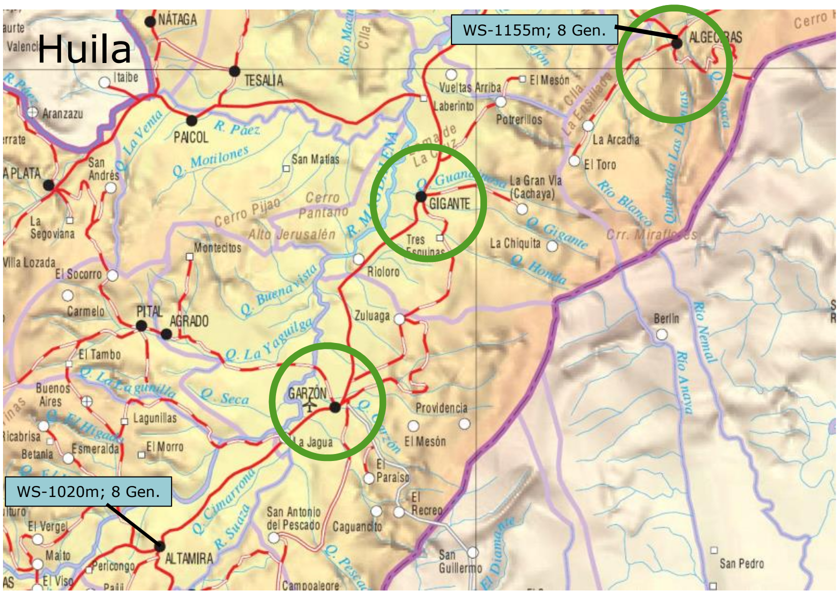


Figure 4. Presence of *N. elegantalis* in Huila (locations in green circles) and location of nearest weather stations in Altamira and Algeciras.

To better estimate the number of generations at specific locations, the altitude should be taken into account. When the altitude of the weather stations is plotted against the number of degree-days at that location, a clear relationship is demonstrated, as expected (Fig. 5). The equation for the number of expected generations of *N. elegantalis* at a particular location in relation to the altitude of the location is:

$$\text{Number of Generations}_{LOC} = 11.6 - (0.0035 \text{ x Altitude}_{LOC})$$

Using this formula, the estimated number of generations of *N. elegantalis* was calculated for all locations in Columbia where the organism is reported by Diaz *et al.*, 2011. A summary of the results is presented in Table 3.

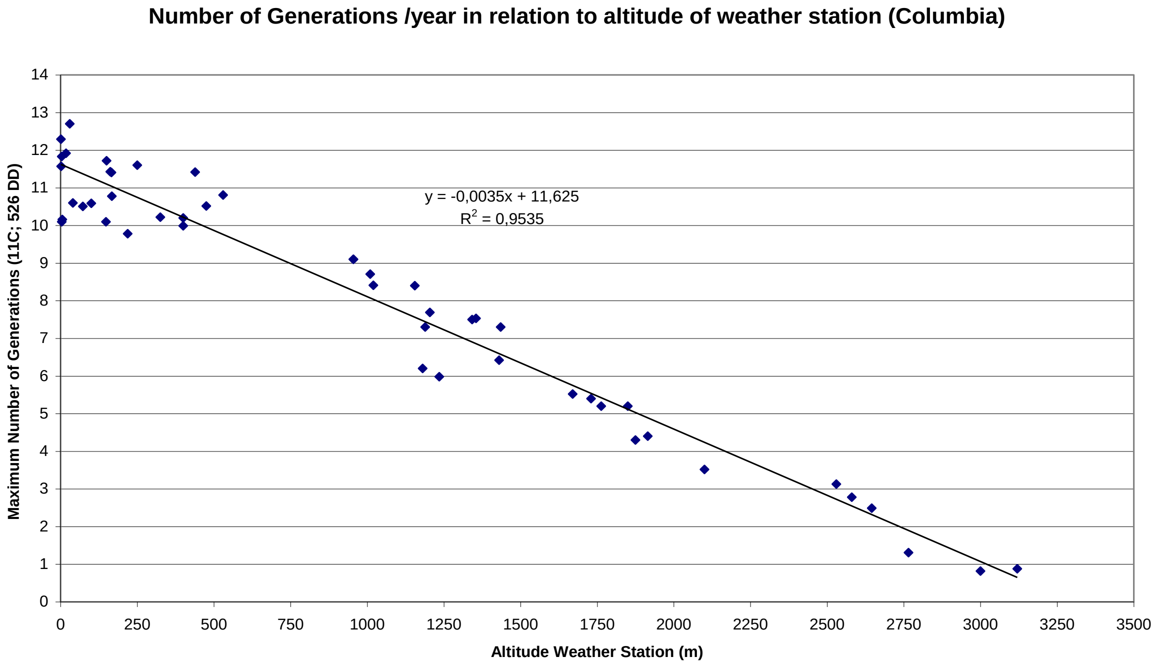


Figure 5. Relation between altitude and expected generations of *N. elegantalis* at locations with weather stations in Colombia, based on 526 degree-day accumulation above a minimum temperature of 10.5 ºC (CLIMEX v3).

Table 3. Estimated number of generations of *N. elegantalis* in departments of Colombia at locations where the pest was shown to be present (derived from dataset of Diaz *et al*., 2011). The minimum, maximum and mean of altitude are indicated as well as the number of generations for each department. Altitude information on locations was kindly provided by A. Diaz. The number of generations was estimated using the equation derived from Fig. 2.

			Altitude (m)				**Generations / year**			
Department	**Region**	**Loc#**	**Min**	**Max**	**Mean**		**Min**	**Max**	**Mean**	**Truncated**
Antioquia	Andean region	6	1938	2145	1993		4,1	4,8	4,0	4
Boyacá	Andean region	11	1160	2200	1767		3,9	7,6	5,4	5
Caldas	Andean region	6	1502	2070	1786		4,4	6,4	5,0	5
Cauca	Andean region	1	990	990	990		8,2	8,2	8,0	8
Cesar	Carribean	1	1240	1240	1240		7,3	7,3	7,0	7
Cordoba	Carribean	1	55	55	55		11,4	11,4	11,0	11
Cundinamarca	Andean region	20	1209	2560	1789		2,7	7,4	5,4	5
Huila	Andean region	10	932	2250	1637		3,8	8,4	5,9	5
Magdalena	Carribean	4	1000	1669	1344		5,8	8,1	6,9	6
Nariño	Pacific	1	2	2	2		11,6	11,6	11,6	11
Nariño	Andean region	4	1800	2200	1954		3,9	5,3	4,8	4
Norte de Santander	Andean region	8	1200	2263	1592		3,7	7,4	6,1	6
Quindio	Andean region	3	1751	1785	1762		5,4	5,5	5,5	5
Risaralda	Andean region	3	1580	1760	1695		5,5	6,1	5,7	5
Santander	Andean region	10	1000	2235	1623		3,8	8,1	5,9	5
Tolima	Andean region	9	1224	2279	1889		3,6	7,3	5,0	5
Valle del Cauca	Andean region	24	936	1557	1227		6,2	8,3	7,3	7
	Overall	122	2	2560			2	11		

In Colombia *N. elegantalis* occurs at altitudes ranging from 2 to 2560m, which corresponds with an estimated 11 to 2 generations per year. Thus, at the locations with the highest altitude, *N. elegantalis* is only able to complete 2-3 generations per year. For example in Cabrera (Cundinamarca), *N. elegantalis* was present in *Solanum quitoense* at an altitude of 2560m. To get an impression of the climatic conditions at these high altitude locations, the weather station data can be used which are located at similar altitudes. The weather station "Belencito" (Boyacá) is located at an altitude of 2530m (see Fig. 6). The mean minimum weekly temperature at this location does not drop below 7 ºC. Thus, in Colombia, *N. elegantalis* is probably not exposed to temperatures below 7 ºC for a long time and development is possible on all days of the year. This could indicate that *N. elegantalis* has no diapause, but that development slows down in periods with a low temperature. There is no information which low temperatures are lethal for the different life stages of *N. elegantalis,* for example if the organism survives periods of frost.

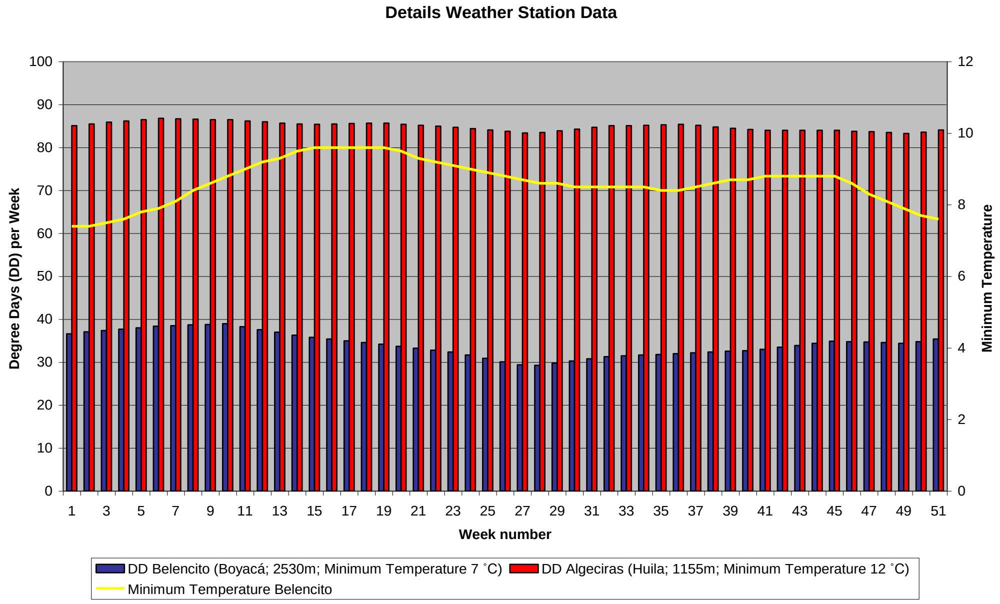


Figure 6 Weekly weather station data for Belencito (Climex v3)

Humidity / Rain requirements

An attempt was made to find the ideal humidity/rain requirements in relation to the presence of field populations of *N. elegantalis.* A preliminary analysis shows that the relative humidity and rainfall conditions in areas where the organism occurs can vary significantly (Table 4 and Fig. 7).

N. elegantalis is present in humid areas with a mean monthly rainfall of up to 1914 mm and a relative humidity of 83%. However, in Argentina the organism is also present in dry regions with a mean monthly rainfall of 608 mm and a relative humidity of 44% (similar to the annual rainfall in Mediterranean climate). It is unknown if irrigation takes place and could be a reason for the presence of the organism there.

Las Lomitas (Formosa, Argentina) has a mean RH of 49%

Thus, there are uncertainties on the humidity requirements of the organism.

Table 4 Relative humidity (RH%), rainfall (mm), minimum and maximum temperature (°C) data for locations in Colombia and Argentina where *N. elegantalis* is present (CLIMEX v3).

	RH 3pm	**RH 9am**	**Rain**	**Tmax**	**Tmin**
Altameira (CO)	60.1	81.2	1086	28.2	18.1
Algeciras (CO)	57.6	83.0	1106	29.4	16.9
Tulio Ospina (CO)	55.9	79.8	1431	27.5	15.6
Bertha Moniquira (CO)	83.4	56.4	1914	24.7	11.8
Rivadia (ARG)	44.3	67.1	608	29.8	15.6
Las Lomitas (ARG)	48.6	72.5	863	29.2	15.8
Minimum	44.3	56.4	608	24.7	11.8
Maximum	83.4	83.0	1914	29.8	18.1

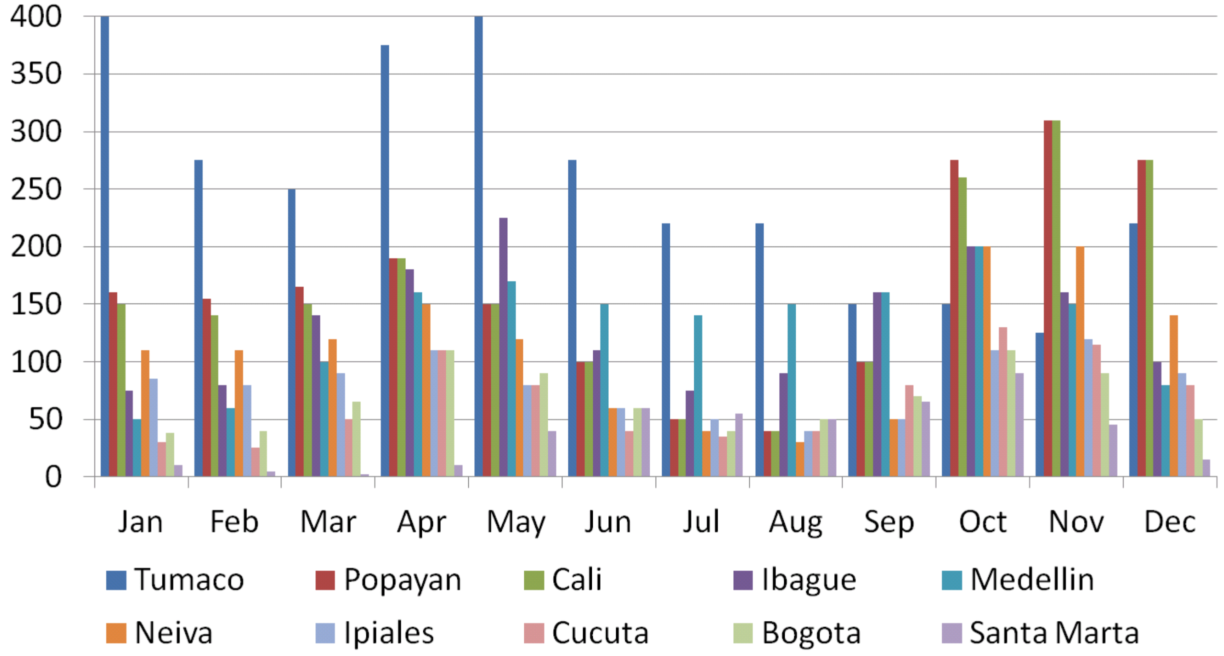


Figure 7: Monthly rainfall at 10 locations in Colombia where *N. neoleucinodes* is present. Rainfall data taken from www.weather-and-climate.com.

Potential distribution in EPPO region

N. elegantalis occurs in at least 5 Köppen-Geiger climate zones, including the temperate zones *Cfa* and *Cfb* that are present in the EPPO region. 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 development model with a base temperature of 10.5 ºC and 526 degree-days has been applied in CLIMEX (v3). The number of generations that *N. elegantalis* can have in one year is presented for the PRA area, based on weather station data (Fig. 8) and interpolated gridded data (Fig. 9).
In southern Europe and North Africa the number of expected generations is 4-7 and in Northern Europe 1 generation. 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 the EPPO region. In Colombia the mean minimum temperature generally does not drop below the threshold development temperature of 10.5 ºC. In several areas in the EPPO region the minimum temperature drops below the threshold development temperature in wintertime, such as in Verona, Italy (Fig 10a). In southern and eastern Mediterranean areas, development of *N. elegantalis* is possible throughout the year, as for example in Haifa, Israel (Fig 10b).

Greenhouse conditions

Assuming that the mean temperature in a greenhouse is 20 ˚C, the expected time for one life cycle is: 526DD/(20-10)=53 days. In Northern countries of the PRA area, the expected number of generations in greenhouses (March-August) is 2-3 generations.

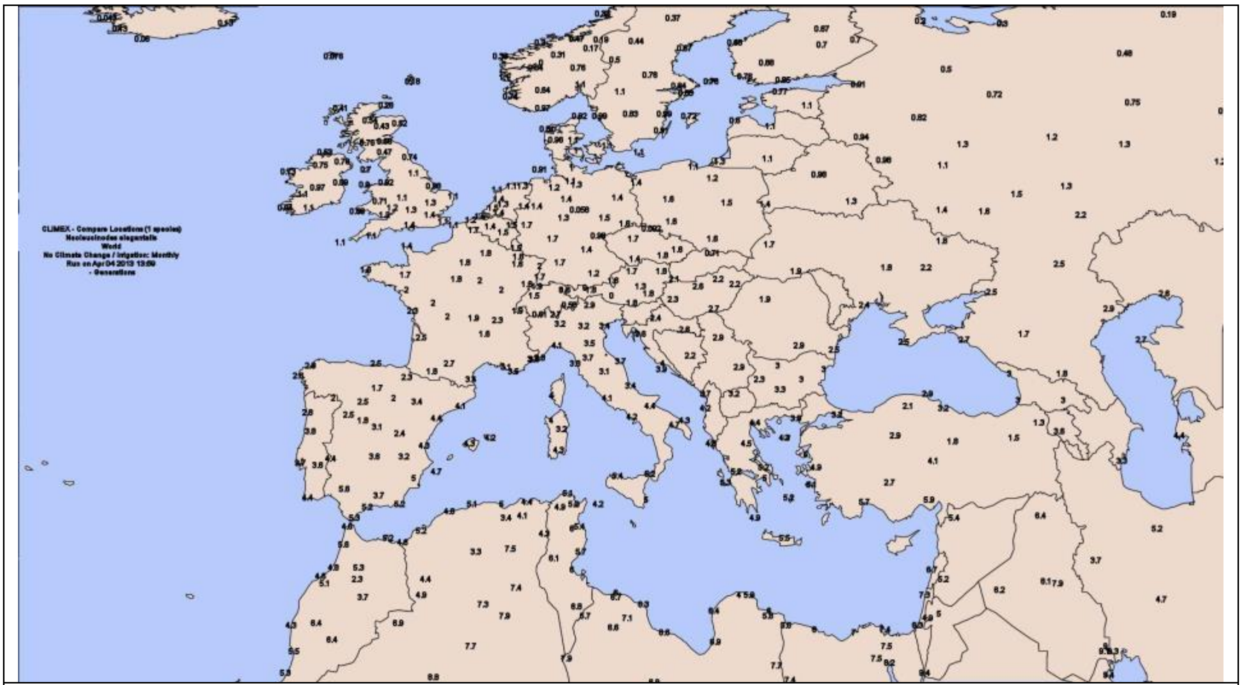


Figure 8
Map showing the maximum number of expected generations of *N. elegantalis* at locations with weather stations in the EPPO region, based on 526 degree-day accumulation above a minimum temperature of 10.5 ºC (CLIMEX v3).

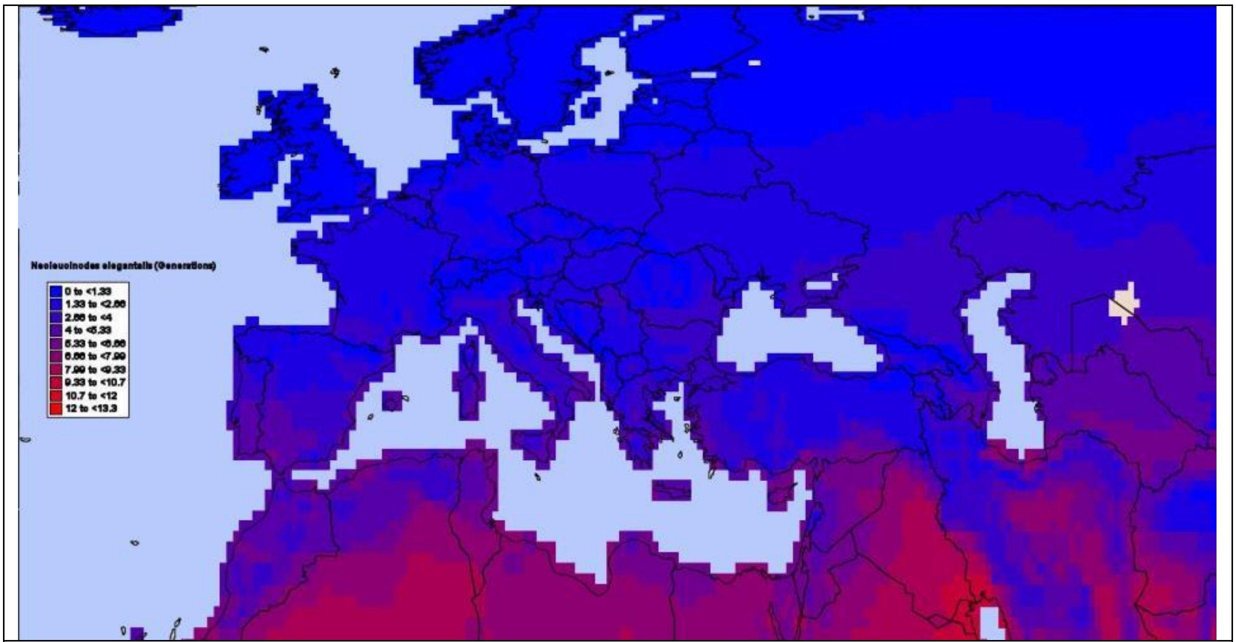
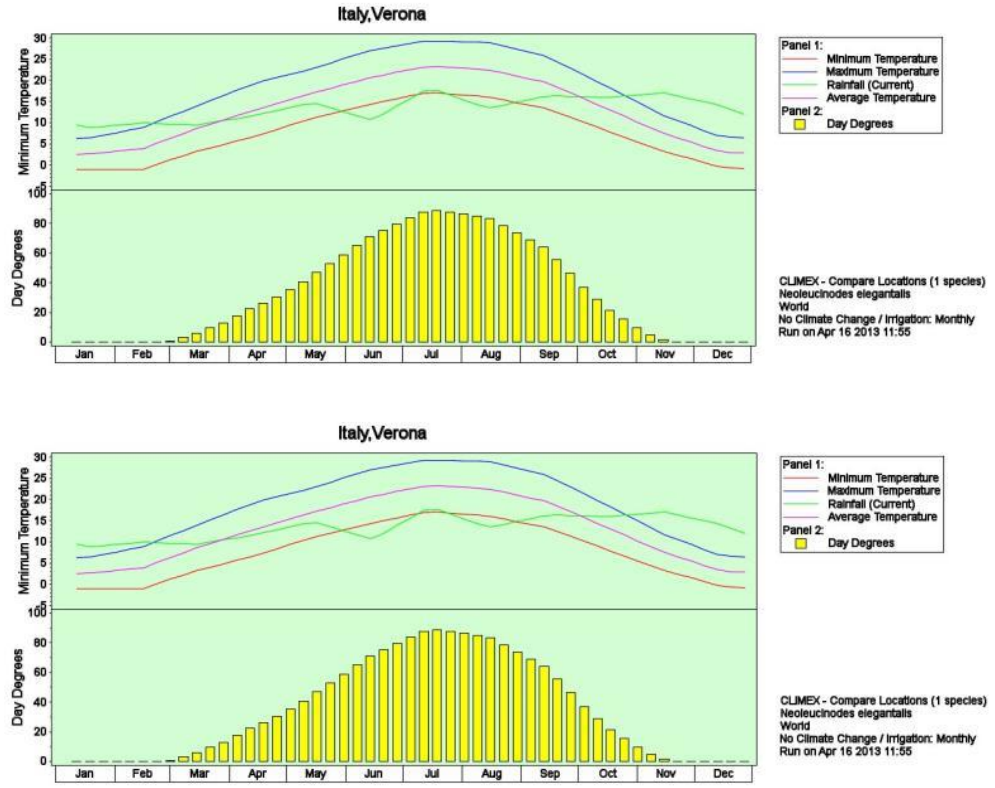


Figure 9
Map showing the maximum number of expected generations of *N. elegantalis* at locations with weather stations in the EPPO region, based on 526 degree-day accumulation above a minimum temperature of 10.5 ºC (CLIMEX v3), extrapolated gridded data.

A



B

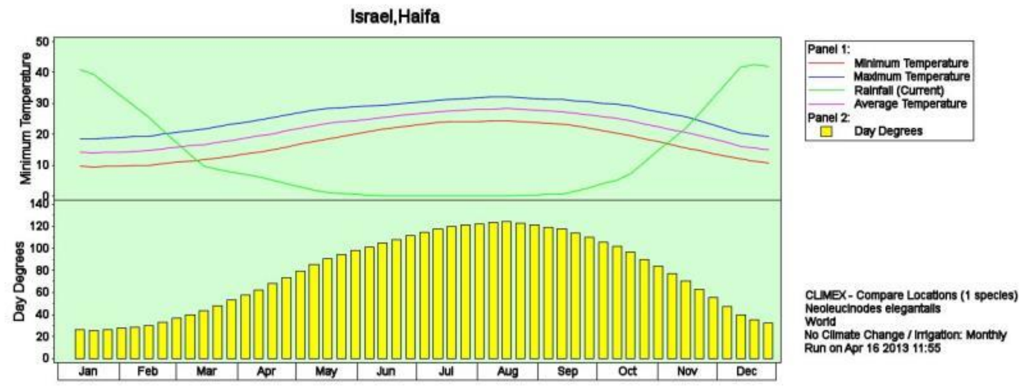


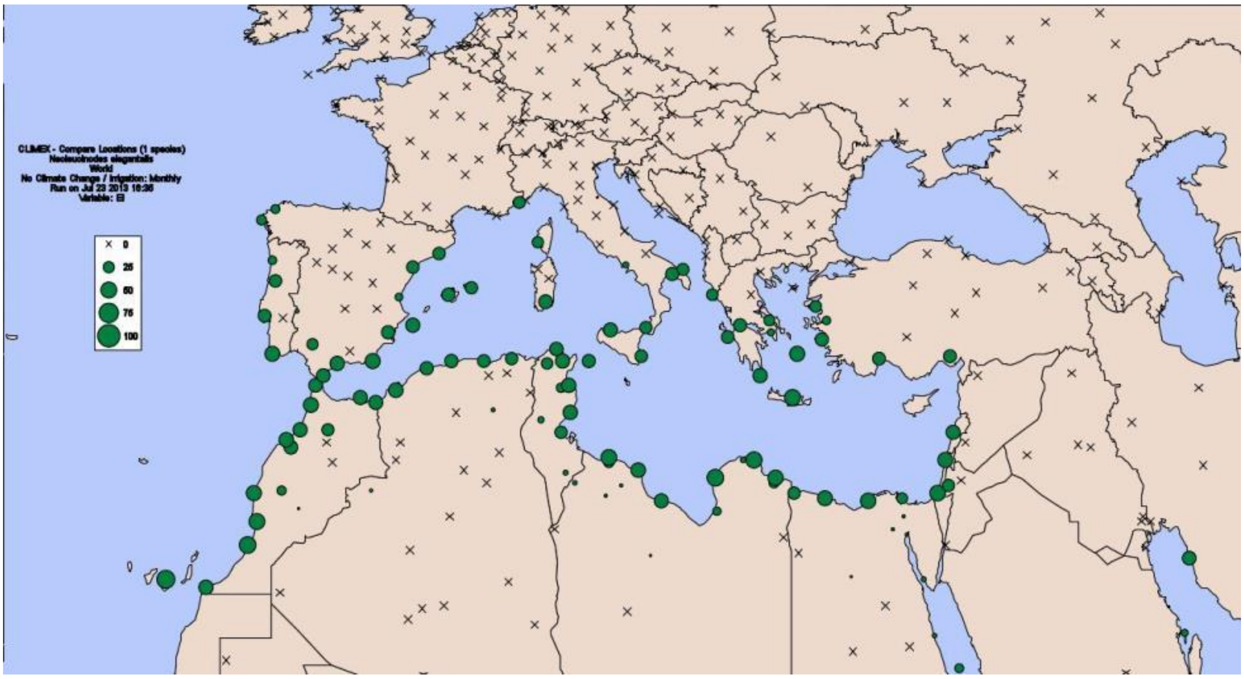
Figure 9 Monthly weather station data for Verona (IT) and Haifa (IL)

Lethal temperature

The minimum development threshold is estimated to be 10.5 ºC. No information could be obtained on the lethal temperature for the different life stages of *N. elegantalis.* This information will greatly enhance the reliability of the prediction of the potential distribution area in the EPPO region.

Climex model

Based on the current distribution of *N. elegantalis*, a preliminary attempt to adjust the CLIMEX model parameters in such a way that the resulting ecoclimatic suitability map resembled the geographic distribution pattern as good as possible. In Fig. 10 the results and model parameters are presented. From this model it can be concluded that *N. elegantalis* is able to establish outdoors in the coastal areas of the Mediterranean basin.



Moisture Index	SM0: 0.1	SM1: 0.4	SM2: 0.7	SM3: 2		
Temperature Index	DV0: 10.5	DV1: 20	DV2: 25	DV3: 35		
Light Index (not used)						
Diapause Index (not used)						
Cold Stress	TTCS: 5	THCS: -0.001	DTCS: 15	DHCS: -0.01	TTCSA: 0	THCSA: 0
Heat Stress	TTHS: 35	THHS: 0.0015	DTHS: 0	DHHS: 0		
Dry Stress	SMDS: 0.25	HDS: -0.01				
Wet Stress	SMWS: 2	HWS: 0.002				
Cold-Dry Stress (not used)						
Cold-Wet Stress (not used)						
Hot-Dry Stress (not used)						
Hot-Wet Stress	TTHW: 35	MTHW: 2	PHW: 0.01			
Day-degree accumulation above DV0	DV0: 10.5	DV3: 35	MTS: 7	:	:	
Day-degree accumulation above DVCS	DVCS: 8	*DV4: 100	MTS: 7			
Day-degree accumulation above DVHS	DVHS: 35	*DV4: 100	MTS: 7			
Degree-days per Generation	PDD: 526					

Figure 10 Results of CLIMEX model for *N. elegantalis.* Green dots indicate locations where climate is suitable for establishment outdoors based on ecoclimatic index
DV0 is the limiting low temperature, DV1-DV2, the optimal range, DV3 the limiting low temperature. The CLIMEX model includes both a ‘heat strees’ and a ‘dry stress’ factors to take into the fact that the pest seems to prefer humid and not too hot conditions.

APHIS has published risk maps for *Neoleucinodes elegantalis* using the data from Marcano *et al.* (1991). The APHIS model uses slightly different parameters for the base temperature (APHIS: 9.4 ºC; EPPO: 10.5ºC) and degree-days requirements (APHIS: 556 DD; EPPO: 526 DD). The results of models for the EPPO region with both sets of parameters are presented in Fig. 11. There is a slight difference between the two models. The APHIS model predicts a slightly larger area with suitable conditions than the EPPO model.

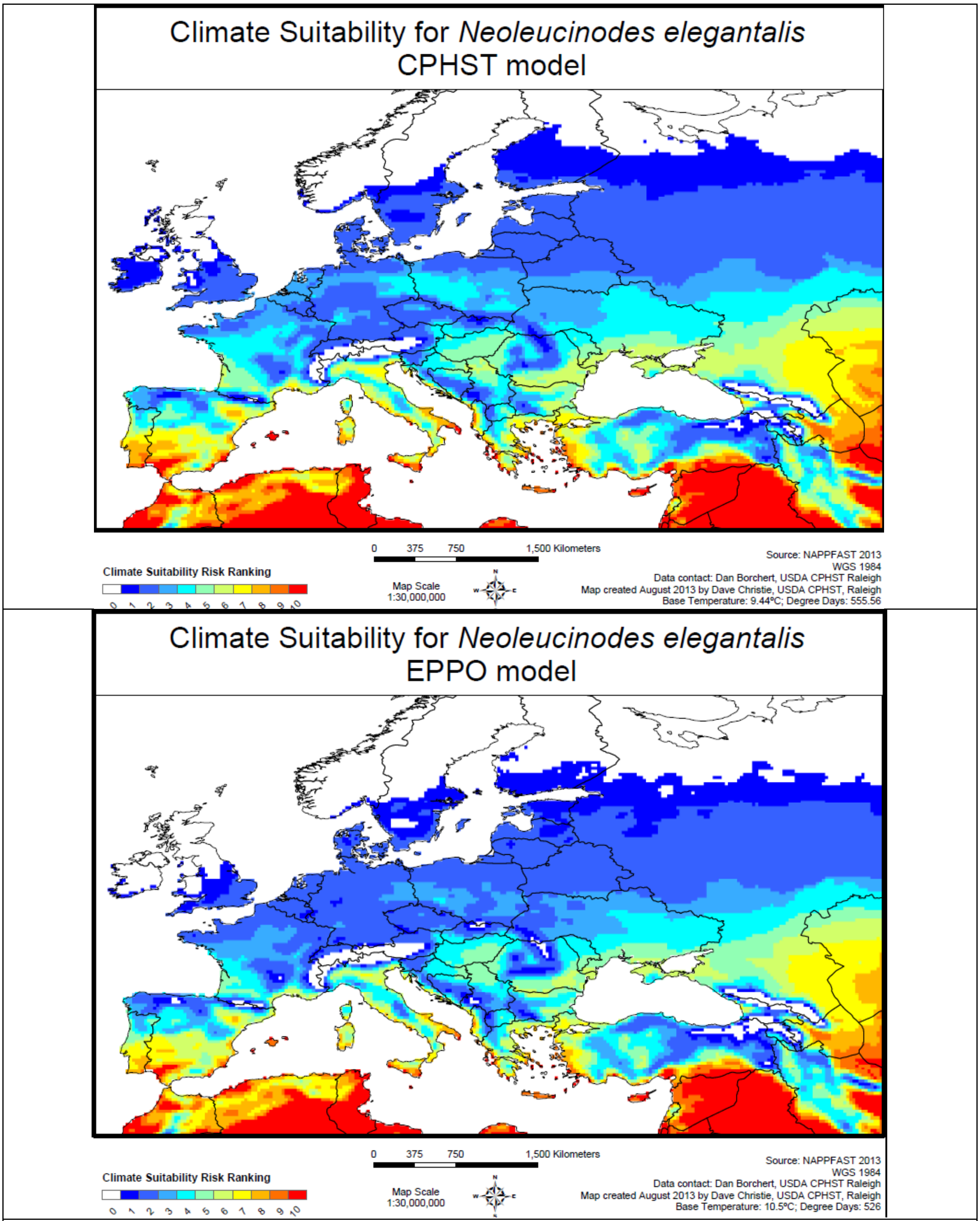


Figure 11

Climatic suitability according to NAPPFAST models with parameters used in APHIS-CPHST model (top) and EPPO model (bottom). A value of 1 represents a low likelihood of pest growth and survival, while a 10 indicates high likelihood of pest growth and survival. Additionally, a value of zero indicates that the climate is unsuitable.

Figures kindly provided by D. Christie and D. Borchert, APHIS, USA

Conclusions

In its current area of distribution, *Neoleucinodes elegantalis* occurs in 5-6 climate zones. The majority of the distribution area in South America is (sub)tropical, but the organism is also present at high altitudes which have a more temperate climate, comparable to climate zones present in parts of the EPPO region.

The minimum development threshold temperature is estimated to be 10.5 ˚C and the number of Degree-Days for development from egg to adult is 526. One generation is possible in northern Europe and transient populations may occur in summertime. In the southern parts of the EPPO region, up to 7 generations are predicted and in these areas the organism may establish in the field.

There is no information available on the suitability of glasshouses as a favourable environment for *N. elegantalis*. However, areas where hosts (e.g. tomato, aubergine, peppers) are grown under protected cultivation in the EPPO region are likely to be at risk.

N. elegantalis has probably no diapause phase. It is predominantly a warm climate pest and development is limited by cold temperatures.

Temperature accumulation above the minimum developmental threshold and the availability of suitable (fruiting) hosts is the main factor controlling *N. elegantalis* establishment and distribution.

More information is needed on optimal temperature for mating, lethal temperatures and humidity requirements for *N. elegantalis.*

Appendix 5. Consideration of pest risk management options

The table below summarizes the consideration of possible measures for fruit and plants of host species.

Option	Fruit	Plants	Comments/ Justification
Existing measures in EPPO countries	No	NO	Not sufficient to prevent the risk of entry of the pest
Options at the place of production			
Visual inspection	Not alone	Not alone	All life stages are difficult to see. Part of infested fruit may be sorted at harvest if the staff is trained adequately. High chance not detecting low infestation levels or early infestation. Pheromone blend does not attract all races.
Testing	No	No	Not relevant.
Treatment of crop	Not alone	Not alone	Not reliable to guarantee pest freedom. Will not eliminate larvae already in fruit.
Resistant cultivars	No	No	Not available currently.
Growing the crop in in glasshouses/screenhouses	Not alone	Not alone	Monitoring will be easier in glasshouses/screenhouses. Complete physical protection against *N. elegantalis* is difficult to implement in commercial production.
Specified age of plant, growth stage or time of year of harvest	No	Yes	Plants that have never borne fruit (e.g. seedlings) can not be infested
Produced in a certification scheme	No	No	Not relevant for an insect.
Pest free site of production	Yes	Yes	Screened glasshouses with trapping with pheromone traps. For plants carrying fruit, handling and packing should be done within the pest-free place of production, and avoiding reinfestation during transport. Only new packaging should be used.
Pest free area	Yes	Yes	PFA is a possible measure as described in ISPM 4. It should be established on the basis of general surveillance for continents where the pest does not occur, but pheromone traps and inspection for other cases. Pest-free seedlings should be used. There should be control on movement of all host fruit and plants, other hosts, equipment and packaging, etc. in and out of the area.
Options after harvest, at pre-clearance or during transport			
Visual inspection	Not alone	Not alone	Interceptions of infested fruit at import inspection are reported but there is a high chance not detecting low infestation levels or early infestation.
Testing	No	No	Not relevant.
Treatment of the consignment	No	No	Methyl bromide treatment of fruit can destroy the pest but it will be phased out in 2015. Limited experience with other treatments (e.g. irradiation, Costa *et al.* 2009). Very low tolerance of consumers for presence of larvae in fruit. Treatment of plants with systemic insecticides cannot guarantee pest freedom. Different active ingredients are needed to kill different life stages (eggs/larvae).
Prevention of infestation by packing/handling method	Not alone	Not alone	Only new packaging should be used. After import, packaging should be destroyed or safely disposed of (as larvae that have emerged during transport may pupate on the packaging).
Limited distribution in time and/or space or limited use	Difficult to control	No	For fruit, consignments may be imported during winter time (temperature below 5°C) for immediate processing or direct consumption where *N. elegantalis* 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. Adults that have emerged during transport might also escape. Not applicable for plants as the intended use is for planting
Options that can be implemented after entry of consignments			
Post-entry quarantine	No	Yes	Not suitable for perishable fruit. Possible in theory for plants (but may not be practical/cost-effective).
Surveillance and eradication in the importing country	Difficult to control	No	In the part of the EPPO region where the pest cannot establish outdoors, infested consignments could in theory be imported in the importing country. This would require the separation of trade and production flows (separate facilities for imported consignments and for growing tomato, eggplant and sweet pepper) and a good surveillance system (including trapping at packing stations). Eradication is considered possible in greenhouses in that part of the PRA area (see under 16). This would be possible only as long as the trade volumes are very low. This may be possible in individual EPPO countries in the northern part of the region, but may not be feasible overall.