NATIONAL EMERGENCY RESPONSE PLAN FOR CARIBBEAN COUNTRIES

Tomato Leafminer, *Tuta absoluta* (Meyrick)

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The technical information presented in this document is an adaptation of the USDA-APHIS-PPQ **New Pest Response Guidelines *Tuta absoluta* (Meyrick) Tomato Leafminer (2019)**.

"*Please note: This document is based on the best information available at the time of development; however, at the time of the emergency, new scientific and technical information may be identified. In addition, each pest incursion has unique, site-specific characteristics that are not easily predictable. Therefore, this document should be considered only as a general guideline. As the pest situation evolves and new information is gathered, the response implemented, including survey protocols, may need to be modified from the original recommendations*".

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Section I. Introduction

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In the Caribbean Region, pest incursions frequently threaten economic development, natural resources and the environment. This can be attributed to the geography of the Islands in the Region, the presence of high-risk pathways, and the limited number of plant health professionals involved in safeguarding. As such, over the years, there have been incidents of pest introductions that rapidly spread to other countries in the Region, for example, Pink Mealybug, *Maconellicoccus hirsutus* (Green) (Insecta: Hemiptera: Pseudococcidae), Red Palm Mite, *Raoiella indica* Hirst (Arachnida: Acari: Tenuipalpidae).

Most recently, Most recently, the tomato leafminer, *Tuta absoluta* (Meyrick) entered entered the Caribbean Region and now poses a threat to vegetable production and the livelihoods of producers. Having a comprehensive emergency response strategy to rapidly tackle this potential incursion is critical for safeguarding the borders of the United States and the Caribbean. This publication aims at providing information that can be used to prevent the entry, establishment and spread of *T. absoluta*.

This Emergency Response Plan for the tomato leafminer, *T. absoluta* provides basic information on the biology, ecology, surveillance and management of the pest. It also provides an outline of the administrative responses to prevent the entry, spread and establishment of the pest. Specific sections include:

- Summary of the pest biology.
- Guide for the identification the pest in the field.
- Preliminary methods for surveillance and monitoring of the pest.
- An outline of possible eradication measures and management actions that could be considered in the event of an incursion.
- Emergency response actions that should be considered in the event of an incursion.

It is expected that this publication will contribute to:

i. Preventing or delaying the entry of the tomato leafminer, *Tuta absoluta* into the Caribbean.
ii. Protecting the production of tomatoes and of other Solanaceae crops cultivated.
iii. Training technicians, producers and other key stakeholders in the (a) prevention of the entry, spread and establishment of the pest, and (b) management of the pest once it has become established.
iv. Reducing the potential impact of the pest.

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Section II. Pest Overview

Scientific Name

- *Tuta absoluta* (Meryick, 1917)

Taxonomic Position

- Animalia: Arthopoda: Insecta: Lepidoptera: Gelechiidae

Synonyms

- *Gnorimoscema absoluta* (Meryrick, 1917)
- *Phthorimaea absoluta* (Meryrick, 1917)
- *Scrobipalpula absoluta* (Meryrick, 1917)
- *Scrobipalpuloides absoluta* (Meryrick, 1917)

Common Names

- Tomato leafminer
- Tomato leaf worm
- South American tomato pinworm

Summary

Tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is native to South America and is a serious pest of *Solanum lycopersicum* L. tomato (Mohammed et al., 2015 Vargas, 1970) and other solanaceous crops such as potato, *Solanum tuberosum* L.; eggplant, *Solanum melongena* L and pepper *Capsicum annum* L., (Portakaldali et al., 2013).

Larvae feed on the inner tissues of leaves, stems and tender shoots, resulting in reduced growth and decreased fruit yield. Some instars will also feed on developing and mature fruit. The greatest impact of the leafminer occurs when the larva mines commercial fruit, rendering it unmarketable (Joshi et al, 2017; Vargas, 1970)

Key facts:

- Pest often causes significant damage to crops, even when pest management programmes are in place.
- Tomato is the most affected crop: infestation levels of tomato fruits can reach 100%
- Once established, the tomato leafminer spread is expected to be rapid; it spread across Europe in less than a decade after being introduced to Spain and has recently been reported from several locations in Asia and Africa.
- Eradication or management will require the implementation of multiple strategies such as chemical applications, mass trapping, cultural control and possibly other measures.

Biology and Ecology

The tomato leafminer has a high reproductive rate (EPPO, 2005; IRAC, 2017a). The number of generations per year varies greatly based on environmental conditions: in some areas, the species completes around five generations per year; in others, there may be as many as twelve generations annually. Generations overlap, with all stages appearing at the same time when hosts are available (Silva et al., 2015). Tomato leafminer reproduces sexually and adults can mate multiple times and with multiple individuals. Female tomato leafminer moths use a passive calling behavior to attract a mate (Lee et al., 2014).

Adult leafminers are most active at dusk and dawn and rest among leaves of the host plant during the day (Fernandez and Montague, 1990; Viggiani et al., 2009). The Tomato leafminer completes its life cycle in 29 - 38 days depending on prevailing conditions. Optimum development occurs between 23-27 °C. On average, adult females survive for 10-15 days, and males live for six or seven days (Estay P., 2000), but adults can live up to 40 days when provided with a food source (CABI, 2016).

A single female can lay up to 260 eggs in her lifetime. Eggs are laid singly (rarely in batches) on all above-ground parts of the host plant, although the leaves are preferred. The plants can be infested at any stage of development, from seedlings to mature plants. If oviposition occurs before flowering, eggs are mostly laid on the underside of the apical leaves; after flowering, eggs may be on either side of the apical or middle leaves. Eggs hatch 4-5 days after egg are laid (Torres et al., 2001).

The larvae go through four instars over 13-15 days. During this time, the larvae form mines in leaves predominantly, but also in fruits - unripe and ripe - and the plant stem. The feeding of the larvae creates large mines and galleries. The galleries formed in fruits can be invaded by secondary pathogens and cause the fruit to rot. The galleries formed in the stem can deform the growth of the plant. They consume the mesophyll, leaving the epidermis intact (Vargas, 1970). Larvae also spin silken shelters on leaves or tie leaves together for shelter. Although the larvae spend most of their lives inside mines, second instars can leave the mine, which exposes them to predation, well timed application of pesticides and possibly parasitism.

Pupation takes 9-11 days and can occur in the soil, on the leaf, within the mines or in the fruit. When pupation occurs outside of the soil a thin silky cocoon is built.

Host Plants

Tomato is the preferred host, but in its absence, tomato leafminer infests other cultivated solanaceous hosts, such as potato, eggplant, and pepper, and other uncultivated solanaceous plants; it also occasionally infests non-solanaceous species (Bawin et al., 2015a; Desneux et al., 2010). All reported plant associations are listed in Table 2.1.

The leaves are the only affected plant parts for most hosts; however, in the case of a few hosts, including tomato, other plant parts, such as the fruit, are affected.

Not all tomato varieties are equally susceptible to tomato leafminer. Tomato cultivars with high densities of type IV glandular trichomes, or high amounts of 2- tridecanone, acyl sugars, or zingiberene are resistant to the tomato leafminer (de Oliveira et al., 2012).

Geographic Distribution

Tomato leafminer is native to and widespread in South America (Meryrick, 1917; Urbaeja et al.2007; Viggiani et al.;2009). In 2006, the tomato leafminer was detected in Spain which was its first report outside of South America (EPPO, 2008; Urbaneja et al., 2007). Subsequently, it has spread to other locations in Europe, the Middle East and Africa. In 2011, the moth was to confirmed to have spread from South America into Panama (Central America) (EPPO,2012). By 2014 it was reported to have spread to Costa Rica (IPPC,2014) as well as India (Sridhar et al.,2014). This was the first report of the pest in southern or eastern Asia. Since then the leafminer has spread further into Asia (Esenali Uulu et al., 2017; Saidov et al. 2018. In 2019, the tomato leafminer was found in Haiti (Verheggen and Fontus, 2019), a first record for the Caribbean.

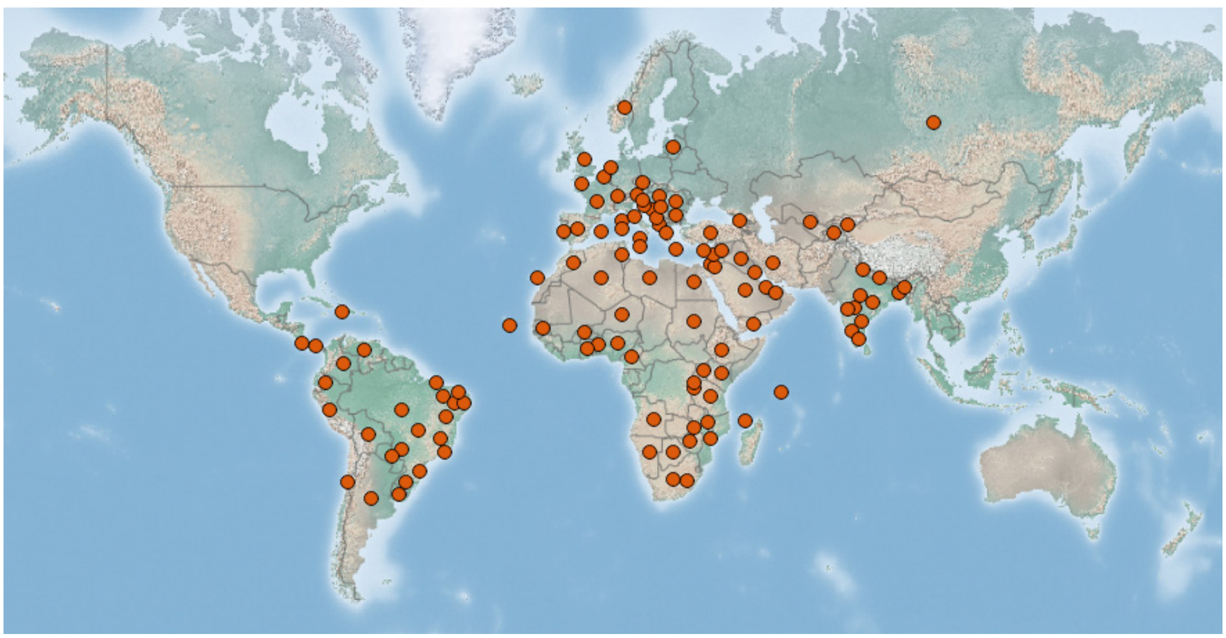

Figure 2.1 Distribution of Tuta absoluta (CABI Invasive Species Compendium https://www.cabi.org/isc accessed November 26, 2019)

The most recent distribution data for the tomato leafminer can be accessed through the Global Pest and Disease Database (GPDD) or PestLens.

Dispersal

Natural Dispersal

Tomato leafminer larvae occasionally leave their mines (Torres et al. 2001), moving quickly and spinning silken threads to move around the plant safely (Fernandez and Montagne, 1990). Adults have well developed wings that allow them to disperse actively. Additional research is required to determine the extent to which their flight capacity has contributed to their spread in introduced locations. In an overview of the pest, Stol et al. (2009) stated that the leafminer may spread by flying or drifting in the wind, as suggested by captures of the pest in woodland and farms tens of kilometers away from tomato fields. It should be noted however that the time frame in which these captures occurred is not specified. In a mark recapture study, tomato leafminer moths were found to move 250 meters in two hours and 0.4 km overnight (Salama et al., 2015). Tomato leafminer has spread more than 2,000 km in two years in Brazil and across several countries in three years in Europe (Silva et al., 2011).

The tomato leafminer can enter greenhouses and produce packing houses by flying, particularly if the structures are not well protected with insect meshing and double entry doors (Cuthbertson et al., Van Damme et al., 2015). Host crops and Solanaceous weeds near these facilities increase the likelihood that the leafminer will find its way into these environs.

Human-meditated Spread

Based on the history of the leafminer's introduction and spread it was noted by (Desneux et al. 2011) that this pest may naturally disperse without human assistance. However, if the pest is already present in tomato production sites, human mediated spread to packing houses, processing facilities or markets can occur through the movement of infested fruit. Containers and vehicles with tomatoes may be pathways via which the leafminer can spread. Farming equipment and workers could also move the leafminer to new areas especially if they move from one field immediately to another, which is a practice very common in the Caribbean. Movement of tomato leafminer on ornamental Solanaceae in the nursery trade is also possible.

Table 2.1 Host plants of *Tuta absoluta*

Plant Family	Scientific name	Common name	Plant Part(s) Attacked	References
Amaranthaceae	*Amaranthus spinosus* L.	spiny amaranth		Mohamed et al., 2015
Amaranthaceae	*Amaranthus viridis* L.	slender amaranth		Bayram et al., 2015
Asteraceae	*Sonchus oleraceus* L.	common sowthistle		Polat et al., 2015
Asteraceae	*Xanthium strumarium* L.	rough cocklebur		Bayram et al., 2015
Asteraceae	*Xanthium strumarium subsp. Brasilicum* (Vell.) O. Bolos & Vigo *syn.:X. brasilicum* Velloso	ramtouk		Mohamed et al., 2015
Brassicaceae	*Raphanus raphanistrum* L.	wild radish	Leaf	Abdul- Ridha et al., 2012
Brassicaceae	*Sinapis arvensis* L.	charlock mustard		Polat et al., 2015
Chenopodiaceae	*Beta vulgaris* L.	beet		Drouai et al., 2016
Chenopodiaceae	*Chenopodium album L.*	Lambsquarters		Portakaldali et al., 2013
Chenopodiaceae	*Chenopodium bonus- henricus L.*	Good King Henry		Drouai et al., 2016
Chenopodiaceae	*Chenopodium rubrums L.*	Red goosefoot		Drouai et al., 2016
Chenopodiaceae	*Spinacia oleracea L.*	Spinach		Bayram et al., 2015
Convolvulaceae	*Convolvulus arvensis* L.	field bindweed	Leaf	Sabry and Ragaei, 2015
Cucurbitaceae	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	Watermelon		Mohamed et al., 2015
Euphorbiaceae	*Jatropha curcas* L.	Barbados nut; physic nut		Mohamed et al., 2015
Fabaceae	*Medicago sativa* L.	Alfalfa	Leaf	Abdul- Rassoul, 2014

Plant Family	Scientific name	Common name	Plant Part(s) Attacked	References
Fabaceae	*Phaseolus vulgaris* L.	kidney bean	Leaf	Duric et al., 2017 ; EPPO,2009; rialriquelme et al., 2017
Fabaceae	*Vicia faba* L.	fava bean	Leaf	Abdul- Ridha et al., 2012
Fabaceae	*Vigna unguiculata* (L.) Walp.	cowpea	Leaf	Abdul- Ridha et al., 2012
Malvaceae	*Malva sylvestris* L.	High mallow	Leaf	Bawin et al., 2015b
Poaceae	*Sorghum halepense* (L.) Pers.	johnsongrass		Bayram et al., 2015
Solanaceae	*Atropa belladonna* L.	belladonna	Leaf	Bawin et al., 2015a
Solanaceae	*Capsicum annum* L.	Pepper	Leaf	Portakaldali et al., 2013; Sylla et al., 2019
Solanaceae	*Datura quercifolia* L.	Chinese thorn-apple		Garcia and Espul,1982
Solanaceae	*Datura stramonium L.*	jimsonweed		Vargas, 1970
Solanaceae	*Lycium barbarum* L. syn.: L *halimifolium* Mill.	Matrimony vine	Leaf	Bawin et al., 2015b
Solanaceae	*Lycium chilense* Bertero	Chilean wolfberry		Urbaneja et al.,2007
Solanaceae	*Nicotiana glauca*	tobacco		Garcia and Espul,1982
Solanaceae	*Nicotiana rustica* L.	Aztec tobacco	Leaf	Bawin et al., 2015b
Solanaceae	*Nicotiana tabacum* L.	tobacco		Galarza, 1984
Solanaceae	Physalis angulate L.	Cutleaf groundcherry		Bayram et al., 2015
Solanaceae	Physalis peruviana L.	Cape- gooseberry		Bayram et al., 2015; Garzia, 2009
Solanaceae	*Solanum aethiopicum* L.	Ethiopian eggplant, Ethiopian nightshade	Leaf	Sylla et al., 2018
Solanaceae	*Solanum americanum* Mill.	American black nightshade	Leaf	Smith et al., 2018
Solanaceae	*Solanum bonariense* L.	grandadillo		Galarza,1984
Solanaceae	*Solanum chilense* (Dunal) Reiche, syn.: *Lycopersicum puberulum* Ph.		Leaf	Vargas, 1970
Solanaceae	*Solanum coagulans* Farssk. syn.: *S. dubium* Fresen.	Gubbain		Mohamed et al., 2015
Solanaceae	*Solanum dulcamara* L.	Climbing nightshade	Leaf	Vargas, 1970
Solanaceae	*Solanum elaeagnifolium* Cav.	Silverleaf nightshade		Drouai et al., 2016
Solanaceae	*Solanum habrochaites* S. Knapp & D.M. Spooner, syn.: *Lycopericum hirsutum* Dunal *f. glabratum* C.H. Mull.		Leaf	Bottega et al., 2015
Solanaceae	*Solanum lycopersicum* L.	tomato	Leaf, Fruit,Bud, Stem	Bajracharya et al.,2016; Kulic,2010; Vargas,1970
Solanaceae	*Solanum melongena* L.	eggplant	Leaf, Fruit, Shoot	Mohamed et al.,2015; Portakaldali et al., 2013
Solanaceae	*Solanum muricatum* L	pepino		Portakaldali et al., 2013
Solanaceae	*Solanum nigrescens* M Martens & Galeotti	divine nightshade		Galarza, 1984
Solanaceae	*Solanum nigrum* L.	black nightshade	Leaf	Smith et al.,2018
Solanaceae	*Solanum pimpinellifolium* Jusl.	Currant tomato	Leaf	Bottegga et al., 2015
Solanaceae	*Solanum pseudocapsicum* L.	Jerusalem cherry		Galarza, 1984
Solanaceae	*Solanum quitoense* Lam.	naranjilla		Povolny, 1975
Solanaceae	*Solanum saponaceum* Dunal			Povolny, 1975

Plant Family	Scientific name	Common name	Plant Part(s) Attacked	References
Solanaceae	*Solanum sisymbriifolium* Lam.	Sticky nightshade		Galarza, 1984
Solanaceae	*Solanum tetrandrum* R.			Povolny,1975
Solanaceae	*Solanum tuberosum* L.	potato	Leaf, tuber	Mohamed et al., 2015; Portakaldali et al., 2013; Povolny, 1975
Solanaceae	*Solanum villosum* (L.) Mill	hairy nightshade		Bayram et al., 2015

Table 2.2 Pathways for movement of *Tuta absoluta* into and within the entire [1]Greater Caribbean Region (GCR) (PERAL 2019. Review of the PERAL 2009 Greater Caribbean Region (GCR) Pathway Analysis June 21, 2019)

Pathway	Preliminary risk rating for the pest
Human Movement	Very High
Hitchhikers/Trade	Very High[28]
Propagative Materials	Very High
Airline Passenger Baggage	Medium
International Mail	Medium
Natural Pest Spread	Medium[31]

[28] Although *T. absoluta* has not been intercepted as a hitchhiker, a "very high" rating may apply since adults fly and therefore could fly onto ships or into cargo holds, etc. [31] Based on adult flight and occurrence in the GCR.

1 Greater Caribbean Region (GCR) defined as all countries bordering the Caribbean Sea, plus the Bahamas, Turks and Caicos, El Salvador, Suriname, Guyana, and the U.S. Gulf States (Florida, Alabama, Mississippi, Louisiana, and Texas)

3 Section III. Pest Identification and Damage

Species Description/Morphology

Adult

The adult moth is on average 10 mm long, has filiform antennae, silver-grey scales and black spots on the anterior wings. The abdomens of male moths are narrow and have pointed posteriors compared to the wider, bulkier abdomens of females. Abdominal scales are grey in males and cream-colored in females (Vargas, 1970). (Figs. 3.1 and 3.2). To confirm identification of tomato leafminer, the genitalia must be dissected and examined (Gilligan, 2019).

Fig. 3.1 Adult Tomato Leafminer. (Image credit: Sangmi Lee, Mississippi Entomological Museum)

Fig. 3.2 *Tuta absoluta* adults (Image credit: E.Saini, Instituto Nacional de Tecnología Agricola, Buenos Aires, Argentina)

Eggs

The eggs are oval-shaped (Fig. 3.3). Newly laid eggs are creamy white and turn yellow to yellowish orange during development (Estay P., 2000). When mature, eggs turn dark, and the outline of the larval head capsule can be seen through the outer membrane; this is called the blackhead stage (Vargas, 1970). Eggs average 1.38 mm long by 0.21 mm wide (Vargas, 1970).

Fig. 3.3 *Tuta absoluta* eggs (Image credit: E.Saini, Instituto Nacional de Tecnología Agricola, Buenos Aires, Argentina)

Larvae

Larvae are flat, and their color changes from creamy white to deep green during development (Fig. 3.4). The last instar takes on a light green-pink coloration. When larvae are ready to molt, they stop eating and purge their stomach contents, causing their coloration to return to creamy white. The larva has a black head and is about 0.9 mm in length which decreases to 7.5 mm by the fourth and last instar.

Fig. 3.4 *Tuta absoluta* larva (Image credit: E.Saini, Instituto Nacional de Tecnología Agricola, Buenos Aires, Argentina)

Pupae

Pupae are found within strong silken cocoons on folded leaves and mainly at soil level. Newly formed pupae are greenish and turn dark brown as they mature (Fig. 3.5) (Estay P., 2000). Male pupae are generally lighter and smaller (length 4.27 ± 0.24 mm and width 1.23 ± 0.08 mm) than female pupae (4.67 ± 0.23 mm and 1.37 ±0.07 mm) (Fernandez and Montagne, 1990).

Fig. 3.5 *Tuta absoluta* pupa (Image credit: EPPO Gallery, http://photos.eppo.org/index.php/image/3508-gnorab-30)

Signs and Symptoms

Tomato leafminer can attack plants at any developmental stage, from seedlings to mature plants. The larvae mine the leaves, shoots, apical buds, flowers, and fruit of tomato as well as the leaves and tubers of potato (Pastrana, 2004) although they prefer leaves and stems. Conspicuous irregular mines and galleries, as well as dark frass, make infestations easy to spot. Fruits can be infested soon after they have formed, and the galleries made by the larvae can be colonized by pathogens that cause fruit rot. The damage caused by this pest is severe, especially in young plants and leads to a decrease in production and fruit quality. Tomato leafminer larvae also mine potato tubers beneath the epidermis. Larval feeding can cause the tubers to rot (Pastrana, 1967).

Leaves

After hatching, larvae mine the leaf tissue (Figures 3.6 and 3.7). They feed only on mesophyll cells, leaving the epidermis intact. The serpentine- shaped mines increase in length and width as the larvae develop and feed. In some cases, especially at the beginning of the infestation, the mines can be mistaken for those caused by leafminer flies in the family Agromyzidae. In severe infestations, the larvae consume all the leaf tissue and leave behind a skeletonized leaf and copious amounts of frass (Fig. 3.8). It is common for larvae of the second to fourth instars to spin silken shelters on leaves or tie leaves together (Vargas, 1970).

Fig 3.6 Enlarging gallery of *Tuta absoluta* with a larva and frass inside (A) tomato leaf, (B) eggplant leaf, and (C) some mines on bean leaves (Image credit: EPPO Gallery, **http://photos.eppo.org/index.php/album/219-tuta-absoluta-gnorab**; tutaabsoluta.com, Russell IPM Ltd.)

Fig. 3.7 *Tuta absoluta* damage on tomato in Panama. (A) Leaf mines on foliage and (B) damage on both leaves and tomato fruit (Image credit: A. Roda, 2011).

Fig. 3.8 Damage to various crops: (A) tomato in Jordan, (B) eggplant in Sudan, and (C) potato (photos courtesy of tutaabsoluta.com, Russell IPM Ltd.)

Shoots

Larvae can penetrate and mine tender shoots, usually gaining entry through the apical end or at the angle formed between the petioles and the leaves (Vargas, 1970) (Fig. 3.9). They can also pull together new shoots using silk produced by specialized salivary glands.

Fig. 3.9 Larva of *Tuta absoluta* inside (A) a tomato stem and (B) an eggplant tender shoot (photo courtesy of (A) EPPO Gallery, http://photos.eppo.org/index.php/album/219- tuta-absoluta-gnorab- (B) tutaabsoluta.com, Russell IPM Ltd.)

Flowers and Fruit

Tomato leafminer larvae can destroy the developing fruit by mining its flesh (Figs. 3.10, 3.11, and 3.12). Infested fruit will usually fall to the ground. Larvae can infest the flowers, but the most severe damage is found in developing fruit (early instars) or maturing fruit (later instars). The larva usually enters the fruit under the calyx and tunnels the flesh, leaving frass-clogged galleries that cause the fruit to drop or to rot on the vine. Larvae can also enter the fruit through the terminal end or through fruit parts that are in contact with leaves, other fruits, or stems.

Fig. 3.10 Damage to tomato fruits (photos courtesy of tutaabsoluta.com, Russell IPM Ltd.)

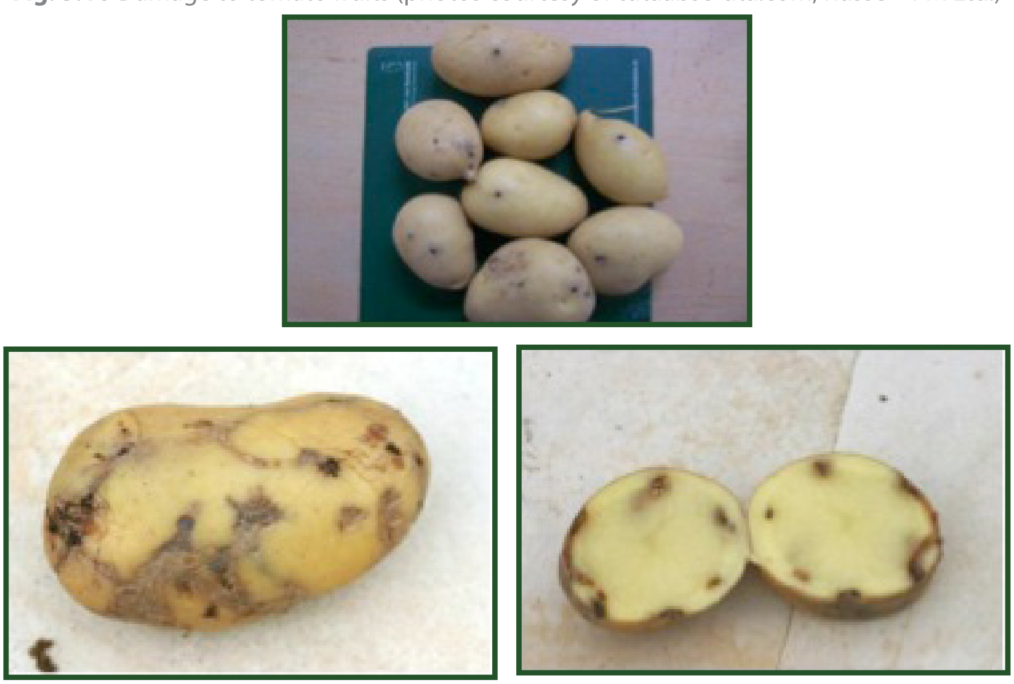

Fig. 3.11 Potato tuber damage (internal and external) caused by Tuta absoluta (photos courtesy of Fredon-Corse, http://www.fredon-corse.com/courriers/lettre250309.htm; Ensaf Mohamed, tutaabsoluta.com, Russell IPM Ltd.)

Fig. 3.12 Damage to eggplant in Sudan (photos courtesy of Ensaf Mohamed, tutaabsoluta.com, Russell IPM Ltd.)

Similar Species

Two gelechiid species similar to the tomato leafminer, *T. absoluta*, are *Phthorimaea operculella* (Zeller) (potato tuber moth) and *Keiferia lycopersicella* (Walsingham) (tomato pinworm). Within the Caribbean region, the potato tuber moth is listed as being present in Antigua and Barbuda, Bermuda, Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico and St. Vincent and the Grenadines (CABI Invasive Species Compendium; November 2019) while the EPPO Global Database (July 2019) lists the tomato pinworm as being present in the Bahamas, Bermuda, Cuba, Dominican Republic, Guyana, Haiti, Jamaica and Trinidad and Tobago. Both species may also be found as pests in tomato fields in the United States.

Tomato leafminer is most similar to tomato pinworm, primarily because both have light and dark-banded antennae, labial palps, and similar color on the forewings. The forewings of tomato leafminer, however, have somewhat more defined dark patches, while those of tomato pinworm are light brown to gray with brownish streaks. In addition, the hindwings of tomato pinworm have hair pencils on the anterior margin (Brambila *et al*., 2010a, 2010b). Photos comparing the three species are presented in Fig. 3.13. Dissection and examination of adult male genitalia is required for accurate identification of all three species.

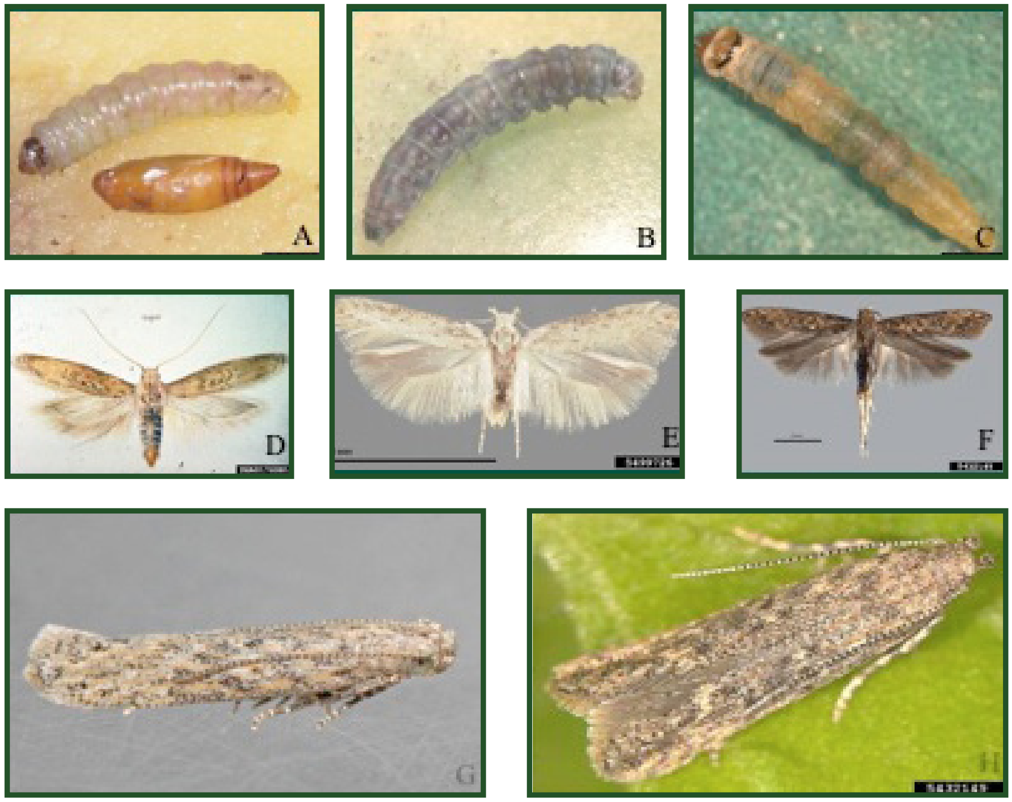

Fig. 3.13 *Tuta absoluta* and similar species: (A–C) larvae of potato tuber moth (*Phthorimaea operculella*), tomato pinworm (*Keiferia lycopersicella*), and tomato leafminer (*T. absoluta*); (D–F) mounted adults of potato tuber moth, tomato pinworm and tomato leafminer; (G, H) resting adults of tomato pinworm and tomato leafminer (photos courtesy of Bugwood.org: Central Science Laboratory, Harpenden, British Crown; Alton N. Sparks, Jr., University of Georgia; Merle Shirac 2018rd, Gerald R.Carner, and P.A.C Ooi, Insects and their Natural Enemies Associated with Vegetables and Soybean in Southeast Asia; Marja van der Straten, NVWA Plant Protection Service; Sangmi Lee, Hasbrouck Insect Collection, Arizona State University; Mark Dreiling; James Hayden, FDACS Division of Plant Industry)

A new gelechiid species, *Sinoe capsana* Lee, was frequently captured in tomato leafminer detection traps in Florida; this moth is paler than tomato leafminer and can be easily separated from it on sticky traps (Roda *et al*., 2015).

4 Section IV. Surveillance and Monitoring

Surveillance and monitoring to detect the presence, absence and population levels of *T. absoluta* is critical for decision making and timely interventions. As such this section, provides [2]a protocol for the conduct surveillance activities at the international ports of entry and the field

The purpose of this protocol is to establish a surveillance methodology that will allow for the early detection and delimitation of *T. absoluta* should it become introduced. Practical applications of detection and delimiting surveys (as defined in ISPM 5[3] and in ISPM 26[4]: 2018/2019) are provided. Suggestions for preparation, packaging and shipping of samples for identification are provided at the end of this section.

Pest Distribution

To aid in early detection of *T. absoluta*, general surveillance strategies including gathering information from other sources, should be used (ISPM 6[5]: 2018). Pest distribution lists may be useful to alert the NPPO of the importing country as well as the importing facilities to the potentially higher risk of a certain commodity.

Pathways for introduction

T. absoluta could be introduced by the importation of infested tomato fruit, tomato plants, and used tomato crates or packing boxes. High risk pathways by which *T. absoluta* can be introduced and spread include:

- Seedlings
- Tomato and eggplant fruits
- Production facilities and outdoor markets
- Farm equipment and transportation vehicles.

I. General Survey Techniques

Survey techniques include visual inspections as well as trapping. This guide makes reference to tomato as it has been recorded as the primary host of T. absoluta, however, the survey methodologies may be adapted for application in other hosts including potato, eggplant, pepper, tobacco, black nightshade (*Solanum nigrum*) and beans (*Phaseolus vulgaris*).

Visual Inspection

Before initiating a survey, become familiar with other pests in the area. Eggs, larvae, and mines of tomato leafminer can be confused with those of other pests, such as tomato pinworm. In some cases, especially early in an infestation, leaf mines of tomato leafminer can also be mistaken for those caused

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2 Note - The Surveillance Protocols are subject to periodic review and amendment.

3 International Standard for Phytosanitary Measures (ISPM) 5 - Glossary of phytosanitary terms

4 ISPM 26 - Establishment of pest free areas for fruit flies (Tephritidae)

5 ISPM5 - Surveillance

by leafminers in the family Agromyzidae (Diptera); however, the latter do not leave solid excrement in the mines.

Plant damage may not be visible for three to four weeks after adult detection in pheromone traps if the introduced population has not yet established in the field or the greenhouse. Inspect potential host plants and other nearby resting places for tomato leafminer adults, which rest among host plants during the day and are active at dusk and dawn (Fernandez and Montagne, 1990; Viggiani et al., 2009). Sweep-net sampling, as well as disturbing plants to incite adult flight, might be useful to discover new infestations in greenhouses or fields.

- Look for single eggs on all above-ground parts of the host plant, especially the apical parts. Because eggs are particularly difficult to find on plants, surveyors must be trained to locate them.
- Look for larvae inside mines in the plant tissue.
- Look also for puncture holes with excrement, especially on fruit, and serpentine or blotch-shaped mines. Randomly select seedlings and inspect the upper third for leaf mines.
- Look for pupae on leaf tissue, in the soil, and in packing materials when host material is transported.
- Inspect protected structures; monitor upper sections of door and window frames of greenhouses/ protected structures.
- Inspect crates and packing boxes whenever they are available at packing distribution or receiving facilities. Leaves, stems and calyces should be inspected thoroughly for mines as they are the preferred infected sites.
- Refer to the images of the different life stages in Section III.
- Collect samples of the pest while inspecting potential host plants.
- Submit specimens and plant material to the proper authority.
- Be sure to inspect and clean clothing and equipment used during the inspections and between fields to prevent spread of the insect.

Trapping

Pheromone lures and delta traps are used for the trapping of the tomato leafminer.

Pheromone lure

Tomato leafminer lure includes a rubber septum with pheromones (3E, 8Z, 11Z)-3,8,11-tetradecatrien-1-yl acetate and (3E,8Z)-tetradecadien-1-yl acetate) loaded on a rubber septum at a dosage of 0.5 mg. The lures only attract males. Depending on the environmental conditions the pheromone should last up to six weeks. Please refer to the specifications from the approved suppliers.

All pheromones should be stored in sealed containers at temperatures below 0° C. Only one pheromone component should be stored per container (do not mix with other types of pheromones). Opened storage containers should be re-sealed after use. Pheromones can be stored for a maximum of two years if refrigerated properly. During transportation to the field, the pheromones should be kept cool and out of direct sunlight (in a cooler).

The pheromone should be installed before assembling the trap by laying the release device with the lure directly on the center of the sticky surface, ensuring that air passes through it.

Disposable gloves should be worn at all times when handling pheromones, and a new pair of gloves between types of pheromone. This avoids cross-contamination of the volatile compounds and possible interference with their attractiveness. Gloves should not be disposed of in the vicinity of traps.

Trap Type

Delta Traps are often used in the detection of small lepidopteran pests. Two types of Delta traps are available: cardboard delta triangle covered with sticky surface or another option with a removable liner. Either one is suitable for the current purposes, although Delta traps with non-drying sticky liners are preferred. Traps are available from several suppliers in multiple colors, and all should be considered equivalent for this survey. Dry touch liners can capture and better preserve insects for examination than liners using soft glue, which tend to wick through the specimen and ruin moth scale patterns.

Folding the trap is facilitated by breaking all creases and perforations. The end of the sides should not be folded in, to enhance moth capture. The peak of the trap should be stapled and an attachment wire threaded through the perforation. The Contact information of the NPPO should be placed on the trap. Please see section below for further information.

Trap placement and density

One trap should be placed at each trap placement site except where trap placement sites are very large, i.e. greater than 5,000 m^2. It is recommended that for each additional 5,000 m^2 the area should be treated as a separate trap placement site and another trap should be placed.

T. absoluta does not fly very high and prefers young shoots so traps should be placed at an initial height of approximately 0.40 m. They should be maintained at the approximate height of the canopy and raised as the plant grows, but where they do not interfere with normal activities. Traps may be attached to planting stakes or other objects such as irrigation piping if the objects are in close proximity to the site. While it may be preferable to have traps within a planting row, these will receive pesticide applications and will remain inaccessible during re-entry intervals after applications. Traps at alternative locations may also be inaccessible, so it is important to communicate with the field manager / farmer immediately before entering the field.

In facilities that handle product which may be either sealed (for example in plastic wrap) or non-sealed (for example in trays or cardboard boxes), traps should be placed near non- sealed products because there will likely be higher plant volatiles present, which would increase attraction of absoluta to the area and could increase the trap detection efficiency.

Servicing the trap

Gloves should be used to handle traps and liners in order to prevent their contamination. Traps and lures should be checked every two weeks and lures replaced every four to six weeks. After a positive detection is made, the delimitation survey is initiated for which the servicing interval should be shortened to give the survey more precision and to allow for quicker response in determining the true extent of the population.

- Traps should be replaced if missing, damaged, or if the sticky surface has been compromised by debris and other crawlers e.g. lizards.
- Traps with suspect moths must be collected for diagnostic submission and replaced with a
- new trap and lure.
- Liners should be replaced at the two-week servicing if they are covered with dust or insects;
- the lure should be transferred to the new insert with gloves or forceps.
- Old liners (older than 4-6 weeks) should be checked for pheromones lures, replacing any that may be missing.
- Old lures can remain in the trap for one servicing interval, and then they should be removed.
- At the end of the survey, if the trap is empty, it should be collapsed, squashed flat and placed in a suitable container for disposal.

Possible Sources of Traps

- https://www.arbico-organics.com/product/scentry-large-plastic-delta-trap/insect-traps-lures
- https://www.iscatechnologies.com/products/plastic-delta-trap
- https://www.alphascents.com/plastic-delta-trap-red.html
- http://scentry.com/monitoring-products/

Biosecurity precautions

When visiting facilities, surveyors should make sure they have taken steps to reduce the spread of pests such as removing soil and debris from clothing and footwear and washing hands with soap or an approved antimicrobial. Where targeted facilities have biosecurity procedures in place, surveyors should become aware of the procedures and follow them.

Data collection

Records should be maintained that provide data which at a minimum should provide the location of every trap (the GPS coordinates), a sketch map of local trap location, the name of the facility or land owner, the name of the trapper, the day the trap was placed at a particular site, servicing dates, when the trap was decommissioned and the results of each trap, whether negative, positive or suspicious. Positive results also should include the day the pest was detected and how many target pests were in the trap. Records of infested tomato plants or alternate hosts also should be collected and maintained. Site numbers assigned to the traps should generally conform to the following: two letter pest code - one letter for region - site number - trap letter (Ex: TA - D - 0001 - a) (See figure 4.2 of suggested procedures page at the end of this section).

Data storage

Existing country databases may be used to store all survey data. The files should be updated at least weekly or as new information is available. Further guidance on recordkeeping may be obtained in ISPM 6: 2018.

II. Detection Surveys

(i) Purpose

Detection surveys are conducted to determine if a pest exists in a country.

(ii) Target life stages

The detection surveys described are targeted to adult moths (trapping); complementary surveillance for additional life stages, especially larvae, may also be useful.

(iii) Timing and duration

T. absoluta can have ten or more continuous generations in a year under optimal conditions and can be present year round where suitable environmental conditions exist. For tomato production sites, timing for the *T. absoluta* survey is directly linked to the tomato production cycle. This survey should be implemented as soon as the tomato production cycle starts (whether under protected cultivation or in open field) and should be concluded 30 days after tomato harvest or after the crop residues are removed. In packing/receiving facilities, not under a production cycle, traps should be placed as soon as the product is available. Trapping may be stopped after packing activities have concluded.

(iv) Survey locations

T. absoluta could be introduced to the region primarily by the importation of infested tomato fruit, tomato plants, and used tomato crates/packing boxes. Site selection should be prioritized according to the volume of importation and the risk of host plants. Facilities importing tomato products from the countries where *T. absoluta* is present should be considered for trapping. High-risk locations should be targeted.

Other potential survey locations may also include market stalls selling tomatoes, or high-risk sites such as: nurseries selling tomato seedlings, tomato farms, border crossings, customs inspection area, truck waiting yards, seaports, and airports.

(v) Trap placement sites

Once a location is selected for survey, trap sites are then determined and traps are placed within each location.

Trap placement sites should include reception area in packing houses, sorting and packing areas, truck loading areas, waste disposal areas, composting facilities using plant waste from tomato farms, raw plants reception areas, composting areas, compost storage areas, wholesale vegetable markets, reception areas of incoming trucks, stores of bulk tomato, vegetable repacking and distribution centers, washing and packing lines, food processing/salad packing/ tomato processing plants, and washing and processing areas (Table 2).

Grid maps of the survey area may also be prepared and areas identified to be high-risk locations selected by their proximity to the grid point. Sampling points are then established. As this is a pheromone-based survey, the sample point is the same as the trap placement site.

Table 4.1 Suggested trap placement sites based on potential high-risk locations for the introduction of *Tuta absoluta*

Survey location	Trap placement sites
Tomato seedling nursery	Production area Compost area
Tomato farm	Production area, open field, Green houses Sorting and packing area Waste disposal area
Composting plant (using plant waste from tomato farms)	Raw plants reception area Composting area Compost storage area
Wholesale vegetable markets	Truck loading area Stores of bulk tomato
Vegetable repacking and distribution centres	Truck loading area Washing and packing lines
Food processing / salad packing / tomato processing plants	Truck loading area Washing and processing area

III. Delimiting Surveys

(i) Purpose

Delimiting surveys may be used to establish the boundaries of an area considered to be infested by *T. absoluta*. A delimiting survey involves looking at a pest infestation and investigating the extent to which a pest has spread from the initial point of detection.

(ii) Target life stages

The target life stage of a delimiting survey is primarily adult moths; however, if the survey has been limited to a facility, larval stages may also be included.

(iii) Timing

The timing will be set by the date of the first detection that was observed and how quickly a survey can be planned and organized.

(iv) Target areas and site selection

The delimiting survey area could be an officially defined country, part of a country or all or parts of several countries (ISPM 5). The area may be described using political or natural geographic boundaries, or as specific places / sites of production.

(v) Delimiting survey procedure

Delimiting surveys are conducted in an ever-increasing radius from the initial detection at locations and sites that may have had or currently contain a suitable host(s) and a conducive climate or environment for the pest to establish and reproduce.

For delimiting surveys, traps can be placed at distances of two to five kilometres at the rate of two traps per hectare, in a circle from the initial site of infestation, (this can be modified as needed). Once a positive trap catch occurs within this predetermined distance, two to three additional traps are placed at each site at shorter intervals, 30 to 100 meters (for example).

IV. Sample Handling and Laboratory Submission

If there are no moths in the trap or if there are only medium to large moths, with body length greater than 1.0 cm, the trap or trap liner should not be removed from the field as the size would preclude *T. absoluta*.

If moths with body length less than 1.0 cm are present, they should be examined with a hand lens in the field. A field screening aid is available at: (http://caps.ceris.purdue.edu/screening/tuta_absoluta)

If suspect moths or other life stages are present, or if there is uncertainty in the field regarding the species, the suspect moths must be submitted for identification by a trained entomologist / taxonomist.

Sample preparation

The sample should be carefully packaged and sent overnight to the designated identifier or office in the respective country. NPPO guidelines should be followed for sample preparation. Details on suggested procedures for packaging and shipping may be found on page 25.

Labelling samples for shipping

"Tomato Leafminer Survey" should be indicated on the sample container. All samples should be shipped by express courier to the closest official NPPO diagnostic laboratory. Laboratory notification through email is suggested to ensure that the sample is tracked and properly handled.

Reporting procedures

For information on responsibilities of and requirements for contracting parties in reporting the occurrence, outbreak and spread of pests in areas, please refer to ISPM 17[6]: 2002.

6 ISPM 17 – Pest reporting

Suggested procedure for preparation, packaging and shipping of samples for identification of *Tuta absoluta*

The following are suggested procedures only. Each country may define their guidelines according to their specific requirements.

1. When sending whole traps

Traps with suspect *T. absoluta* must be removed from the site and the entire trap must be placed into a paper bag for submission. A paper label should be inserted into the paper bag with the trap. The paper label must contain the sample number or trap number, if applicable, collector's name, location, host and date of collection written in HB pencil. To prevent shifting, trap(s) and packing material should be packaged within a sturdy box that will resist crushing during shipping and be submitted as soon as possible after collection.

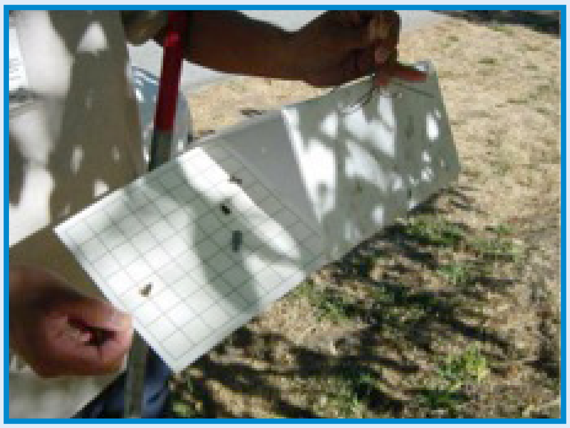

Figure 4.1 Delta trap with liner.

2. When sending trap liners

Trap liners from Delta traps with suspect moths should be carefully packed prior to shipping. The following are the suggested steps.

Ensure that trap number, the date the trap was installed and removed, and the number of suspect moths is recorded on the bottom of the liner, preferably with permanent ink (Figure 4.2).

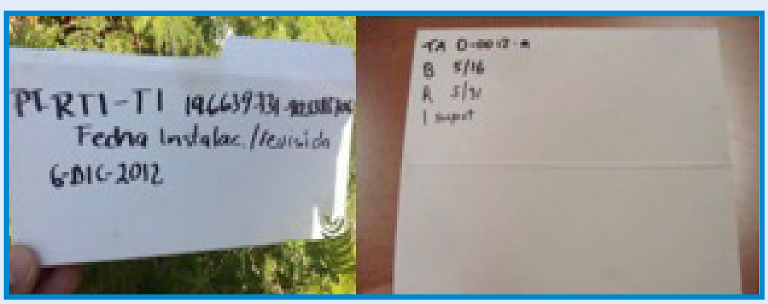

Figure 4.2 Examples of information included on trap

3. Fold the liner over so that it forms a “C” shape. For the liner to form a “C” shape it needs to be rolled against (=90 degrees, or perpendicular) the original fold of the trap; otherwise, the trap will fold flat and the specimens could be damaged. Secure the liner with two elastic bands. Ensure that the edges do not come in contact with each other.

Figure 4.3 Folded trap

Figure 4.4 Folded trap showing “C” shape

4. Place the liner into a sealable bag. Sealing air in the bag will cushion the liner and help protect it from getting crushed.

   Place the first sealable bag and a form (designed to record details of the trap as trap number, installation date, servicing date, number of suspect moths) into another bag. Sealing air in the bag will cushion the liner and help protect it from getting crushed.

Figure 4.5 Placement of trap in sealed bag.

Figure 4.6 Placement of form and sealed bag with trap into second sealed bag.

5. Place the liners into a sturdy box for shipping to ensure that they will not be crushed. Place other material (packing peanuts, bubble wrap, etc.), if necessary, in the box to ensure that the liners will not move around.

6. Send an email to the office / identifier receiving the box with information about the trap liner being shipped and details entered on the form that is accompanying the trap liner.

Source: Surveillance Protocol for the Tomato Leaf Miner, *Tuta absoluta*, for NAPPO Member Countries

Section V. Eradication and Management

5

This chapter outlines the actions that are to be taken if *T. absoluta* is detected. Options to eradicate the pest as well as to suppress pest populations below an economic threshold are given. An Integrated Pest Management approach is recommended for the suppression of the pest and where possible the use of non-chemical methods should be promoted with limited reliance on chemical control. Before wide scale use of any tactic, its suitability to eradicate, contain, or suppress pest should be assessed.

The efficacy and feasibility of each tactic should depend on the pest situation at the time of detection. Factors including detection location (e.g., natural or urban environment, agricultural crop, greenhouse, or orchard), area of spread, climatic region, time of year, phenology of the host, and current practices already in place contribute to determining whether a particular management option is appropriate.

I. ERADICATION OPTIONS

Quarantine and Regulatory Procedures

- Hold notices: After an infestation is known to exist, operations personnel will issue hold orders on all properties known to be infested with tomato leafminer.
- Emergency quarantine: An emergency quarantine shall be adopted if any of the infestation criteria listed under Eradication Activities are met.
- Quarantine area should include a **2-5 km radius** from the initial detection. All movement of potential host material out of the area should be restricted until cleared by delimitation or monitoring surveys. If a new detection is made, expand the quarantine area to include a 2-5 km radius around the new detection site, as well as the 10-km radius from the initial detection site.
- **Important:** During this entire process it is essential to be in contact with representatives from the Ministry of Agriculture. They can provide advice on handling media inquiries to ensure that accurate information is disseminated. Keeping the public properly informed ensures that essential activities may continue without interruption.

Host Removal

- Eradication of tomato leafminer may be feasible when the pest population is confined to a small area, detection occurs soon after the introduction, or pest population density is low.
- Measures will include, but may not be limited to, removal and destruction of all infested plant material, removal of host material within 3.2 km of the find, and treatment of the soil and surrounding vegetation with an approved pesticide after removal of the infested plants. Infested host plants should be cut, allowed to dry, and burned. If growers plan to replace their removed crops, it is recommended that they plant non-host plants in the area to disrupt the lifecycle of any remaining tomato leafminers (IRAC, 2017b).

Chemical Control

A description of insecticides used to control tomato pinworm that may also be effective against tomato leafminer is provided. The addition of an adjuvant, such as mineral oil, can increase the effectiveness of insecticides against tomato leafminer (IRAC, 2017a; Saad et al., 2014). Insecticides which have been used against *T. absoluta* are outlined in Table 5.1. It is important to confirm with the National Pesticide Board which products are registered for use on tomato.

Table 5.1 Insecticides used to control *Tuta absoluta* in various countries

MOA Group	Common name	Global Use (reference)	Notes
3A	Deltamethrin	Spain (FERA, 2009b; Russell IPM, 2009c)	In the United States, deltamethrin is registered for control of tomato pinworm on tomato.
4A	Thiamethoxam	Brazil (IRAC, 2007)	Thiamethoxam is registered as a soil treatment for tomato pinworm on tomato, pepper, and eggplant (CDMS, 2019).
5	Spinosad	Brazil (IRAC, 2007), Malta (Mallia, 2009), and Spain (FERA, 2009b; Russell IPM, 2009c)	Spinosad provides effective control of lepidopteran pests and has low toxicity to non-target organisms (Thompson et al., 2009). It is registered for tomato pinworm in tomato (CDMS, 2019).
6	abamectin[2]	Brazil (IRAC, 2007) and Malta (Mallia, 2009), United States of America (California) (USDA NPG 2019)	The University of California recommends abamectin for control of tomato pinworm in IPM programs (Zalom et al., 2008). Registered for tomato against tomato pinworm (CDMS, 2019).
6	emamectin benzoate[2]	Spain (MARM, 2010) and Egypt (Saad et al., 2014; Soliman et al., 2014), United States of America (California) (USDA NPG 2019)	Emamectin benzoate is a second-generation avermectin analog that is significantly more potent than abamectin when used at lower doses (Jansson et al., 1996). Shown to be highly effective against tomato leafminer larvae in Egypt (Saad et al., 2014; Soliman et al., 2014). Addition of mineral oil increased effectiveness in one study (Saad et al., 2014).
11A	*Bacillus thuringiensis* var. *kurstaki* (Btk)	Argentina (Riquelme et al., 2006), France (FREDON-Corse, 2009), Malta (Mallia, 2009), and Spain (FERA, 2009b; Russell IPM, 2009c)	For larval control, neutral solutions of Btk should be applied to crops once per week at the end of the day (FREDON- Corse, 2009). The leaf epidermis presents a significant barrier to control with chemical or microbial insecticides (Salvo and Valladares, 2007). Therefore, Btk may not be effective once tomato leafminer larvae enter plant parts (Sixsmith, 2009). Btk is registered for use on tomato against tomato pinworm in the United States.

MOA Group	Common name	Global Use (reference)	Notes
13	Chlorfenapyr	Brazil (IRAC, 2007)	Chlorfenapyr has been used to control tomato leafminer in Brazil (IRAC, 2007) and is registered in the United States for control of tomato pinworm on greenhouse grown tomato, pepper, and eggplant (CDMS, 2019). It is effective against leafminers in numerous crops (Yu, 2008) but was shown to be less effective than emamectin benzoate or methomyl in Egypt (Soliman et al., 2014).
22A	indoxacarb[2]	Brazil (IRAC, 2007), France (FREDON-Corse, 2009), Malta (Mallia, 2009), and Spain (FERA, 2009b; Russell IPM, 2009c), United States of America (California) (USDA NPG 2019)	Indoxacarb selectively targets lepidopteran pests and is effective at controlling outbreaks of tomato leafminer (FERA, 2009b; Picanço, 2006; Sixsmith, 2009).
18	Methoxyfenozide	United States of America (California) (USDA NPG 201))	Used in California against Keiferia lycopersicella that may be effective against *T. absoluta*
28	chlorantraniliprole[2]	Spain (MARM, 2010) and Egypt (Saad et al., 2014), United States of America (California) (USDA NPG 2019)	Chlorantraniliprole is registered for control of tomato pinworm on tomato in the United States, and product literature and scientific literature also indicate that it is effective against tomato leafminer (Dupont, 2008; Nozad-Bonab et al., 2017; Saad et al., 2014). Addition of mineral oil increased effectiveness in one study (Saad et al., 2014). Chlorantraniliprole has both larvicidal and ovicidal activity and shows excellent root uptake and translocation in tomatoes, which continues for up to 28 days from a single soil application. It also has exceptional translaminar activity, offering 100 percent larval control of tomato fruitworm, *Helicoverpa zea*, 18 days after a single foliar application.
28	cyantraniliprole	India (Bhat et al., 2017) and Chile (Larraín et al., 2014)	Cyantraniliprole has been shown to be effective for controlling tomato leafminer (Bhat et al., 2017). Cyantraniliprole is as effective against tomato leafminer as chlorantraniliprole (Bhat et al. 2017). Both foliar and soil applications are effective against tomato leafminer (Larraín et al., 2014). This chemical is registered for tomato pinworm on tomato in the United States (CDMS, 2019).
uncertain	Azadirachtin	Spain (Van Deventer, 2009)	Azadirachtin has been recommended for use as a preventive spray and for light infestations (less than 30 adult catches per week) of tomato leafminer in Spain (Servicio de Sanidad Vegetal - Murcia, 2008; Van Deventer, 2009). In the United States, the compound is registered for use on tomato to control tomato pinworm.

Insecticide Resistance

There are numerous reports of tomato leafminer developing resistance to insecticides (Bassi et al., 2015; Grant et al., 2019; Roditakis et al., 2017; Roditakis et al., 2015). Repeated use of insecticides with the same mode of action (MOA) will select for individuals with resistance to the insecticide MOA (Haddi et al., 2012; Ponti et al., 2012). To avoid inducing resistant populations, it is important to rotate insecticides with differing MOA (IRAC, 2017b). A particular MOA can be used for a 30-day period, but then a period of at least 60 days should pass before the same MOA is used again (IRAC, 2017b). The Insecticide Resistance Action Committee provides valuable information on preventing insecticide resistance in tomato leafminer (IRAC, 2017b). A method for testing a population for insecticide resistance is also available from the Insecticide Resistance Action Committee (IRAC, 2012).

Active ingredients to which tomato leafminer has developed resistance are listed in Table 5.2. Although resistance to particular insecticides was observed only in specific locations, it is still a concern for the United States because tomato leafminer populations that may enter the country may also carry these resistance genes at high frequency and thus avoid the process of developing resistance in the new environment (Guedes and Siqueira, 2013).

Table 5.2 Active ingredients to which *Tuta absoluta* has shown resistance

MOA group[1]	Active ingredient	Location reported	Year reported	Reference
3A	bifenthrin	Brazil	2011	IRAC-APRD, 2016
3A	beta-cyfluthrin	Brazil	2014	IRAC-APRD, 2016
3A	alpha-cypermethrin	Brazil	2015	IRAC-APRD, 2016
3A	deltamethrin	Brazil Argentina	2001 2005	Branco et al., 2001; Lietti et al., 2005
3A	esfenvalerate	Chile	1997	Salazar S. and Araya C., 1997
3A	etofenprox	Brazil	2014	IRAC-APRD, 2016
A	permethrin	Brazil	2000 2011 2014	IRAC-APRD, 2016; Siqueira et al., 2000a
5	spinosad	Chile Brazil United Kingdom	2012 2015 2015	Grant et al., 2019; IRAC- APRD, 2016
6	abamectin	Brazil Argentina	2000 2005	Lietti et al., 2005; Siqueira et al., 2000a
6	emamectin benzoate	Greece Italy	2016 2016	Roditakis et al., 2018
14	cartap	Brazil	2000	Siqueira et al., 2000a, 2000b
15	diflubenzuron	Brazil	2011	Silva et al., 2011
15	teflubenzuron	Brazil	2011	Silva et al., 2011
15	triflumuron	Brazil	2011	Silva et al., 2011
22A	indoxacarb	Brazil	2011	Silva et al., 2011

MOA group[1]	Active ingredient	Location reported	Year reported	Reference
28	chlorantraniliprole	Italy, Brazil, United Kingdom, Spain	2015 2015 2016 2019	Grant et al., 2019; Kenogard, 2019; Roditakis et al., 2017
28	cyantraniliprole	Brazil, Spain	2015 2019	Kenogard, 2019; Silva et al., 2016
28	flubendiamide	Brazil	2015	Silva et al., 2016

[1]IRAC, 2018

Labeling

All applicable label directions must be followed, including but not limited to requirements for personal protection, equipment, maximum treatment rates, storage and disposal to control tomato pinworm (Webb and Hochmuth, 2010). If growers plan to replace their removed crops, it is recommended that they plant non-host plants in the area to disrupt the lifecycle of any remaining tomato leafminers (IRAC, 2017b).

II. MANAGEMENT OPTIONS

If eradication is not achieved a comprehensive Integrated Pest Management strategy should be implemented to suppress populations of the tomato leafminer. The strategy should utilize a combination of cultural control, behavioural control, biological control, host plant resistance and if needed chemical applications.

Cultural Controls

- Continuously monitor potential hosts and vicinity for the pest.
- Remove infested plants and destroy plant residue immediately after harvest.
- Implement crop rotation with non-hosts or a fallow period of five to eight weeks.
- Destroy wild hosts near the infested cultivated hosts.
- Secure greenhouses using double-entry doors and insect screens.
- Screen the movement of the pest on hosts and on non-hosts as a hitchhiker; decontaminate or destroy infested materials as needed.
- Destroy pupae in the greenhouse through soil solarization.

Populations of tomato leafminer can emerge from infested plants left in greenhouses or fields after harvest and can arrive at these sites via the movement of infested plants. Failing to secure greenhouses, produce packing sites, or tomato processing plants with insect screening or double entry doors can lead to the spread of the moth. All life stages of the pest can be introduced to these environments on clothing (Fig. 5.1), pots, carts, and greenhouse tools. Therefore, it is important to thoroughly inspect and clean these items before entering enclosed tomato production areas, produce packing areas, or tomato processing plants. Production nurseries, tomato production sites, and tomato packing sites should follow strict sanitation guidelines to prevent the arrival and spread of tomato leafminer.

Nurseries and Protected Agriculture (greenhouse) tomato production

Solanaceous weeds in the vicinity of infested greenhouses should be removed and destroyed to prevent the build-up of a potential population reservoir (Koppert, 2009). Installing double, self-closing doors and covering windows and other openings with 1.6 mm or smaller insect mesh can prevent the entry and exit of tomato leafminer adults in greenhouses. Workers in greenhouses should check their clothing for tomato leafmi–ner eggs, larvae, and adults before moving to other greenhouses.

Inside the greenhouse, leaves and stems should be routinely checked for larvae, pupae, adults, and leaf mines and other signs of the insect. The undersides of fruit calyxes and the fruits themselves should be checked for small heaps of frass that indicate larval entry holes (Mallia, 2009). Infested plants or plant parts should be removed, especially at the beginning of cultivation, and residues should be disposed of carefully (InfoAgro Systems, 2009).

Field-grown tomatoes

For both greenhouse and field-grown tomatoes, early control measures are important prior to pest establishment, beginning with the systematic monitoring and destruction of leaf mines on seedlings as they appear (Urbaneja et al., 2013). Destruction and incorporation of crop residues after harvest effectively interrupts the life cycle of tomato leafminer by killing the immature stages present in the plant material. Tilling equipment should be cleaned using high pressure washing after use in infested fields. All harvesting containers, field boxes, and carts should be cleaned and inspected before being moved to other areas.

Solanaceous weeds in the vicinity of infested areas should be removed and destroyed to prevent build-up of a potential population reservoir (Koppert, 2009). If tomato leafminer is detected at any time during the growing cycle, the infested material should be removed and destroyed to interrupt the pest life cycle and prevent spread (Russell IPM, 2009c).

Vegetable packing stations

The United Kingdom has published best practice guidelines for managing tomato leafminer at tomato packing sites because these could provide a pathway for movement of the pest to the open environment (FERA, 2009a). Strict waste management procedures are employed so that no plant waste is left uncovered and exposed. Larvae, pupae, and adults might hide in plastic or cardboard packing materials in tomato grading areas.

To mitigate the risk, personnel at packing sites are encouraged to regularly examine and clean grading containers or to use plastic bags in grading containers and replace the bags daily. Tomato crates that are returned to suppliers should be cleaned to prevent introduction of tomato leafminer to growing sites.

Alternatively, non-returnable tomato packing boxes can be used; these should be assembled and stored in an area of the packing station away from infested crates (Sixsmith, 2010). Inspection measures at packing stations call for examination of fruit with calyces for evidence of larval mining.

In particular, vine or truss tomatoes should have stems and calyces examined, and this should be a priority over the examination of fruit. At all times, windows and other openings should be kept covered with 1.6 mm or smaller mesh to prevent the entry or exit of moths (InfoAgro Systems, 2009). Tomatoes awaiting packaging should also be protected with insect-proof mesh or a plastic tarpaulin. Solanaceous weeds should be removed and destroyed to prevent the build-up of a potential population reservoir.

Other cultural controls

Cultural control methods for tomato leafminer include crop rotation with non-host crops, plowing, adequate fertilization and irrigation, destruction of infested plants and post-harvest plant debris, and disposing of infested residue. Although destruction of potentially infested material may reduce future infestations, the effectiveness of this measure depends on the pest pressure in the vicinity. For instance, the limited destruction of infested fruits and plant material is less effective in an area with wide cultivation of tomato or year-round occurrence of alternative hosts (Guedes and Picanço, 2012). Additional cultural methods to decrease populations of tomato leafminer have been reported.

In greenhouse crop production, soil solarization for at least four to five weeks during a warm period may eliminate pupae that remain on the ground (InfoAgro Systems, 2009; Urbaneja et al., 2013).

In open fields, MARM (2008) recommends a six-week fallow period between cultivation of susceptible crops in the same area. The host-free period can be reduced if additional strategies to destroy pupae in the soil are used together with this method (MARM, 2008). Host-free periods are most effective when practiced area-wide, so cooperation among growers is important (Le Strange et al., 2000; Stansly, 2009).

Behavioral Control

Mass trapping

The goals of mass trapping and survey trapping differ: survey trapping is intended to detect the pest and determine its spread, whereas mass trapping is used to reduce the population and control the pest at a location. The effectiveness of trapping as a control measure may depend on several factors, including the pest density. By capturing adult males, the mass-trapping system affects the number of females that can mate and produce viable offspring. Some methods that combine a pheromone lure and a light trap attract and kill both male and female moths. Non-target species may also be captured and killed.

Mass trapping will **not** capture all of the tomato leafminer moths in an area (Bayram et al., 2017; Berxolli and Shahini, 2017; Cherif et al., 2018; Cocco et al., 2012) because only males are attracted to the pheromones, and females may reproduce through parthenogenesis (Caparros Megido et al., 2012; Han et al., 2018).

IMPORTANT – Other management tactics, such as chemical applications must be combined with mass trapping to further reduce the tomato leafminer population (Berxolli and Shahini, 2017; Cherif et al., 2018).

Delta traps with pheromone lures

Use the information in the *Surveillance and monitoring* section for trap design and placement but modify the survey trapping protocol so that the density of the traps is increased to 40-50 per hectare in open fields or 20-25 per hectare in greenhouses (Berxolli and Shahini, 2017; Lobos et al., 2013).

Keep in mind that pheromone traps alone will only capture males. Mass trapping may be done in conjunction with delimitation survey activities if resources allow.

Combined pheromone and light water trap (Ferolite trap)

A modified light and water trap was developed for tomato leafminer that can capture thousands of males and a substantial number of females per night (Russell IPM, 2009a). The light trap, Ferolite-TUA, uses a combination of pheromone lures and a specific light wavelength that is highly attractive to tomato leafminer (Russell IPM, 2016). The product literature states that the trap has an improved effectiveness of 200 - 300 percent over the standard pheromone trap (Russell IPM, 2016). A greenhouse study demonstrated that Ferolite traps caught twice as many moths as pheromone traps alone (Özkan et al., 2017). Water traps require regular refilling of the water pans, especially during hot summers (Aksoy and Kovanci, 2016).

Conflicting information exists on whether the pheromone-baited delta traps or the Ferolite traps are better for mass trapping. While several sources state that the Ferolite trap is an improvement over the standard pheromone trap (Özkan et al., 2017; Russell IPM, 2016), one study compared pheromone-baited water traps with or without a light source to pheromone-baited delta traps and found that the pheromone-baited delta traps caught significantly more moths than the pheromone-baited water traps with or without a light source (Aksoy and Kovanci, 2016).

Sticky rolls

Rolls of wide, double-sided tape can be strung along the length of greenhouses or field crop rows to capture tomato leafminer moths. Some rolls come pre-baited with tomato leafminer pheromone in the sticky glue (Russell IPM, 2016). Sticky rolls will also capture non-target pests such as other moths, whiteflies, aphids, and flies.

Mating disruption

Mating disruption aims to saturate the environment with female pheromones in order to confuse males, disrupt mating, reduce the number of fertilized females, and subsequently reduce pest populations and plant damage (Caparros Megido et al., 2012). High doses and rates of pheromones are used for mating disruption and have historically yielded mixed results (Caparros Megido et al., 2013; Cocco et al., 2013a; Vacas et al., 2011). Micheroff Filho et al. (2000) found high levels of male orientation interruption (60-90 percent), but damage to tomato plants was not significantly reduced. Vacas et al. (2011) and Cocco et al. (2013b) report effective control of tomato leafminer only in high-containment greenhouses. Sannino et al. (2014) also report satisfactory control of tomato leafminer in tomato greenhouses when both pheromone lures and insecticidal controls are used. Parthenogenesis from unfertilized eggs, however, might compromise the efficacy of mating disruption in tomato leafminer (Caparros Megido et al., 2012; Han et al., 2018) if that form of reproduction occurs naturally in the species. Features of the technique:

- Dispensers loaded with 60 mg pheromone lure
- 500-1,000 dispensers/ha
- Only shown to work in high-containment greenhouses that prevent immigration of pests from outdoors, which are attracted to the high-dose of pheromone indoors

Sterile insect release

In a laboratory study, Cagnotti et al. (2012) examined the impact of irradiation on an F1 population and evaluated the feasibility of using it as a control strategy. The study showed that 200-250 Gy induced sterility in males, which affected the fecundity and fertility of the F1 population.

Effectiveness of mass behavioral control methodologies

Although mass trapping and mating disruption have been used to reduce the population of tomato leafminer in different production systems, some biological traits of the pest may limit the effectiveness of these control strategies. Some of these limiting factors that may impact implementation of these strategies include:

- Mass trapping and mating disruption may not capture or confuse all males (Caparros Megido et al., 2013).
- One male can mate up to 12 times in consecutive days, averaging 6.5 matings in a lifetime. Females also mate with multiple males (Santos Silva, 2008), suggesting that reducing male numbers may not necessarily lower the number of fertilized females.
- Parthenogenesis has been reported in this species in the laboratory (Caparros Megido et al., 2012). Females thus may be able to reproduce without a mate.
- Costs associated with some of the strategies, such sterile insect technique and mating disruption, may be prohibitive (Ponti et al., 2012).
- Because the pest feeds on many hosts and can spread rapidly via natural and human-mediated pathways, some of the behavioral control strategies may be less effective (Ponti et al., 2012).

Biological Control

Numerous predators and parasitoids feed on or infest the pupae, larvae, and eggs of tomato leafminer. Pest management strategies should focus on both conservation of natural enemies in the field and periodic augmentative releases of commercially available biological control agents (Desneux et al., 2010; Ghoneim, 2014; Zappala et al., 2013).

Predators

Nesidiocoris tenuis (Reuter), a mirid insect that is already established in Florida and Puerto Rico, may be an effective predator against *T. absoluta* (Roda, 2019a). *Nesidiocoris tenuis* feeds on tomato pinworm, tomato fruitworm, and *Helicoverpa armigera* (Hübner) (cotton bollworm) eggs and larvae, as well as the eggs of *Ephestia kuehniella* (Zeller) (Mediterranean flour moth) (Devi et al., 2002). It controls the whitefly *Bemisia tabaci* (Gennadius) and feeds on tomato leafminer eggs and larvae in other parts of the world (Desneux et al., 2010; Zappala et al., 2013). Although *N. tenuis* is an effective predator of tomato leafminer, caution should be exercised prior to mass release because it may directly damage tomatoes if prey is scarce (Arnó et al., 2010). Planting sesame plants near tomato fields will help increase *N. tenuis* populations and reduce damage they may cause to tomato. A robust population of *N. tenuis* was found after it was introduced into tomato-sesame intercrop fields (Roda, 2019a).

Another mirid insect, *Macrolophus praeclarus* Distant, is already established in Florida and Puerto Rico and feeds on tomato leafminer (Roda, 2019a). *Macrolophus praeclarus*, however, is listed as reportable in PestID (2019). Like *N. tenuis*, *M. praeclarus* will control whiteflies (Roda, 2019a). It causes less direct feeding damage to tomato than *N. tenuis* does (Roda, 2019a).

Another mirid predator used against tomato leafminer is *Macrolophus pygmaeus* (Rambur) (De Backer et al., 2017; Mollá et al., 2014; Urbaneja et al., 2008), although it is not present in the United States, and further testing would have to be conducted before it could be released.

Parasitoids

In recent reviews, Zappala et al. (2013) and Desneux et al. (2010) listed more than 50 species that parasitize eggs, larvae, and pupae of tomato leafminer. Among these, the trichogrammatid egg parasitoid *Trichogramma achaeae* Nagaraja & Nagarkatti is widely used as a biological control agent against tomato leafminer. The inundative release rate is 50 adults/m2 (500,000 adults/ha) (Cascone et al., 2015; Chailleux et al., 2013; Chailleux et al., 2012; Urbaneja et al., 2012). *Trichogramma pretiosum* Riley is also an egg parasitoid of tomato leafminer (Chailleux et al., 2012; Ghoneim, 2014).

Important larval parasitoids include *Neochrysocharis formosa* (Westwood) [present in Hawaii (Nishida, 2002)], *Necremnus* sp. nr. *artynes* (Walker), *Stenomesius* sp. nr. *japonicus* (Ashmead) (all Eulophidae) and *Bracon nigricans* Szépligeti (Braconidae) (Gabarra et al., 2014; Urbaneja et al., 2012; Zappala et al., 2013).

Entomopathogens

Entomopathogens reported to infect tomato leafminer are listed as follows:

Entomopathogenic bacteria

- *Bacillus thuringiensis* var. *kurstaki* (Btk) (Younes et al., 2018)

Entomopathogenic fungi

- *Beauveria bassiana* (Balsamo) Vuillemin (Younes et al., 2018)
- *Metarhizium anisopliae* (Metchnikoff) Sorokin (Nozad-Bonab et al., 2017)

Entomopathogenic nematodes

- *Steinernema carpocapsae* (Weiser) (Kamali et al., 2017)
- *Steinernema feltiae* (Filipjev) (Van Damme et al., 2016)
- *Heterorhabditis bacteriophora* Poinar (Kamali et al., 2017)
- *Heterorhabditis amazonensis* JPM 4 (Sabino et al., 2019)

Entomopathogenic viruses

- Phthorimaea operculella granulovirus Tu1.11 (Ben Tiba et al., 2019)
- Granulovirus VG003 (Gómez Valderrama et al., 2018)
- Granulovirus VG013 (Gómez Valderrama et al., 2018)

Of these, Btk is the most widely used entomopathogen against tomato leafminer. González-Cabrera et al. (2011) showed that a formulation of 90.4 million international units (MIU)/L applied weekly reduced the percentage of infested fruits from approximately 51 percent down to 2 percent.

Host Resistance

Solanum habrochaites S. Knapp & D. M. Spooner (syn.: *Lycopersicon hirsutum* Dunal forma *glabratum* C. H. Mull.) has been widely studied for its resistance against tomato leafminer; the development period of the larva is long and immature mortality is high on this species (Bottega et al., 2015; de Azevedo et al., 2003; Ecole et al., 1999; Leite et al., 1999; Leite et al., 2001; Proffit et al., 2011).

Chemical Control

Chemical applications to suppress T. absoluta populations should be used judiciously and in the context of an IPM Programme - see below.

III. INTEGRATED PEST MANAGEMENT (IPM) PLAN

An IPM program should integrate different techniques and may include the following steps (Stol et al., 2009):

- Monitor the occurrence of tomato leafminer in the field using pheromone traps (2-4 traps/ha; 50-70 m between traps). Refer to the *Survey* section for general guidelines on trap installation and survey procedure.
- Mass-trap tomato leafminer during the crop cycle for management and post- harvest for monitoring of emerging populations that may impact the next crop cycle. Refer to *Mass Trapping* for guidelines on mass trapping tomato leafminer adults.
- Release predators and parasitoids such as *N. tenuis*, *M. praeclarus*, and *T. achaeae* to increase egg mortality. Refer to the *Biological Control* section for additional information.
- If eradication has failed, and a permanent population is being managed, monitor the tomato leafminer population in the field using pheromone traps, and only consider pesticide applications if the number of moths captured has reached an economic threshold (FREDON-Corse, 2009). Consider the potential impact on non-target organisms when determining the selection, use, and timing of pesticide application. Integrate the use of biological control agents and selective insecticides such as Btk into IPM programs (Biondi, 2013). Refer to *Chemical Control* for additional information.
- Remove all crop residues immediately after harvesting, as tomato leafminer adults may emerge from the dried plants in the field, influencing the next crop cycle.
- Table 5.3 summarizes the guidelines from France and Spain on the estimated level of risk from infestations of tomato leafminer based on male moth captures (FREDON-Corse, 2009; Stol et al., 2009).

Table 5.3 Level of risk based on numbers of adult male *Tuta absoluta* trapped (adapted from FREDON-Corse, 2009 and Stol et al., 2009)

If this number of adult males trapped (risk):	Then begin mass trapping using:	And apply:
<10 in 1 month (low)	20 water traps/ha	- N/A
<3 in 1 week (low)	20 water traps/ha	- Btk and azadirachtin preventive spraying
3-30 in 1 week (moderate)	25-40 traps/ha	- Introduction of natural enemies - Btk, azadirachtin, and other insecticides if needed; treatment every 10 days
>30 in 1 week (high)	25-40 traps/ha	- Btk weekly spraying - Other insecticides, such as indoxacarb for young plants and spinosad for older plants; treat every 10 days

Section VI. Management of the Emergency Response

It is the responsibility of all countries to prevent or retard the entry of any exotic[8] pest and to be prepared to deal with a pest incursion, should it arise. Plant Quarantine Units must be prepared to act by having the necessary physical, financial and human resources ready to be mobilized in the event of an emergency situation.

This section outlines the administrative actions that should be considered to prevent or retard the entry of *T. absoluta* and provides an emergency operations plan should *T. absoluta* enter the country. The information presented should be implemented under a country's legislation on plant quarantine. The emergency response system provides: (i) description of the management of the response, (ii) the administrative steps that should be taken to prevent the introduction of the pest as well as its containment, eradication and management and (iii) possible items for budgeting available resources.

DESCRIPTION OF THE ADMINISTRATION OF THE EMERGENCY ACTION PLAN

The emergency response to *T. absoluta* is an organised approach to prevent its introduction into the country and to contain or eradicate this pest should it enter. A National Emergency Pest Committee (NEPC), which is responsible for the administration of the response should be established.

The NEPC should be headed by the Minister of Agriculture or the Permanent Secretary with membership from national agencies - governmental or non-governmental as may be required (Fig 6.1). It is an inter-ministerial, inter-sectoral and inter-institutional group, with representatives from various Government Ministries, statutory boards and the private sector. The nature of the representation should ensure that it includes the required interest groups and obtains the necessary support to achieve its objectives. The composition of, and representation on the NEPC, is shown in Table 6.1. The proposed representation is not exhaustive and the Minister may invite other agencies as necessary.

The task of the NEPC is to promulgate policies and coordinate inputs and activities of the different Government Ministries and other agencies. The agencies represented on the NEPC have been selected based on their role in the prevention of entry of exotic plant pest into the country and their possible role in the control, eradication and containment in case of an introduced pest.

The NEPC coordinates the activities and ensures that the functions of each agency are adequately implemented. For example, the Director of Agriculture ensures that plant protection and quarantine measures are effectively carried out. The Collector of Customs or his nominee ensures that Customs personnel at the ports of entry are appropriately informed of the legislation and policy decisions of the

7 The following chapter is an excerpt from the Emergency Action Plan for Exotic Plant Pests and Diseases: A Model for Caribbean Countries. ISSN-0534-5391 A2/LC-97-02. Authored by Everton Ambrose. Castries, Saint Lucia. Revised February 2003. Modifications have been made to include the current Regional Plant Protection Organization for the Caribbean.

8 Pest - Any species, strain or biotype of plant, animal, or pathogenic agent, injurious to plants or plant products

Committee concerning the surveillance of arriving passengers and agricultural produce. The General Manager of the Air and Sea Ports Authority ensures the proper disposal of international garbage, and so on.

Importantly, the NEPC must ensure that the National Plant Protection Organisation (NPPO) contacts the Regional Plant Protection Organization (RPPO) for the Region, that is, the Caribbean Agricultural Health and Food Safety Agency (CAHFSA) and make them aware of the new pest incursion. Reporting to CAHFSA does not fulfill the international obligations of contracting parties to the IPPC; as such, countries must also notify the IPPC of any new pest incursion. Once CAHFSA is alerted and the country has formally notified the IPPC, the Agency will notify the countries in the Region of the detection of *T. absoluta*.

Given that *T. absoluta* is a priority pest for the Region, the NEPC should meet regularly (possibly twice/year) to review and refine the implementation of procedures and to update the members on any developments as necessary. In the event T. absoluta is detected in the country, the committee should meet as often as necessary.

The NEPC establishes the Emergency Pest Task Force (EPTF) or Technical Committee with the Chief Technical Officer as the Task Force Coordinator. This is the technical operational committee and is responsible for all technical activities to be undertaken. It consists of the following components:

- Field Component
- Police Component
- Laboratory Component
- Plant Protection Board

The emergency response should include the conduct of regular field exercises (at least once/year) to enhance the reactive capacity. There is need for strong coordination and for each person to know his/her role in the Plan. The system should be in a state of readiness at all times.

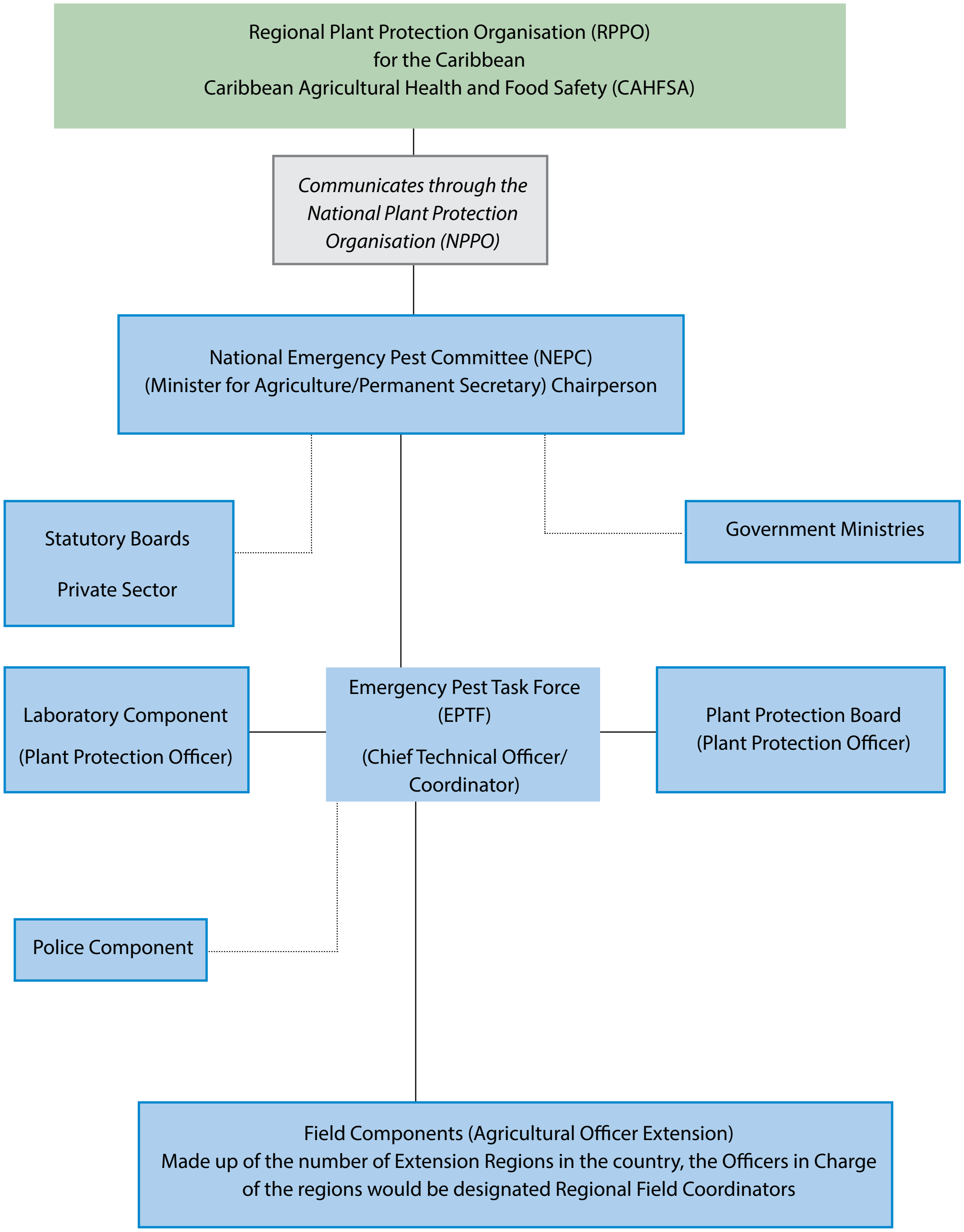

Figure 6.1 Organizational chart of the national emergency pest committee

Table 6.1 Inter-Institutional Composition of the National Emergency Pest Committee

Agency	Department or Division	Suggested Representative
Ministry of Agriculture	Administration	Minister/ Permanent Secretary
	Department of Agriculture and Divisions	Chief Agricultural Officer/ Director of Agriculture/ Plant Protection Officer
	Agricultural Information Unit	Officer in Charge
Ministry of Health	Environmental Health Unit	Chief Environmental Health Officer
Ministry of Public Utilities	Air and Sea Ports Authority	General Manager
Ministry of Communications and Works	Transportation Communications	Chief Engineer
Ministry of Finance and Planning	Customs	Comptroller of Customs
	Finance	Director
Ministry of National Security	Police Force	Commissioner
	Fire Department	Chief Fire Officer
Ministry of Legal Affairs	Attorney General Chambers	Counsel
Ministry of Local Government	Local Government Department	Local Government Officer
Statutory Boards	Production/ Marketing Division	General Manager of each
Private Sector	Organisations	Executive Secretary or Managing Director of each
	Chamber of Commerce	
	Other NGOs e.g. Supermarkets Associations, where present	

EMERGENCY ACTIONS FOR *TUTA ABSOLUTA*

The emergency response system for *T. absoluta* should include; (i) steps to prevent the entry of the pest and (ii) the containment, eradication and management of the pest.

PREVENTION OF INTRODUCTION OF *T. ABSOLUTA*

Component activities for the prevention of the introduction of *T. absoluta* include:

- Development and Implementation of Legislation Relating to Plant Protection and Quarantine.
- Surveillance - Port inspection and field monitoring.
- Proper handling and disposal of international garbage.
- Public information.
- Monitoring and review of preventative measures.

Component Activity I. Plant Protection and Quarantine Legislation

Countries should enforce strict quarantine procedures to prevent the entry and spread of *T. absoluta*. The Act and Regulations pertaining to the Country should be presented as an Annex to the Plan. In the Act, provisions are made for the establishment of a Plant Protection Board, a component of the EPTF which monitors plant protection and quarantine activities in the country on a regular basis. The Plant Protection Board should meet regularly.

Component Activity II. Surveillance - Port (Air, Sea and Frontier) and Field

Areas of the plant quarantine system relating to surveillance activities at the international ports of entry and the field should be on alert for possible pest incursions. For port and field surveillance to be effective, all plant quarantine and customs officers must be trained in the detection of the pest and disposal of suspicious materials. The following measures should be taken:

(a) Import Permit

All planting material must be accompanied by an import permit. This is issued by a Plant Quarantine Officer with the approval of the Plant Protection Board. The decision taken should be based on a pest risk analysis.

(b) Arrival Notification

The Comptroller of Customs or his/her representative should notify an Officer of the plant quarantine service of the arrival at the port of any plant or plant product which may be regulated by the Plant Protection Act of the country (*insert link to Plant Protection Act*).

The Comptroller of Customs or his/her representative should not release or dispose of the above-mentioned item(s), unless so authorized by the plant quarantine service.

An importer should notify a plant quarantine service officer in advance of the arrival of regulated material.

(c) Baggage Inspection

Passenger baggage is a potential pathway of entry for *T. aboluta*. Hence there should be extreme vigilance.

The passenger must provide the Immigration Officer a signed Customs Declaration Form (*this should be included in the Annex*) which indicates whether he/she is carrying any regulated item(s). The Immigration Officer stamps the form and indicates to Customs whether the passenger is carrying a regulated item. The Customs Officer also enquires from the passenger whether he/she is carrying any regulated item(s). The Customs Officer may examine the baggage.

If a regulated material is present, the Customs Officer requests the services of the Plant Quarantine Inspector.

If the Plant Quarantine Inspector is not on site, the Customs Officer shall detain the material and may give the passenger a retention slip. The Customs Officer then informs the plant quarantine service and requests that an Officer inspects the material with minimal delay.

(d) Container Inspection

Due to the nature of *T. aboluta*, there is a high probability that it could fly onto ships and into cargo holds; therefore, inspection of containers is critical. It is the responsibility of the importer to ensure that the plant quarantine service is informed of the presence of regulated material in the container. The container is opened by the Customs Officer in the presence of the Plant Quarantine Officer. The Customs Officer shall not release any regulated material unless duly authorized by a Plant Quarantine Officer.

(e) Mail Inspection

It is the responsibility of the importer to ensure that the plant quarantine service is informed of the presence of regulated material in the mail. International mail is a medium risk pathway for the entry of *T. absoluta*. The Customs Officer or the Postmaster should not release any regulated material unless it is authorized by a Plant Quarantine Officer.

(f) Ship and Aircraft Inspection

The Plant Quarantine Officer should be a member of the boarding party, which also includes Customs Officer, Immigration Officer and a Public Health Inspector. Otherwise a Plant Quarantine Officer may board a ship or aircraft if he/she suspects that it is carrying a regulated material.

If a Plant Quarantine Officer is not present at the ports, the Customs Officer should assist by giving the ship's captain to sign an appropriate declaration.

(g) Survey Activities

Survey and monitoring activities for *T. absoluta* must be undertaken to determine its status in the country. The survey activities may involve the other Sections of the Ministry of Agriculture, other governmental and non-governmental agencies and the public. Training in survey procedures should be conducted and the surveyors would have to ensure that all areas are covered within a specific period to time. Refer to technical information provided in Section 4.

Component Activity III. Proper Handling and Disposal of International Garbage

All plant material or portion thereof, from an international carrier to be disposed of, must be placed in a metal container (in the carrier) that can be covered to ensure that no plant pests can leave the container. If there is no incinerator, then the garbage is disposed of (after the carrier has left territorial waters) in a manner a manner which would not cause the introduction of *T. absoluta* into the country and according to international regulations. If facilities for disposal exist, this shall be done under the supervision of the plant quarantine service.

Component Activity IV. Public Information

There should be continuous campaigns to create and maintain the public awareness of pests of quarantine importance such as *T. absoluta* and the need to be vigilant.

Activities include:

- Development and dissemination of Pest Alerts and Bulletins
- Regular press releases
- Radio and television spots, films, slides, videos
- Publication and dissemination of leaflets at public events
- Placement of posters and/or billboards at conspicuous locations at ports of entry
- Provision of information to travellers, travel agents, shipping agents concerning the prohibition of entry of agricultural produce without a permit
- Talks to the Customs, Police and other appropriate collaborating agencies and partners.

Component V. Monitoring and Review of Preventive Measures

It is important that the activities that are being undertaken to prevent the entry and spread of R. solanacearum R3bv2 are monitored to ensure that actions are effective and are being efficiently implemented. Monitoring of preventative measures are the responsibility of the: (i) Minister of Agriculture / Permanent Secretary (Chairman - NEPC), (ii) the Chief Agricultural Officer / Director of Agriculture and (iii) the Crop Protection Officer/Pest Management Officer.

Minister of Agriculture / Permanent Secretary (Chairman - NEPC)

- The NEPC monitors and reviews measures being undertaken in relation to the prevention of entry of exotic pests.

Chief Agricultural Officer / Director of Agriculture

- Conducts, through the EPTF, regular education sessions for all personnel actively involved in the implementation of preventative measures, such as Port Personnel, Customs Officers, Plant Protection / Quarantine Officers and the like, including the public.
- Ensures that information is available on sources of material and equipment in an emergency.
- Conducts (at least once/year) field exercises simulating introduction of *T. absoluta* to assess the reactive capacity of the mobilization plan for control/eradication and containment of an exotic pest.

Crop Protection Officer/Pest Management Officer

- Conducts regular training sessions for Plant Protection / Quarantine Officers, Extension Officers to educate and update them on symptoms of *T. absoluta*.

- Ensures that the relevant plant protection laboratory knows of reference centres for the confirmation of *T. absoluta* and approved steps for preserving and submitting material.
- Ensures that the Plant Protection Board is active and involved in Plant Protection decisions.
- Knows where to source information on *T. absoluta*.

CONTAINMENT, ERADICATION OR MANAGEMENT OF EXOTIC PESTS

Part A - Emergency Action Plan (Sequence of Events)

The EPTF implements the containment and eradication operation of the Action Plan. The sequence of events is given below and in the flow chart (Fig. 6.2).

Step 1	Suspicious case seen by farmer.
Step 2	Farmer reports to Extension Officer who investigates the case.
Step 2a	Diagnosis reveals endemic pest. Farmer advised of control measures by EO. **Sequence stops**.
Step 2b	EO unable to identify pest. Reports to Plant Protection Officer.
Step 3	PPO investigates.
Step 3a	Diagnosis reveals endemic pest. EO advised of control measure. **Sequence stops**.
Step 3b	Diagnosis creates suspicion of the presence of *T. absoluta*. Farmer and EO given precautionary instructions, specimens collected and pictures taken for preliminary laboratory diagnosis, by PPO.
Step 4	PPO notifies Supervisor / Chief Technical Officer (CTO) who notifies the Permanent Secretary / Minister.
Step 5	CTO activates Emergency Pest Task Force (EPTF) and additional samples and/or pictures *of T. absoluta* are collected and dispatched by the PPO to established Diagnostic Centres for more positive identification and confirmation. Information on the pest (biology, hosts behaviour pattern and the like to help in eradication or containment) is requested by the PPO from the Diagnostic Centres (DC) and Regional and International Organizations.
Step 6	The Minister / PS puts into operation the emergency mobilization plan and activates the National Emergency Pest Committee and notifies the relevant Ministries and Agencies of their role. Minister notifies Cabinet and issues declaration on internal plant quarantine regulation.

Step 7 The EPTF sets up the Headquarters and area centres, orders nation- / island- survey to determine possible spread and collects additional specimens and takes pictures. Issues general information and instructs the Field Component and Quarantine Officers. *Survey protocols outlined in Section IV.*

Step 8 Report received from DC by the PPO and eradication plan is put into operation by the CTO.

Part B - Components and Description of Tasks

Component: National Emergency Pest Committee (NEPC)

Responsibility: Promulgation of policies and coordination of input of the different Government Ministries and other agencies to prevent the entry of, control and/or eradicate any exotic pest (*e.g. T aboluta*).

Responsible Person: Chairman (Minister of Agriculture)

Functions

- Through NEPC, promulgates policies for the prevention of entry, control and eradication of foreign pest (e.g. *T. absoluta*).
- Coordinates the various inputs and makes available the resources of the different Ministries and agencies in achieving (a).
- Makes representation to Cabinet for additional financial assistance needed and in the issuance of special orders or proclamations related to (a).
- Ensures that all policies promulgated by the NEPC are implemented by the EPTF.
- Designates the Chief Technical Officer as EPTF Coordinator.

Component: Emergency Pest Task Force (EPTF)

Responsibility: Mobilisation and execution of the national emergency action plan and implementation of policies promulgated by the NEPC.

Responsible Person: Task Force Coordinator (TFCo) / Chief Technical Officer (CTO)

Functions

- Serves as the Executive Officer of the NEPC and ensures that all policies promulgated are expeditiously and effectively implemented.
- Ensures that the EPTF is in constant alert and readiness, and schedules regular field exercises to enhance its reactive capacity.
- Activates mobilization of the EPTF as soon as a report is made by the Plant Protection Officer.
- Makes immediate notification of the NEPC for mobilization of the EPTF.
- Coordinates the actions of the various components of the EPTF.
- Coordinates the activities of all the regions and assigns personnel as needed to the Regional Field Coordinator (RFCo).

- Orders the RFCo to proceed with disinfestation of infested areas as soon as diagnosis has been confirmed.
- Through the RFCo, implements surveillance to monitor the efficacy of control / eradication measures.
- Through the RFCo, serves official quarantine notices.

Component: Regional Field Coordination (RFC)

Responsibility: Execution of all the field operations in the event of an outbreak of an exotic pest e.g. *T. absoluta* in that area.

Ideally, the RFC shall consist of personnel within the region where the outbreak occurs. Authority for movement of support personnel from another region is vested upon the TFCo through the Officer-in-Charge of Extension.

Responsible Person: Regional Field Coordinator (RFCo)Establishes a field operating unit

Functions

- Selects location of headquarters close to the infested areas, which should not be more than an hour drive to the most distant area of the outbreak area.
- Selects suitable headquarters building at a location with easy flow of traffic and with ample space for storage of supplies and equipment, suitable communications and eating facilities. There should be ample parking space for field vehicles.
- Makes available a map of the area under his/her jurisdiction and points out areas of infection / infestation to all RFC personnel.
- Establishes communication with the local authorities, public, police in order to ensure security of the infected / infested area.
- Refers all requests for information regarding the outbreak by the news media to the TFCo until an Information Officer from the Agricultural Information Service has been assigned to the RFCo; gives those requesting information the telephone number of the TFCo and explains that the latter has the most complete source of up-to-date information.
- Establishes means of communication with personnel stationed in problem areas.
- Lists personnel complement of RFC and assigns them specific tasks to enable them to be put to work immediately upon arrival in the affected area.
- Gives specific assignments to support personnel arriving from the other regions.
- Requests the assignment of a Secretary.
- Meets with all personnel every evening for debriefing on the day's activities and problems, institutes remedial measures to problems, and plans for activities for the following day.
- Instructs all personnel that information to be released to the media will be through the Information Officer only.
- Gives daily debriefing report to the TFCo.
- Utilises appropriate technology to improve the effiency and effectiveness of communicating with the RFC personnel.

Component: Laboratory Services

Responsibility: Handling preliminary diagnosis and submitting specimens to reference laboratory for confirmation of field diagnosis, and development of local capability for laboratory diagnosis.

Responsible Person: Laboratory Team Leader / PPO (This person may be the PPO or a Senior Laboratory Technician)

Functions

- Collects specimens for laboratory diagnosis.
- Prepares necessary photographs of specimens collected.
- Assembles and keeps in constant readiness additional emergency kits for further collection and shipment of specimens.
- Makes prior arrangement with airlines or courier service and the reference laboratory on how specimen could be shipped as quickly as possible.
- Supervises shipment of hand-carried specimens.
- Once the EPTF is activated, makes arrangements to receive incoming specimens from the RFC and store them until confirmation is made and local laboratory diagnostic capabilities are established.
- Once local laboratory capabilities are established to handle diagnosis, supervises the operation of said laboratory.

Component: QuarantineComponent

Responsibility: Establishment and staffing of quarantine and buffer zones.

Responsible Person: Quarantine Officer (This person is a plant protection staff member or a senior member of the extension service).

Functions

- Assists the TFCo in planning and establishing quarantine and buffer zones.
- Posts pest warning signs on all roads at the outer perimeters of the quarantine and buffer zones.
- Coordinates the establishment of 24-hour police patrol (if necessary) to cover roads in both buffer, and quarantine zones to control movement of plants and other products.
- Establishes a list of all farms or areas that have received plants or plant products or any products, which are capable of transmitting the pest.
- Arranges for the inspectors to visit these farms or areas and establish control measures.
- At his/her discretion, allows the movement, on a permit basis, of perishable crops for human consumption and other non-plant products from affected farms and farms not known to be affected within the quarantine area.

Component: Information Service

Responsibility: Dissemination of information to the media and the public

Responsible Person: Information Officer. (This person is from the Agricultural Information Service. The TFCo will request the Minister of Agriculture to immediately assign and dispatch this person to the Regional Office).

Functions

- Maintains communication with the TFCo in order to keep abreast of developments and news items related to the situation
- Compiles list(s) of local news outlets (e.g. radio, newspaper, television) to notify of the situation.
- Prepares pertinent information, publication, background, materials, and photographs for distribution to mediapersonnel.

Component: Local Field Operations

Responsibility: Provision of support to operations

Responsible Person: Extension Officers

Functions

- Examines plants referred by farmers.
- Reports to the Plant Protection Officer without delay, the presence of suspicious pest case.
- Takes relevant photographs that can be included in the report to the Plant Protection officer.
- Implements all instructions of the PPO to prevent spread of *T. absoluta*.
- After confirmation of *T. absoluta* and under the supervision of the RFCo, searches for cases and identifies all affected plants.
- Supervises and carries out destruction of all affected plantsand plant parts.
- Implements on-the-spot disinfestation of the area.

Component: Police Component

Responsibility: Provision of security

Responsible Person: Commissioner of Police

Functions

- Assists quarantine officials in securing the area.
- Prevents access as directed by the Quarantine Officer.

Component: Fire Department

Responsibility: Supervise, monitor and assist with cutting burning and disposal.

Responsible Person: Chief Fire Officer

Functions

- Makes fire equipment available for use in cleaning.
- Supervises clearing and burning of infected material.

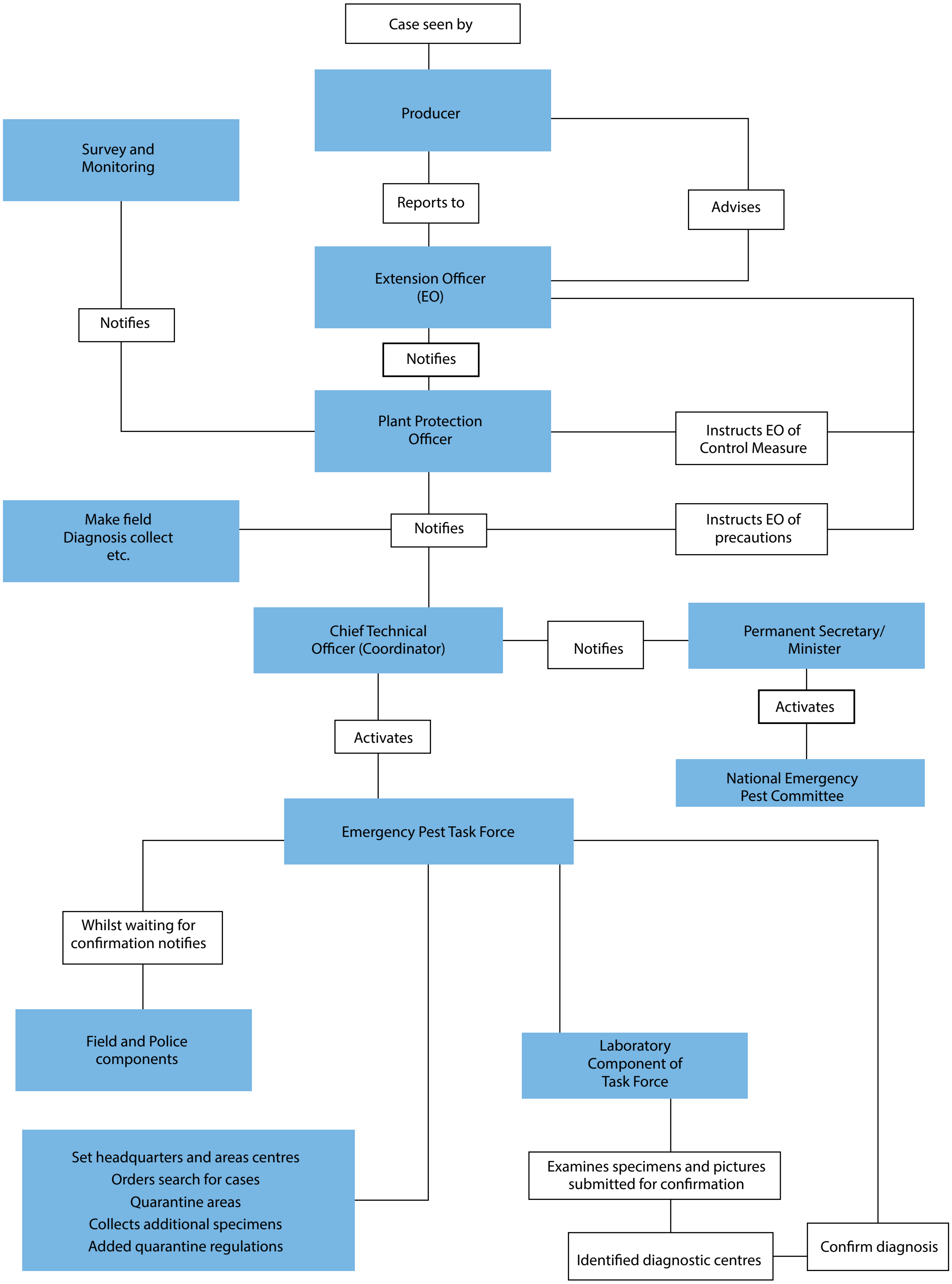

Figure 6.2 Flow-Chart – Mobilisation of the National Emergency Pest Committee

IMPORTANT NOTE

All country plans should have the following information presented as Annexes

Annex 1:	List of Names, Addresses and Telephone Numbers of Members of National Emergency Pest Committee
Annex 2	Map of (Country) by Agricultural Region and Ports of Entry
Annex 3	The Plant Protection and Quarantine Act
Annex 4	Customs Declaration Form
Annex 5	Cabinet Decisions
Annex 6	Sample of Declaration to be Signed by Captain
Annex 7	Pest List of (Country)

Financial Resources

When planning the national response for the prevention, entry and or establishment of *T. absoluta*, it is important to prepare a detailed budget outlining the material supplies required for each action. The Table below presents a possible list of items to be included in the budget and the template for setting-up a budget sheet to capture costs and the sources of funds.

Table 6.2 Budget items required for prevention, entry and or establishment of *Tuta absoluta*

Action	Budget Items	Action	Budget Items
Surveillance	- Traps	**IPM**	- Field kit (magnifying glasses, bags, etc.)
	- Pheromones		- Insecticides
	- Databases		- Biological control agents
	- Tags		- Application Equipment
	- Motor Vehicle (gasoline, mileage for field officers)		- Traps for Mass trapping
	- GPS		- Pheromones lures
	- Magnifying Glasses		- Motor vehicle costs Fuel
	- Stationery		- Demonstration site
	- Shipping costs and brokerage fees		- Data collection tools (clip board, pens, paper)
	- Camera		- Sample collection (bags, crates, scales, tags, markers)
			- Shipping costs and brokerage fees
			- Camera
Diagnosis	- Entomological bottles	**Public awareness and Training**	- Projector
	- Alcohol		- Screen for projection
	- Cooler		- Stationery
	- Disposables (Cotton, paper towels)		- Reference material and samples
	- Office supplies (stapler, staples, small clips, pends, highlighters, folders, tags)		- Reproduction of reference material
	- Computer supplies (paper, toner)		- Media (newspaper articles, Videos, posters, brochures and other information products.
	- Preservation of samples (vials, minuten pins, petri dishes, forceps, scapels)		- Establishing and maintaining hotline
	- Equipment – computer, microscopes		

Example of Budget Sheet

Action	Materials	Unit Cost USD	Quantity	Total Costs USD	Source of Funds
TOTAL					

NB. Add as many rows required

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