بسم الله الرحمن الرحيم

Hebron University
College of Graduate Studies
M. Sc. Program in Plant Protection

Field Studies on Biology, Ecology and Management of the Tomato Borer, *Tutu absoluta* Meyrick [Lepidoptera: Gelechiidae] in the Southern High Lands of West-Bank, Palestine

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This thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Plant Protection, College of Graduate Studies at Hebron University, Hebron, Palestine

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Dedication

I Would Like To Dedicate This Thesis To:

My Parents

My Wife

My Daughter

Acknowledgments

I would like to thank all who helped me during my study:

My sincere appreciation and respect to my Supervisor Dr. Abdul-Jalil Hamdan for his tireless supervision, serious guidance, support and encouragement.

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Abstract

Tuta absoluta is a devastating pest of tomato. It is originated from South America. This pest is crossing boarders and devastating tomato production both protected and open fields. The infestation of *T. absoluta* also reported on potato, Eggplant and common beans Recently, *T. absoluta* considered to be a serious threat to tomato production in Mediterranean region.

This research is conducted in Al-Arroub Agricultural Research Station, at the southern highlands of Palestine during 2011-2012 and had three objectives, which were: to monitor the annual flight activity and seasonal abundance of the *T. absoluta*; to record the host susceptibility and rate of infestation of *T. absoluta,* and to investigate the susceptibility various tomato cultivar under open field and greenhouse condition; and to investigate the effect of some common sense control measure as alternatives to chemical insecticides.

Throughout this research, tomato; eggplant and pepper plants were found to be susceptible to *T. absoluta* infestation both in open field and in greenhouse cropping system. In addition, the highest rate of infestation recorded on tomato, followed by eggplant and the lowest was on pepper plants. Furthermore, all investigated tomato cultivars were susceptible to *T. absoluta* infestation both in the open field and in the greenhouses.

For the second objective, results show that, two peaks of flight activity of *T. absoluta* were recorded in the open field, the 1^{st} peak was recorded at late June and the 2^{nd} peak was at late July. Furthermore, the flight activity of *T, absoluta* that were recorded in the open field was higher than that recorded in the greenhouses.

As for the last objective, both Petroleum oil and *B.t* treatments were significantly higher in their efficiency for control of *T. absoluta* in the open field. Meanwhile, Mass-trapping of *T. absoluta* using sex pheromone sticky traps was able to suppress the *T. absoluta* population in the greenhouse plantation.

In conclusion, further study is recommended to be done on rate of Mass-Trapping Technique that might be applied in open field as well as in the greenhouse cropping system.

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Introduction

Introduction

Tuta absoluta is a devastating pest of Tomato. It is originated from South America. This pest is crossing boarders and devastating tomato production both protected and open fields. The infestation of *T. absoluta* also reported on potato, and Eggplant. Recently, *T. absoluta* considered to be a serious threat to tomato production in Mediterranean region.

Since the introduction of *T. absoluta* in the Mediterranean region, several studies have been conducted on the ecology of this pest as well as on its control, and several native natural enemies have been identified as potential biological control agents. Past research and experience with alien species invasions suggested that invaders are likely to attract natural enemies over time. However, in the case of *T. absoluta*, limited data is available on the natural levels of biological control in open-field environments and the expected reduction in yield loss (Balzan and Moonen, 2012).

T. absoluta has been responsible for losses of 80-100% in tomato plantations in both protected cultivation and open fields. It attacks all aerial parts of the host (leaves, stems and fruits). Once introduced, *T. absoluta* can be spread by seedlings, infested vines with tomato fruit, tomato fruit and used containers. Outdoor markets, vegetable repacking and distribution centers are potential introduction points in the spread of this pest (CFIA, 2010). The economic impact is reflected by an increase in the cost of tomato production (additional costs for crop protection) and yield loss (lower marketable production), as well as potential loss of markets if it were to become established. It is also very challenging to control and limit the spread of the pest (NAPPO, 2012).

The impact that *T. absoluta* could represent for North America underscores the need to implement measures to prevent its introduction into the region or control it if it is introduced. To this end, the North American Plant Protection Organization (NAPPO) provides guidelines for regional surveillance for the tomato leaf miner in North America (Canada, Mexico and United States) (NAPPO, 2012).

Even though the ecology of the pest is well known, limited data is available on management practices in open field cultivations to control yield loss from this newly introduced species. On the other hand, several (integrated) pest management strategies have been developed for the protection of glasshouse tomatoes (NAPPO, 2012).

This pest occurs throughout the entire growing cycle of tomatoes, destined to fresh market and processing, and larval feeding can cause losses of up to 100% by attacking leaves, flowers, stems and, especially fruits (Apablaza, 1992; Barrientos *et al*., 1998; Guilardon *et al*., 2001).

The pest is generally easily found because it prefers apical buds, flowers or new fruits, on which the black frass is visible. On potato, only aerial parts are attacked and *T. absoluta* does not develop on tubers (Notz, 1992; Caffarini *et al*., 1999). The young larvae penetrate into tomato fruits, leaves or stems on which they feed and develop, thus creating conspicuous mines and galleries. Fruits can be attacked as soon as they are formed, and the galleries bored inside them can be invaded by secondary pathogens leading to fruit rot. On leaves, larvae feed only on mesophyl tissues, leaving the epidermis intact. Leaf mines are irregular and may later become necrotic. Galleries in stems alter the general development of the plants.

Recently *T. absoluta* considered to be a serious threat to tomato production in Mediterranean region. The newly introduced pest from South America finding the shores of the Mediterranean a perfect new home where it can breed between 10-12 generations a year and, each female can lay 250-300 eggs in her life time. This pest is crossing boarders and devastating tomato production both protected and open fields. The infestation of *T. absoluta* also reported on potato, Eggplant and common beans. Therefore, this research was proposed for the following **Objectives**:

- To monitor the annual flight activity and seasonal abundance of the *T. absoluta*.
- To record the host susceptibility and rate of infestation of *T. absoluta*, and to investigate the susceptibility of various tomato cultivar under open field and greenhouse condition.
- To investigate the effect of some common sense control measure as alternatives to chemical insecticides.

Chapter One: Literature Review

Chapter one: literature review

1.1 Origin and Distribution

Tuta absoluta is originated from South America. It is a serious pest in South America since the 1980's and distributed in Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela (EPPO, 2005). Since the first detection in Spain in 2006, this pest is spreading rapidly across Southern Europe and North Africa to engulf the whole of the Mediterranean countries.

Until today, the presence of *T. absoluta* has been reported in Italy, France, Malta, United Kingdom, Greece, Switzerland, Portugal, Morocco, Algeria, Tunisia, Libya and Albania during last two years (EPPO, 2008a 2008b 2008c 2009a; 2009b; 2009c; 2009d; and FERA, 2009).

Fig. 1.1: Mediterranean distribution of *Tuta absoluta*

1.2 Host plant

The tomato leaf miner causes direct and indirect damage to the production of tomato, potato, eggplant, and pepper, although it does not specify if the damage includes damage to fruit.

Hosts reported for *T. absoluta* are listed in Table 1.1. The hosts were reported from their current distributions, and the host species may not be present in the United States. If pests are introduced into new areas, they may attack native species that have not previously been identified as host plants. Therefore, host species should be surveyed (where applicable) and surveys should be broadened to native species within the host genera.

Table 1.1: List of reported host plants for *Tuta absoluta*

Host	Common Name	Source
Capsicum annuum L	Pepper	Ministero delle Politiche Agricole Alimentari e Forestali, (2009)
Datura quercifolia Kunth (*Datura ferox* Kunth)	Long-spined thorn apple	EPPO (2005)
Datura stramonium L.	Jimson weed (devil's trumpet)	Vargas (1970)
Nicotiana tabacum L.	Tobacco	Galarza (1984); Fernandez & Montagne (1990b)
Physalis peruviana L	Cape gooseberry	Garzia (2009b)
Solanum americanum Miller	American nightshade	Fernandez & Montagne (1990b)
Solanum lycopersicum L. (*Lycopersicon esculentum* Miller)	Tomato	Vargas (1970); Fernandez & Montagne (1990b)
Solanum melongena L.	Eggplant	Galarza (1984); Fernandez & Montagne (1990b); Ministero delle Politiche Agricole Alimentari e Forestali (2009); Viggiani et al. (2009)

Solanum muricatum Aiton	Sweet cucumber (pepino)	FERA, 2009b
Solanum nigrum L.	Black nightshade	Vargas (1970)
Solanum pseudo-capsicum L.	Jerusalem cherry	Galarza (1984)
Solanum tuberosum L.	Potato	Pastrana (1967); Vargas (1970); Galarza (1984); Fernandez & Montagne (1990b); FREDON-Corse (2009b); Maiche (2009)
Solanum sisymbriifolium Lamb.	Sticky nightshade (litchi tomato)	Galarza (1984)
Phaseolus vulgaris L	Common bean	Ministero delle Politiche Agricole Alimentari e Forestali (2009)

1.3 Biology of *Tuta absoluta*

1.3.1 Identification:

Scientific name: *Tuta absoluta* Meyrick [Lepidoptera: Gelechiidae]

Common names: Tomato leaf miner, tomato borer, South American tomato moth, South American tomato pinworm.

T. absoluta is a holometabolous insect with a high rate of reproduction. It may be able to complete 12 generations per year depending on environmental conditions (EPPO, 2005). In the laboratory (at a constant temperature of 25°C and 75 % R.H.), *T, absoluta* completes a generation in 28.7 days (Vargas, 1970). Given the field conditions in the Arica Valley in Chile, *T. absoluta* could complete seven to eight generations per year at that location (Vargas, 1970). Since this pest can infest hosts grown in protected situations (such as greenhouses), its rapid reproductive rate should be kept in mind. The species can over winter in the egg, pupal, or adult stage (EPPO, 2005).

1.3.2 Life cycle of *Tuta absoluta*

Tuta absoluta is a micro lepidopteran moth with a high reproductive potential, capable of up to 12 generations per year under optimal conditions. Its life-cycle comprises four development stages: egg, larva, pupa and adult, and is completed within 24 days at 27°C.

Eggs are small, cylindrical, creamy white to yellow- orange, and 0.35 mm long. Females usually lay eggs on the underside of leaves or stems and to a lesser extent on fruits. Egg hatch occurs in 4-6 days. After hatching, young larvae penetrate leaves, aerial fruits or stems, on which they feed and develop.

Larvae are cream colored with a characteristic dark head and a lateral spot that extends from the ocellus until the posterior margin. Larvae lack a typical dorsal plate in the prothorax. Instead they have a dark oblique band that does not cover the dorsal midline (NAPPO, 2012).

The insect develops through four larval instars before transforming into the pupal stage. The larval instars do not enter diapauses when a food source is available. As they grow older, they become greenish to light pink in the second to fourth instars (by feeding on leaves) and measure between 1 and 8 mm. The larval period is the most damaging period to plants and is completed within 12-15 days.

The larvae of *T. absoluta* attack the foliage by penetrating into the leaf and feeding on the mesophyll tissues. The feeding behaviour results in irregular mines on the leaf surface (NAPPO, 2012).

Subsequently, damaged leaves shrivel, decreasing the photosynthetic capacity of the plants and potentially decreasing the plant's ability to defend itself from other harmful agents. When the attacks are severe, the leaves have a burnt appearance.

Pupae are cylindrical in shape and greenish when just formed, becoming darker in colour as they near adult emergence. The pupae are often coated with a white silky bud. Pupae have been found in the mines, outside the mines and in the soil, as well as beneath pots and under greenhouse benches (NAPPO, 2012).

1.3.2.1 Eggs

Eggs are laid singly (rarely in batches) on all above-ground parts of the host Plant (Bloem & Spaltenstein, 2011). Eggs are oval with an average 0.383 mm long by 0.211 wide (Vargas, 1970); Newly-laid eggs are creamy white and turn yellow and then yellow-orange during development When mature, eggs turn dark and the outline of the larval head capsule can be seen through the chorion; this is called the blackhead stage (Estay, 2000).

1.3.2.2 Larvae

Larvae complete four instars that are well-defined and are of different size and color (Estay, 2000), but variation in the number of instars is well-documented within any species of Lepidoptera. After hatching, larvae enter the plant tissue and begin feeding, thus creating mines (Bloem& Spaltenstein, 2011).

In tomato, young larvae can mine leaves, stems, shoots, flowers, and developing fruit; later instars can attack mature fruit (Vargas, 1970). Larval mines increase in length and width as the larva develops and feeds. In cases of severe attack, all leaf tissue is consumed leaving behind a skeletonized leaf and large amounts of frass. Larvae spin silken shelters in leaves or tie leaves together (Vargas, 1970).

1.3.2.3 Pupae

Newly formed pupae are greenish and turn dark brown as they mature (Estay, 2000). Male pupae are lighter (3.04±0.49 mg) and smaller (length 4.27±0.24 mm and width 1.23±0.08 mm) than female pupae (4.67±0.23 mg; 4.67±0.23 mm and 1.37±0.07 mm) (Bloem & Spaltenstein, 2011).

1.3.2.4 Adult

Adults are 5-7 mm long and with a wingspan of 8-10mm. The main diagnostic character of this species is filiform antennae (bead like antennae) dark larval head and pink in color in later instars. Adults are nocturnal and usually hide during the day between leaves.

Adults are about 1 cm long, with a wingspan of about 1 cm. There is no obvious sexual dimorphism, although the abdomen in male moths is narrower and pointed posteriorly, while that of females is wider and bulkier. Abdominal scales are gray in males and cream colored in females. Adult moths are mottled gray in color. Antennae are long and filiform (Bloem & Spaltenstein, 2011).

Taxonomic identification requires dissection of the male genitalia. For further information, refer to the images of genitalia in the screening aids provided by Brambila *et al*. (2010). Electronic versions of the screening aids are also available at the Web site of the Cooperative Agricultural Pest Survey (CAPS).

The sex ratio in field-collected populations in Venezuela was 1.33 females:1 male (Fernandez and Montagne, 1990a). Adult males live longer than females. In the laboratory, mated males lived 26.47±7.89 days while virgin males lived 36.17±6.55 days. Mated females lived 23.24±5.89 days while virgin females lived 27.81±10.78 days (Fernandez and Montagne, 1990a).

Both genders mate multiple times. The first mating usually occurs the day after adults emerge. Mating occurs at dawn (Vargas, 1970). Studies in Chile revealed that the greatest number of males was captured in pheromone traps during the period 7 to 11 a.m., suggesting that this is the time when males are searching for calling females (Miranda-Ibarra, 1999).

1.3.3 Adult longevity

Most longevity studies have been conducted using caged flies in close condition with a host plant, Adult longevity was highest at 10°C with adult moths living for 40 days (when supplied with a food source) and lowest at 19°C where they survived for 16 days. Again, this could be related to physiological age and less activity at the lower temperatures (Fernandez and Montagne, 1990a).

1.3.4 Fecundity

The high nutritional quality of tomato had positive effects on the development (less developmental time and higher pupal weight) of *T. absoluta*, and on the capacity of population increase (higher R_o and r, and lower T).

Previous studies conducted by Pereyra (2002) demonstrated that, pupal weight and fecundity of *T. absoluta* were related, since 71% of variation in fecundity was explained by the pupal weight. This means that those females that reached higher pupal masses were able to lay more eggs for the future generation. This positive relationship between pupal weight and fecundity has also been observed for other lepidopteran species (Bessin & Reagan 1990, Awmack & Leather 2002).

Vercher et al. (2010) were able to maintain *T. absoluta* larvae alive during, several weeks at 4°C. When *T. absoluta* does not pupate in the soil, a cocoon is usually built.

Under Mediterranean conditions, adults of *T. absoluta* can be detected all around the year (Vercher *et al*. 2010). Adult lifespan ranges between 10 and 15 days for females and 6–7 days for males (Estay, 2000).

Females mate only once a day and are able to mate up to six times during their lifespan, with a single mating bout lasting 4–5h. The most prolific oviposition period is 7 days after first mating, and females lay 76% of their eggs at that time, with a maximum lifetime fecundity of 260 eggs per female (Uchoˆa-Fernandes *et al*. 1995).

1.3.5 Feeding and oviposition behavior

The insect develops through four larval instars before transforming into the pupal stage. The larval instars do not enter diapauses when a food source is available. As they grow older, they become greenish to light pink in the second to fourth instars (by feeding on leaves) and measure between 1 and 8 mm. The larval period is the most damaging period to plants and is completed within 12-15 days (NAPPO, 2012).

The larvae of *T. absoluta* attack the foliage by penetrating into the leaf and feeding on the mesophyll tissues. The feeding behaviour results in irregular mines on the leaf surface. Subsequently, damaged leaves shrivel, decreasing the photosynthetic capacity of the plants and potentially decreasing the plant's ability to defend itself from other harmful agents. When the attacks are severe, the leaves have a burnt appearance (NAPPO, 2012).

Older (3rd - 4th instars) larvae can feed on all parts of tomato plants. They can leave their mines and travel to new locations to mine again. This behaviour may result in damage to all stages of plant growth. The larvae produce large galleries in the leaves, burrow into stalks, apical buds, and green and ripe fruits. Fully-grown larvae usually drop to the ground on a silk thread and pupate in the soil, although pupation may also occur on leaves or in the calyx (NAPPO,2012).

The average preoviposition period for females was 2.4±0.61 days (Fernandez and Montagne, 1990a). Female fecundity can range between 60 to 120 eggs (Torres *et al*., 2001), but each female can lay up to 260 eggs in a lifetime (CABI, 2011). Oviposition studies in laboratories showed that females can lay eggs for more than 20 days; however, 72.3 percent of the eggs were deposited during the first 5 days and 90 percent in the first 10 days (Fernandez and Montagne, 1990).

1.4 Damage

Infestation of tomato plants occurs throughout the entire crop cycle. Feeding damage is caused by all larval instars and throughout the whole plant. On leaves, the larvae feed on the mesophyll tissue, forming irregular leaf mines which may later become necrotic. Larvae can form extensive galleries in the stems which affect the development of the plants. Fruit are also attacked by the larvae, and the entry-ways are used by secondary pathogens, leading to fruit rot. The extent of infestation is partly dependent on the variety. Potential yield loss in tomatoes (quantity and quality) is significant and can reach up to 100% if the pest is not managed (http://www.irac-online.org/).

Adult female could lay hundreds of eggs during her life time. Tomato plants can be attacked from seedlings to mature plants. In tomato infestation found on apical buds, leaves, and stems, flowers and fruits, on which the black frass is visible. On potato, mainly aerial parts are attacked. However damage on tuber also recently reported (http://www.tutaabsoluta.com/tuta-absoluta).

1.5 Integrated Pest Management

Integrated pest management (IPM) programs are being developed in several countries to manage infestations of *T. absoluta*. Most IPM programs include the monitoring of pest populations; effective methods of prevention and control; and the use of pesticides when needed. Biological control is also implemented if available.

In Spain, IPM for *T. absoluta* includes the mass-trapping of adults prior to planting; clearing of crop residues from planting soil; application of imidacloprid in irrigation water 8 to10 days after planting and application of spinosad or indoxacarb when *T. absoluta* is detected; and elimination of crop residues immediately after the last fruits have been harvested (Robredo-Junco and Cardeñoso-Herrero, 2008).

In Argentina, IPM for *T. absoluta* in greenhouse tomatoes has been tested at INTA (Instituto Nacional de Tecnología Agropecuaria) over the last 10 years with positive results (Botto, 1999; 2011). The strategy includes the monitoring for early detection of adults using pheromone traps and visual inspection of plants, primarily for eggs; and inundative releases of *Trichogrammatoidea bactrae*, initiated when the first adults are trapped and/or the first eggs are observed; use of *Bacillus thuringiensis* in conjunction with (or after) release of egg parasitoids to control larvae; compatible pesticides based on safe pesticide usage if necessary; crop rotation with non-host plants and cultural control practices in the greenhouse and surrounding environment (Botto, 1999; 2011).

1.5.1 Monitoring

Zalom *et al*., (2008) recommended to monitor for the tomato pinworm, *Keiferia lycopersicella*, using Pherocon 1-C trap, (a type of Delta trap) and suggested that traps be installed at the time of planting at the density of one per 10 acres (4.04 ha), but with no fewer than 2 traps per field. They also suggest that a trap with no lure be used to serve as a control for lure effectiveness in the field. In addition Zalom *et al*., (2008) recommended that monitoring for early detection of adults to be conducted by using pheromone traps and primarily visual inspection of plants for eggs.

1.5.1.1 Pheromone-Baited Traps

Traps baited with synthetic sex pheromone were used for monitoring populations of *T. absoluta* in open fields, greenhouses, and packing sites. Sex pheromone-baited traps will capture only adult males. The sex pheromone of *T. absoluta* has been isolated and identified. The main compounds are (3E, 8Z, 11Z)-3,8,11-tetradecatrien-1-yl acetate and (3E, 8Z)-3,8-tetradecadien-1-yl acetate in the proportions of 90:10, respectively (Svatos *et al*., 1996).

1.5.2 Biological Control

Biological control is being investigated in most countries where *T. absoluta* is present. Natural enemies including parasitoids, predators and entomopathogens were investigated.

1.5.2. 1 Egg Parasitoids

Trichogramma pretiosum; T. achaeae, and *Trichogrammatoidea bactrae*, parasitized the eggs of *T. absoluta*. In one study, adults of *T. absoluta* were released onto fully developed tomato plants, followed by the release of *T. pretiosum* 12 hours later. After 24 hours, the level of egg parasitism varied between 1.5 to 28 percent (Faria *et al*., 2008).

Also, in greenhouse grown tomatoes, inundative releases of *T. bactrae* to control *T. absoluta* gave good results (Botto et al., 2009; Riquelme et al., 2006; Cabello et al., 2009a). Furthermore, In greenhouse tomatoes, there was a 91% reduction in damage when 30 *T. achaeae* per plant (75 adults/m2) were released every 3 to 4 days (Cabello *et al*., 2009a). However, under laboratory conditions, 100 percent parasitism by *T. achaeae* was reported and of those, 83% developed to the blackhead stage.

1.5.2. 2 Larval Parasitoids

Larvae of *T. absoluta* spend most of their lifetime inside mines; however, second instars leave their mines during the cooler times of the day making them vulnerable to parasitoids and predation (Torres *et al*., 2001). Of the larval parasitoids, the braconid *Pseudapanteles dignus* is frequently found parasitizing larvae in South America (Sanchez *et al*., 2009).

Studies have shown that female parasitoids attack hosts daily and do not have a preference among larval instars and, parasitism of *T. absoluta* by *P. dignus* can reach up to 46% in late tomato crops (Sanchez *et al*., 2009). In Argentina, researchers have tested inoculative releases of *P. dignus* in greenhouses before *T. absoluta* reaches high population levels (Botto, 2011).

1.5.2. 3 Predators

The damsel bug *Nabis pseudoferus* is an effective egg and larval predator of *T. absoluta* in Spanish greenhouses (Cabello *et al*., 2009b). In two semi-field studies, first stage nymphs of *N. pseudoferus* released onto tomato plants (8 to 12/plant) killed *T. absoluta* eggs, reducing the number of eggs by 92%. In addition, adults and last instar nymphs of *N. pseudoferus* were also observed preying on larvae of *T. absoluta*, even when these were inside the mines (Cabello *et al*., 2009b). Thus, *N. pseudoferus* is widely distributed in Europe and is commercially available, and, the recommended dose for outbreaks was 10 - 15 individual/m2.

However, according to a report from the United Kingdom, *N. tenuis* is problematic because it can attack host plants when prey are in short supply. Plant feeding causes brown rings in the vascular tissue and destruction of the plant's growing points (Sanchez et al., 2008; Sixs mith, 2009).

The mirids, *Macrolophus pygmaeus* and *Nesidiocoris tenuis* are endemic to Spain and feed on eggs and larvae of *T. absoluta*. In one study, adult *M. pygmaeus* and *N. tenuis* consumed 30+ eggs and 2 *T. absoluta* larvae daily (Urbaneja *et al*., 2009). Although both species were observed feeding on all life stages of *T. absoluta*, they preferred first-instar larvae.

1.5.2. 1 Entomopathogens

Bacillus thuringiensis has been recommended for control of *T. absoluta*. More recently, the muscadine fungus, *Metarhizium anisopliae* (Metschn) Sorokin has been studied for control of *T. absoluta* (Pires *et al*., 2009).

Adult females infected with *M. anisopliae* did not reduce their oviposition or fecundity, however, infection with this fungus resulted in 37 %

female mortality, and eggs exposed to *M. anisopliae* were all infected after 72 hours.

Beauveria bassiana (strain GHA 1991) was tested alone or in combination with *B. thurengiensis* for control of *T. absoluta* in open tomato fields in Ibiza, Spain, and, both treatments reduced the number and severity of fruit damage when compared to the control (Torres *et al*., 2001).

1.5.3 Chemical control

Historically, *T. absoluta* has been controlled with chemicals. Organophosphates and pyrethroids were used during the 1970's and 1980's until new products introduced in the 1990's (such as abamectin, spinosad, tebufonzide, and chlorfenpyr) became available (Lietti *et al*., 2005). At least 12 classes of insecticides control *T. absoluta* (IRAC, 2009a, 2009b).

Control failures with organophosphates and pyrethroids in South America (Salazar and Araya, 2001) prompted research on the resistance status of *T. absoluta* (Lietti *et al*., 2005; Siqueira *et al*., 2000a, 2000b); however, newer classes of insecticides are providing good control of this pest (IRAC, 2009a).

Indoxacarb, spinosad, imidacloprid, deltamethrin, and *B. thuringiensis* var. *kurstaki,* were applied for the control of larval infestations in Spain (FERA, 2009b; Russell IPM, 2009b). However, Chlorpyrifos and pyrethrins were used in Italy (Garzia *et al*., 2009a).

Spain authorized the temporary use of four additional pesticides for the control of *T. absoluta* including: chlorantraniliprole, flubendiamide, emamectin, and metaflumizone (MARM, 2010). However, temporary use was granted because existing control methods were insufficient to control *T. absoluta* in some parts of Spain.

Chapter Two: Materials and Methods

Chapter 2: Materials and Methods

Following experiments were conducted in Al-Arroub Agricultural research station during 2011-2012:

2.1 Studies on host susceptibility and seasonal abundance of *T. absoluta* in Al-Arroub Agricultural Station.

2.1.1 Susceptibility of some solanaceae crops to *T. absoluta* infestation in open field:

An area of one dunum was divided into two experimental blocks half dunum each. Each experiment consisted 9 lines:

1st experimental block was planted with three solanaceous host plants (Fig. 2.1): Tomato (*Lycopersicon lycopersicum*, cv 16/84); Eggplant (*Solanum melongena*, cv Classic); and Sweet Pepper (*Capsicum annuum*, cv Orly).

2nd experimental block was planted with three tomato cultivars (1684, 56 & taiba) (Fig. 2.2).

The experiment started in the open field on 26th May 2011. Three replications of each cultivar were randomly distributed within the specific block as shown in Fig.2.1 & 2.2. Each replicate consist of three lines (10 m length*1 m width), each line was planted with 20 plants of the specific crop at spaces of 0.5m between plants along the line. A border of one meter was left between blocks without planting.

Weekly observations were done on 10 plants from the middle line in each replicate. Parameters recorded including:

1. Proportion of infested plants
2. Number of infested leaves/ plant.
3. Number of mines/ plant.

TOMATO 1684	EGGPLANT CLASSIC	PEPPER ORLY	EGGPLANT CLASSIC
PEPPER ORLY	TOMATO 1684	EGGPLANT CLASSIC	TOMATO 1684
EGGPLANT CLASSIC	PEPPER ORLY	TOMATO 1684	PEPPER ORLY

Fig 2.1: The host plant in open field

56	1684	TAIBA	1684
TAIBA	56	1684	56
1684	TAIBA	56	TAIBA

Fig 2.2 Tomato cultivars In open field

2.1.2 Susceptibility of some solanaceous crops to *T. absoluta* infestation in greenhouse conditions:

One plastic house 9m width and 33m length was divided into two experimental blocks:

1st experimental block (Fig. 2.3) was planted with three solanaceous host plants: Tomato (*Lycopersicon lycopersicum*, cv 144); Eggplant (*Solanum melongena*, cv Classic); and Sweet Pepper (*Capsicum annuum*, cv Orly).

2nd experimental block (Fig. 2.4) was planted with three tomato cultivars **(**144, 259, Manar).

The experiment started on 28th May 2011. Three replications of each cultivars of each crop were randomly distributed within the specific block as shown in Fig. 2.3 & 2.4. Each replicate consist of one lines (10m length*1m width), planted with transplants of the specific cultivar at space of 0.5m between plants along the line. A border of one meter was left between blocks without planting.

Weekly observations were done on four plants from each replicate. Parameters recorded including:

1. Proportion of infested plants
2. Number of infested leaves/ plant.
3. Number of mines/ plant.

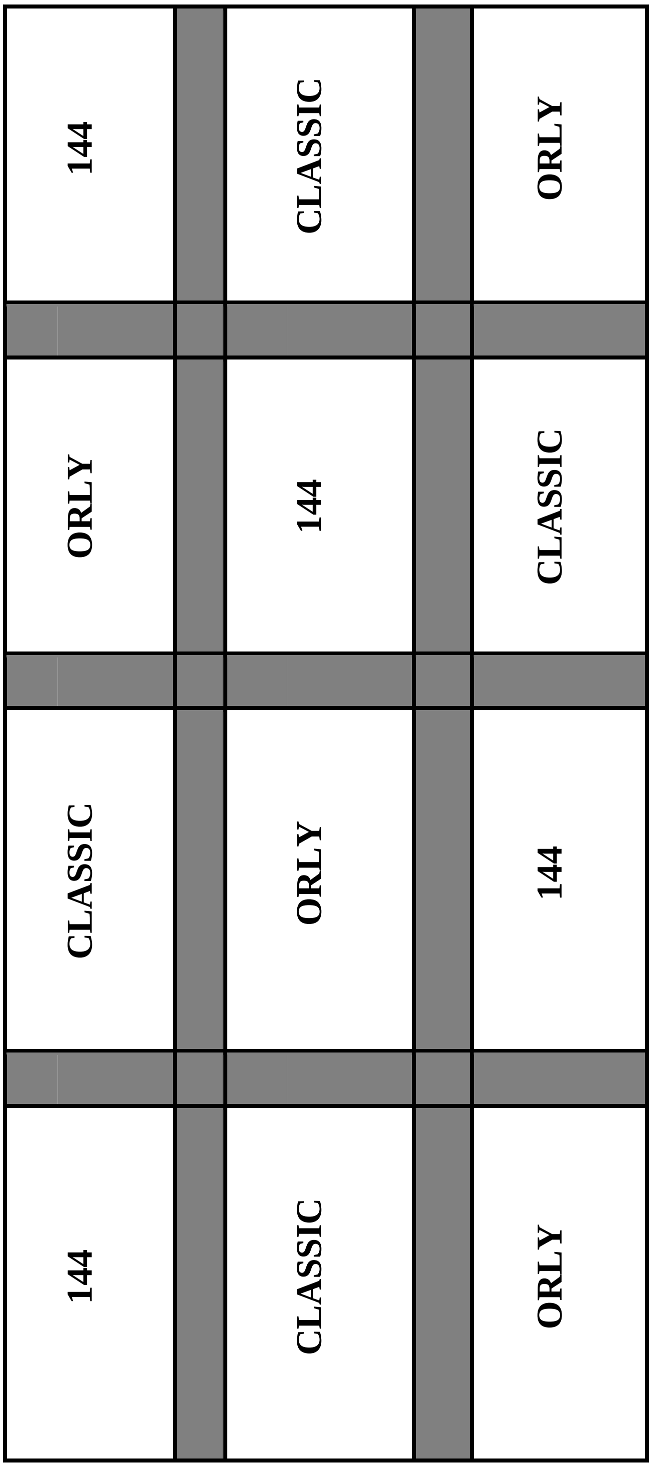

Fig 2.3: Host plants in the green house

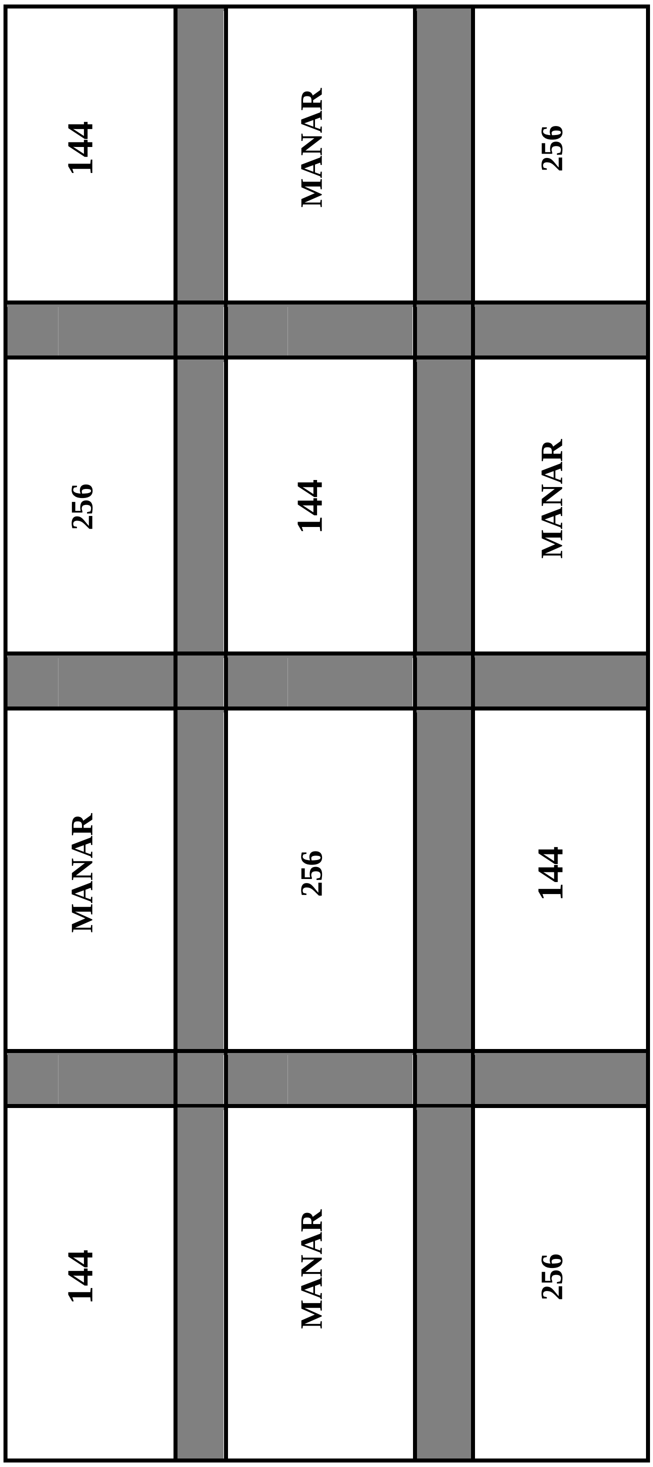

Fig 2.4: Tomato cultivars in the green house

2.2 Study on the effect of cropping system on flight activity of *T. absoluta* within open field and greenhouse plantation throughout 2011.

This experiment started on 26th May 2011 in the open field and, on 28th May 2011in the greenhouse.

- Traps baited with synthetic sex pheromone were used for monitoring populations of *T. absoluta* in open fields and greenhouses. Sex pheromone-baited traps used for capturing adult males. The main compounds are (3E, 8Z, 11Z)-3, 8, 11-tetradecatrien-1-yl acetate and (3E, 8Z)-3,-tetradecadien-1-yl acetate in the proportions of 90:10, respectively (Svatos *et al*., 1996).

One pheromone trap (Jackson trap) was placed in the middle of the open field at 0.5 m high, and another trap placed in the greenhouse at 2m, high.(Fig. 2.5)

- Traps were observed weekly starting from 26th May 2011

- The pheromone lure were changed monthly

Fig 2.5: Jackson Sticky trap used to monitor flight activity *T. absoluta*

2.3 Investigation on some common sense control measures to control *T. absoluta* on tomato plants

This study was conducted in open field as well as in the greenhouse (Table 2.1).

Table 2.1: Time schedule of the control experiments applied in the open-field and in the greenhouses.

Field	Tomato cv	Date of Planting	Treatment	Date of treatment	Date of observation
Open field	1684	21st May 2012	6 treatments	31st July 2012 (Spray)	22nd July; 7th Aug. and 25th Aug.
Greenhouse (1)	144	22nd May 2012	Mass trapping	23rd May 2012 (Insert Traps)	23rd July; 8th Aug. & 26th Aug..
Greenhouse (2)	144	22nd May 2012	*CK	*CK	23rd July; 8th Aug. & 26th Aug..

*: CK= Control

Treatments: Five common sense control measures were applied compared with control treatment in the open field (Fig. 2.6), meanwhile, Mass-trapping Technique was used in the 1st greenhouse by inserting 4 sticky sex-pheromone traps in the greenhouse on 23rd May 2012 (Fig. 2.7) and the 2nd greenhouse was used as control treatment compared with the mass-trapping in the 1st.

Replications: Four replications of each treatment were applied in open field, each replication consists of 3 lines 10 m length. Plant spaces of 1 m between lines and 0.5m within the plants in the same line.

Following common sense control treatments that were used in the open field:

1. **Microbial Insecticide:**
   - Product name: **BIO-T PLUS**
   - Active Ingredient: a liquid concentrate of *Bacillus thuringiensis var. kurstaki*.: 16000 International units per milligram (IU/mg)
   - Use: Insect repellant and anti-feedant
   - Dose: 1.75 ml/L
   - Company: Biodalia Microbiological Technology

2. **Botanical oils:**
   - Product name: **NIMBAR**
   - Active Ingredient: Neem oil 0.4 %, Pyrethrum 0.02%
   - Use: Insect repellant and anti-feedant
   - Dose: 1.25 ml/L
   - Company: Green Guard

3. **Horticulture oil:**
   - Product name: **SAF-T-SIDE**
   - Active Ingredient: Petroleum oil 80%.
   - Use: Insect repellant and anti-feedant
   - Dose: 2.5 ml/L
   - Company: AGRICARE

4. **Insect Growth Regulator:**
   - Product name: RIMON
   - Active Ingredient: **Novaluron 10% EC**
   - Use: Chitin Synthesis Inhibitor Insecticide

- Dose: 1.25 ml/L
- Company: **Makhateshim Agan Industries Ltd**

5. **Chemical insecticides**:
   - Product name: VERTIMEC
   - Active Ingredient: Abamectin 18gm/L
   - Use: Acaricide/Insecticide
   - Dose: 0.75 ml/L
   - Company: Syngenta Crop Protection AG

6. **Control: without any treatment**

Parameters that were recorded 22nd July; 7th Aug. and 25th Aug in the open field:

1. Number of infested leaves/plant.
2. Number of mines/plant.

However, same parameters were recorded in the two greenhouses on 23rd July; 8th Aug. & 26th Aug.

Design of the experiment: Completely Randomize Block Design (Fig. 2.6) was used in the open field with 6 treatments and 4 replications as follow:

VERTEMIC	CONTROL	BIO .T. BLUS	SAF-T-SIDE	REMON	NIMBAR
BIO .T. BLUS	SAF-T-SIDE	VERTEMIC	NIMBAR	REMON	CONTROL
NIMBAR	CONTROL	VERTEMIC	SAF-T-SIDE	BIO .T. BLUS	REMON
CONTROL	REMON	BIO .T. BLUS	NIMBAR	SAF-T-SIDE	VERTEMIC

Fig 2.6: Design of the control experiment in the open field.

Fig 2.7: Use of Sex-Pheromone traps for Mass-Trapping of *T. absoluta* in the greenhouse

Chapter Three: Results

Chapter 3: Results

3.1 Host Susceptibility and Seasonal Abundance of *T. Absoluta*

3.1.1 Susceptibility of some solanaceous crops to *T. absoluta* infestation in open field:

Weekly observations were done on the middle line of each replicate. Proportion of infested plants; number of infested leaves/plant and number of mines/plant were recorded.

3.1.1.1 Proportion of plants infested by *T. absoluta* recorded on three solanaceous crops in the open field:

The results presented in table 3.1 shows the accumulated proportion of infested plants that were recorded on three host plants of T. *absoluta* (Tomato, Eggplant, and Pepper) in the open field throughout the season from 26th May to end of August 2011.

Table 3.1 Proportion of plants infested by *T. absoluta* recorded on three solanaceous crops in the open field. (Proportion* ± S.E)

Host Plant	20-Jun	27-Jun	4-Jul	11-Jul	18-Jul	25-Jul	1-Aug	8-Aug
Tomato	0.52b±0.08	0.67a±0.07	0.72a±0.07	0.77a±0.06	0.80a±0.06	0.80a±0.06	0.80a±0.06	0.77a±0.06
Eggplant	0.57a±0.07	0.60b±0.07	0.60b±0.07	0.67b±0.07	0.59b±0.08	0.70b±0.07	0.70b±0.07	0.70b±0.07
Pepper	0.22b±0.06	0.27c±0.07	0.27c±0.07	0.37c±0.07	0.32c±0.07	0.40c±0.07	0.40c±0.07	0.40c±0.07
P value	0.003	0.001	0.000	0.001	0.000	0.000	0.000	0.001

*: Figures within the same column with different letters differ significantly at $p\ value \leq 0.05$ using one way ANOVA, Fisher's pair wise comparisons.

Statistical analysis showed that the accumulated proportion of infested plant recorded on tomato was significantly higher than that on either eggplant or pepper throughout the growing season.

3.1.1.2 Means number of *T. absoluta* infested leaves/plant recorded on three solanaceous crops in the open field:

The result presented in table 3.2 shows the accumulated mean number of infested leaves/ plant that were recorded on three host plants of T. *absoluta* (Tomato, Eggplant, and Pepper) in the open field thought the seasons from 1st April to end of August 2011.

Statistical analysis showed that throughout the season, the accumulated mean numbers of infested leaves/plant that was recorded on tomato in the open field were significantly higher than that on either eggplant or pepper.

Table 3.2 Means number of *T. absoluta* infested leaves/plant recorded on three solanaceous crops in the open field. (Mean* ± S.E).

Host Plant	20-Jun	27-Jun	4-Jul	11-Jul	18-Jul	25-Jul	1-Aug	8-Aug
Tomato	0.62a±0.10	1.02a±0.15	1.17a±0.18	1.62a±0.21	1.90a±0.19	1.90a±0.19	3.22a±0.34	5.45a±0.48
Eggplant	0.87a±0.14	0.87a±0.14	1.05a±0.16	1.32a±0.17	1.95a±0.27	1.95a±0.27	2.55b±0.38	3.12b±0.46
Pepper	0.27b±0.08	0.35b±0.09	0.40b±0.10	0.62b±0.15	0.72b±0.17	0.77b±0.17	1.17c±0.30	1.67c±0.43
P value	0.001	0.002	0.001	0.001	0.000	0.000	0.000	0.000

*: Figures within the same Colum with different letters differ significantly at p *value* ≤ 0.05 using one way ANOVA, Fisher's pair wise comparisons.

3.1.1.3 Means number of *T. absoluta* mines/plant recorded on three solanaceous crops in the open field:

The result presented in table 3.3 shows the accumulated mean number of mines/plant that were recorded on three host plant of *T. absoluta* (Tomato, Eggplant, and Pepper) in the open field thought the seasons from 26th May to end of August 2011.

Statistical analysis showed that, throughout the season, the accumulated mean number of mines/plant that were recorded on tomato in the open field were significantly higher than that on either eggplant or pepper

Table 3.3: Means number of *T. absoluta* mines/plant recorded on three solanaceous crops in the open field. (Mean* ± S.E)

Host Plant	20-Jun	27-Jun	4-Jul	11-Jul	18-Jul	25-Jul	1-Aug	8-Aug
Tomato	0.92a±0.16	1.55a±0.23	2.32a±0.28	2.92a±0.31	3.35a±0.33	3.35a±0.33	4.72a±0.45	6.92a±0.60
Eggplant	1.07a±0.21	1.10a±0.20	1.67b±0.26	2.12b±0.31	2.92a±0.42	2.92a±0.42	3.77a±0.56	4.17b±0.62
Pepper	0.35b±0.16	0.47b±0.13	0.72c±0.20	1.02b±0.25	1.17b±0.30	1.22b±0.30	1.67b±0.43	2.40c±0.61
P value	0.007	0.001	0.000	0.000	0.000	0.000	0.000	0.000

*: Figures within the same column with different letters differ significantly at $p\ value \leq 0.05$ using one way ANOVA, Fisher's pair wise comparisons.

3.1.2 Susceptibility of some solanaceae crops to *T. absoluta* infestation in the greenhouse plantation.

3.1.2.1 Proportion of plants infested by *T. absoluta* recorded on three solanaceous crops in the greenhouse plantation:

The results presented in Table 3.4 shows the accumulated proportion of infested plants that were recorded on three host plants of *T. absoluta* (Tomato, Eggplant, and Pepper) in the greenhouse plantation throughout the season from 28th May 2011 to end of August 2011.

Statistical analysis showed that no significant differences were found between the three host plants throughout the season from 1st April to end of August 2011.

Table 3.4 Proportion of plants infested by *T. absoluta* recorded on three solanaceous crops in the greenhouse plantation. (Proportion* ± S.E)

Host Plant	22-Jun	29-Jun	6-Jul	13-Jul	20-Jul	27-Jul	3-Aug	10-Aug
Tomato	0.10±0.06	0.10±0.06	0.65±0.10	0.90±0.19	0.85±0.08	0.85±0.08	1.00±0.00	1.00±0.00
Eggplant	0.10±0.06	0.30±0.10	0.50±0.11	0.65±0.10	0.70±0.10	0.75±0.09	0.90±0.06	0.90±0.06
Pepper	0.10±0.06	0.10±0.06	0.60±0.11	0.70±0.10	0.75±0.09	0.90±0.06	0.90±0.14	0.90±0.09
P value**	1.00 NS	0.152 NS	0.631 NS	0.418 NS	0.535 NS	0.445 NS	0.675 NS	0.112 NS

*: Means within the same column with different letters differ significantly at *p value ≤ 0.05* using one way ANOVA, Fisher's pair wise comparisons.

**: NS: No significant differences at p value ≤0.05

3.1.2.2 Means number of *T. absoluta* Infested leaves/plant recorded on three solanaceous crops in greenhouse plantation:

The result presented in table 3.2 shows the accumulated mean number of infested leaves/ plant that were recorded on three host plants of *T. absoluta* (Tomato, Eggplant, and Pepper) in the greenhouse plantation thought the season from 28th May to end of August 2011.

Table 3.5: Means number of *T. absoluta* Infested leaves/plant recorded on three solanaceous crops in greenhouse plantation. (Mean* ± S.E)

Host Plant	22-Jun	29-Jun	6-Jul	13-Jul	20-Jul	27-Jul	3-Aug	10-Aug
Tomato	0.20±0.13	0.20±0.13	0.95±0.19	1.40±0.22	1.55±0.19	1.80±0.26	4.80a±0.41	4.80a±0.41
Eggplant	0.10±0.06	0.40±0.15	0.70±0.17	1.25±0.28	1.35±0.28	1.60±0.29	4.00a±0.42	4.00a±0.42
Pepper	0.20±0.13	0.20±0.13	0.75±0.16	1.00±0.19	1.10±0.20	1.55±0.21	2.65b±0.53	2.65b±0.53
P value**	0.792 NS	0.523 NS	0.585 NS	0.491 NS	0.395 NS	0.773 NS	0.007	0.007

*: Means within the same column with different letters differ significantly at *p value ≤ 0.05* using one way ANOVA, Fisher's pair wise comparisons.

**: NS: No significant differences at p value ≤0.05

Statistical analysis showed that, at the beginning of the seasons (22nd Jun- 27th July), no significant differences in number of infested leaves/plant were recorded between the three investigated host plants, and later on, number of infested leaves/plant recorded on tomato were significantly higher than that on either eggplant or pepper.

3.1.2.3 Means number of *T. absoluta* mines/plant recorded on three solanaceous crops in greenhouse plantation:

The result presented in table 3.6 shows the accumulated mean number of mines/plant that were recorded on three host plants of *T. absoluta* (Tomato, Eggplant, and Pepper) in the green house plantation thought the season from 28th May to end of August 2011.

Table 3.6 Means number of *T. absoluta* mines/plant recorded on three solanaceous crops in greenhouse plantation. (Mean* ± S.E)

Host Plant	22-Jun	29-Jun	6-Jul	13-Jul	20-Jul	27-Jul	3-Aug	10-Aug
Tomato	0.20±0.13	0.20±0.13	1.35±0.32	2.20±0.37	2.40±0.36	2.70±0.43	6.80^a±0.47	7.40^a±0.42
Eggplant	0.20±0.13	0.60±0.22	0.85±0.20	1.95±0.42	2.05±0.41	2.55±0.45	5.75^a±0.61	6.30^a±0.58
Pepper	0.15±0.10	0.15±0.10	0.80±0.17	1.25±0.28	1.40±0.30	2.15±0.35	3.30^b±0.66	3.85^b±0.75
P value**	0.951 NS	0.113 NS	0.222 NS	0.171 NS	0.152 NS	0.63 NS	0.00	0.001

*: Means within the same column with different letters differ significantly at *p value ≤ 0.05* using one way ANOVA, Fisher's pair wise comparisons.

**: NS: No significant differences at p value ≤0.05

Statistical analysis showed that, at the beginning of the seasons (22nd June- 27th July), no significant differences in number of mines/plant were recorded between the three investigated host plants, and later on, number of mines/plant recorded on both tomato and eggplant were significantly higher than that on pepper.

3.1.3 Susceptibility of some tomato cultivars to *T. absoluta* infestation in open field.

3.1.3.1 Proportion of plants infested by *T. absoluta* recorded on three tomato cultivars in the open field:

The result presented in Table 3.6 shows the accumulated proportion plants infested by *T. absoluta* that were recorded on three tomato cultivar (1684, Taiba and 56) in the open field thought the season from 26th May to end of August 2011.

Table 3.7: Proportion of plants infested by *T. absoluta* recorded on three tomato cultivars **in the open field. (Proportion* ± S.E)**

Tomato Cultivars	21-Jun	28-Jun	5-Jul	12-Jul	19-Jul	26-Jul	2-Aug	9-Aug
1684	0.62±0.07	0.67±0.07	0.90±0.04	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00
Taiba	0.57±0.07	0.57±0.07	0.90±0.04	0.97±0.02	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00
56	0.72±0.07	0.70±0.07	0.75±0.06	0.92±0.04	0.97±0.02	0.97±0.02	0.97±0.02	0.97±0.02
P value	0.369 NS	0.470 NS	0.096 NS	0.172 NS	0.371 NS	0.371 NS	0.371 NS	0.371 NS

*: Figures within the same column with different letters differ significantly at *p value ≤ 0.05* using one way ANOVA, Fisher's pair wise comparisons.

**: NS: No significant differences at p value ≤0.05

Statistical analysis showed that, throughout the growing season, no significant differences in proportion of infested plants were recorded between the three investigated tomato cultivar (1684, Taiba and 56) planted in the open field.

3.1.3.2 Means number of *T. absoluta* infested leaves/plant recorded on three tomato cultivars in the open field:

The result presented in table 3.8 shows the accumulated mean number of infested leaves/plant that were recorded on three tomato cultivar of (1684, Taiba and 56) in the open field thought the season from 26th May to end of August 2011.

Table 3.8: Means number of *T. absoluta* infested leaves/plant recorded on three tomato cultivars **in the open field. (Mean* ± S.E)**

Tomato Cultivars	21-Jun	28-Jun	5-Jul	12-Jul	19-Jul	26-Jul	2-Aug	9-Aug
1684	1.07±0.16	1.37±0.18	2.12a±0.17	3.20±0.19	4.30a±0.19	5.40a±0.17	5.45±0.17	5.45±0.17
Taiba	0.80±0.13	0.92±0.14	1.37b±0.11	2.87±0.20	4.57a±0.23	5.20a±0.22	5.45±0.20	5.45±0.20
56	1.02±0.14	1.20±0.16	1.70b±0.20	2.57±0.23	3.67b±0.23	4.52b±0.21	4.95±0.19	4.95±0.19
P Value	0.377 NS	0.167 NS	0.009	0.116 NS	0.014	0.008	0.113 NS	0.113 NS

*: Figures within the same column with different letters differ significantly at *p value ≤ 0.05* using one way ANOVA, Fisher's pair wise comparisons.

**: NS: No significant differences at p value ≤0.05

Statistical analysis showed that, throughout the seasons from 21st Jun- 9th Aug, significant differences between the numbers of infested leaves/plant were recorded only from 19th-26th July, when, the accumulated number of infested leaves/plant recorded on Taiba and 1684 cultivars were significantly higher than that on cv 56.

3.1.3.3 Mean number of *T. absoluta* mines/plant recorded on three tomato cultivars in the open field:

The result presidents in table 3.9 shows the mean number of mines/plant (fig. 3.1) that were recorded on three tomato cultivar (1684, Taiba and 56) in the open field throughout the season from 26th May to end of August 2011.

Table 3.9 Mean number of *T. absoluta* mines/plant of Tomato Cultivar in open field. (Mean* ± S.E)

Tomato Cultivar	21-Jun	28-Jun	5-Jul	12-Jul	19-Jul	26-Jul	2-Aug	9-Aug
1684	1.52±0.24	2.02±0.28	3.07±0.24	4.47±0.26	6.30±0.27	7.32a±0.22	7.52a±0.22	7.52±0.22
Taiba	1.27±0.22	1.57±0.26	2.27±0.22	4.27±0.30	6.37±0.28	7.42a±0.26	7.85a±0.21	7.85±0.21
56	1.55±0.21	1.90±0.25	2.60±0.29	3.75±0.32	5.47±0.31	6.30b±0.28	6.82b±0.27	6.82±0.27
P Value**	0.647 NS	0.474 NS	0.094 NS	0.212 NS	0.059 NS	0.004	0.010	0.371 NS

*: Figures within the same Colum with different letters differ significantly at *p value ≤ 0.05* using one way ANOVA, Fisher's pair wise comparisons.

**: NS: No significant differences at p value ≤0.05

Statistical analysis showed that, at the beginning of the seasons (21st Jun- 19th Jul), no significant differences in number of mines/plant were recorded between the three investigated tomato cultivar, However, from 26th July – 2nd August, number of mines/plant recorded on (Taiba and 1684) were significantly higher than on 56 tomato cultivar.

Fig 3.1: ***Tutal absoluta*** **mine in tomato leaf**

3.1.4 Susceptibility of some tomato cultivars to *T. absoluta* infestation in the greenhouse plantation:

3.1.4.1 Proportion of plants infested by *T. absoluta* recorded on three tomato cultivars in the greenhouse plantation:

The result presented in table 3.10 shows the accumulated proportion of plants infested by *T. absoluta* that were recorded on three tomato cultivars (144, Manar and 256) planted in greenhouse throughout the season from 28th May to end of August 2011.

Table 3.10: Proportion of plants infested by *T. absoluta* recorded on three tomato cultivars in the greenhouse plantation. (Proportion* ± S.E)

HOST PLANT	22-Jun	29-Jun	6-Jul	13-Jul	27-Jul	3-Aug	10-Aug
144	0.15±0.081	0.2±0.0918	0.65±0.109	0.75±0.099	0.85±0.081	1.00±0.000	1.20±0.200
MANAR	0.05±0.050	0.05±0.050	0.55±0.114	0.7±0.128	0.95±0.135	1.00±0.000	1.00±0.000
256	0.1±0.068	0.15±0.819	0.65±0.109	0.8±0.156	0.9±0.191	0.90±0.068	0.90±0.68
P value	0.587 NS	0.377 NS	0.764 NS	0.862 NS	0.885 NS	0.130 NS	0.218 NS

*: Figures within the same rows with different letters differ significantly at *p value ≤ 0.05* using one way ANOVA, Fisher's pair wise comparisons.

**: NS: No significant differences at p value ≤0.05

Statistical analysis showed that, throughout the seasons, no significant differences in proportion infested plant were recorded between the three investigated tomato cultivars.

3.1.4.2 Mean number of *T. absoluta* infested leaves/plant recorded on three tomato cultivars in the greenhouse plantation:

The result presented in table 3.11 shows the mean number of infested leaves/plant that were recorded on three tomato cultivars (144, Manar and 256) in greenhouse thought the season from 28th May to end of August 2011.

Table 3.11: Mean number of *T. absoluta* infested leaves/plant recorded on three tomato cultivars in the greenhouse plantation. (Mean* ± S.E)

HOST PLANT	22-Jun	29-Jun	6-Jul	13-Jul	20-Jul	27-Jul	3-Aug	10-Aug
144	0.2±0.117	0.25±0.123	0.75±0.143	1.2±0.236	1.35±0.233	1.65±0.254	4.90±0.315	4.90±0.315
MANAR	0.05±0.050	0.1±0.100	0.85±0.196	1.05±0.211	1.15±0.233	1.5±0.212	4.75±0.376	4.75±0.376
256	0.1±0.068	0.25±0.160	0.75±0.143	1.05±0.233	1.45±0.266	1.7±0.282	4.15±0.437	4.15±0.437
P value	0.438 NS	0.644 NS	0.881 NS	0.893 NS	0.678 NS	0.842 NS	0.342 NS	0.342 NS

*: Figures within the same rows with different letters differ significantly at *p value ≤ 0.05* using one way ANOVA, Fisher's pair wise comparisons.

**: NS: No significant differences at p value ≤0.05

Statistical analysis showed that, throughout the growing seasons, no significant differences in number infested leaves/plant were recorded between the three investigated tomato cultivars planted in greenhouse plantation.

3.1.4.3 Mean number of *T. absoluta* mines/plant recorded on three tomato cultivars in the greenhouse plantation:

The result presidents in Table 3.12 shows the mean number of Susceptibility min / plant that were recorded on three tomato cultivar of *T. absoluta* (144, MANAR and 256) in greenhouse thought the seasons (28th May till 10st Aug 2011).

Table 3.12 Mean number of *T. absoluta* mines/plant recorded on three tomato cultivars in the greenhouse plantation. (Mean* ± S.E)

Tomato cv	22-Jun	29-Jun	6-Jul	13-Jul	20-Jul	27-Jul	3-Aug	10-Aug
144	0.25±0.143	0.4±0.197	1.00±0.205	1.85±0.350	2.20±0.367	2.50±0.387	6.35±0.357	6.95±0.294
MANAR	0.05±0.050	0.15±0.150	1.05±0.276	1.35±0.310	1.60±0.358	2.40±0.419	6.35±0.399	7.25±0.347
256	0.10±0.068	0.25±0.160	1.00±0.218	1.85±0.386	2.25±0.397	2.95±0.500	5.75±0.575	6.20±0.565
P value	0.316	0.583	0.985	0.511	0.399	0.642	0.562	0.198

***:**Figures within the same rows with different letters differ significantly at *p value ≤ 0.05* using one way ANOVA, Fisher's pair wise comparisons.
**: NS: No significant differences at p value ≤0.05

Statistical analysis showed that, throughout the growing seasons, no significant differences in number mean number of mines/plant that were recorded on the three investigated tomato cultivar planted under greenhouse conditions.

3.2 Flight Activity of *T. absoluta* within Open Field and Greenhouse Plantation

3.2.1 Effect of cropping system on flight activity of *T. absoluta* within open field and greenhouse plantation throughout 2011-2012.

Results presented in Fig 3.2 shows the average numbers of males of *T. absoluta* that were weekly captured/pheromone both in the open field and in the greenhouse plantation during the growing seasons of 2011 and 2012.

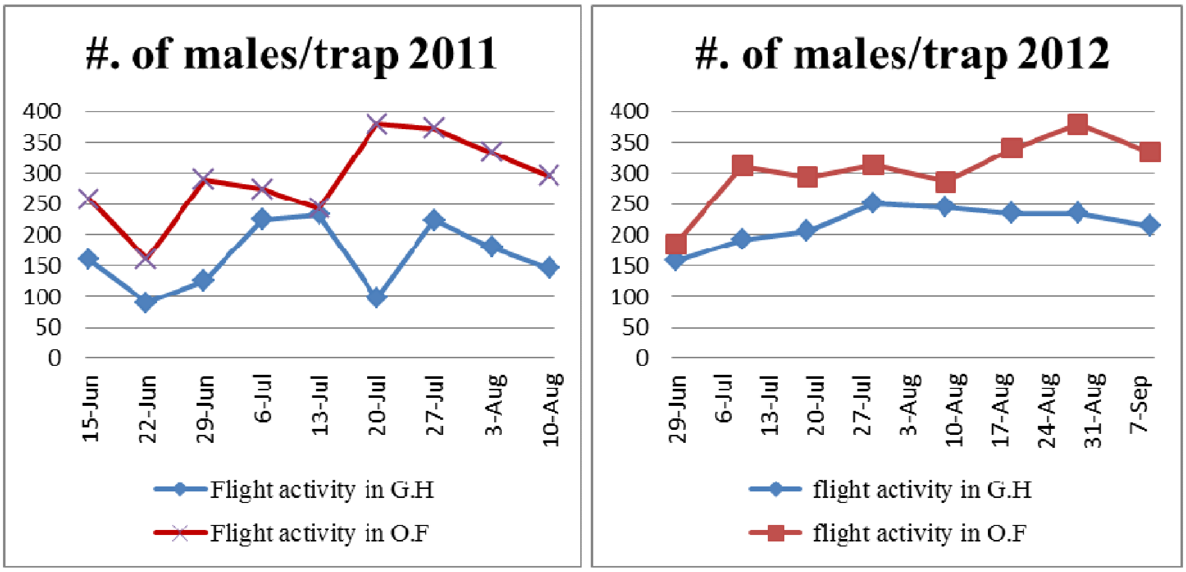

Fig 3.2: Fight activity of *T. absoluta* within open field and greenhouse plantation throughout 2011-2012.

Results in Fig 3.2 shows that the flight activity of *T, absoluta* captured in the open field were higher than that recorded in the greenhouses throughout the growing seasons of both 2011 and 2012.

In the open field, results show that, two peaks of flight activity of *T. absoluta* were recorded during the growing seasons of both 2011 and 2012. During 2011 season, the two peaks were recorded at 20th June and at the 20th July respectively. However, during 2012 season, the two peaks of flight activity were respectively recorded at 6th June and at the end of August.

Results also show that, in the greenhouse, two peaks of flight activity of T. *absoluta* were recorded during 2011 season, where, 1st peak was recorded at 13th July and the 2nd peak was recorded at 27th July. However, the two peaks of flight activity of *T. absoluta* recorded during 2012 were at 27th July and 24th August.

3.3 *Tuta absoluta* Management

3.3.1 Effect of some common sense control measure on *T. absoluta* infestation on tomato plants in the open field

3.3.1.1: Mean numbers of tomato leaves/plant that were infested by *T. absoluta* under various common sense control measures in the open field

The results presented in Table (3.13) and Fig. (3.3) show the mean number of infested leaves/tomato plant that were recorded one week before and after application of six common sense treatments including: BIO.T. BLUS (*B.t*); NIMEBAR (Neem oil), RIMON (Novaluron), SAF-T-SIDE (Petroilium oil), VERTIMEC (Abamactin), and Control (CK) in the Open field throughout 2012 season.

Table 3.13 : Mean numbers of tomato leaves/plant that were infested by *T. absoluta* under various common sense treatments in the open field. Mean *± S.E.

Treatment (Applied on 31st July)	**22-Jul (Before application)**	**7-Aug (After Application)**	**% Decrease of infested leaves**
B.t	16.60 ± 1.25	11.80a ± 0.93	26.92a ± 7.27
Neem oil	16.75 ± 1.31	14.85b ± 1.40	9.73b ± 4.8
Novaluron	17.75 ± 0.96	16.35b ± 0.78	4.16b ± 6.96
Petroleum oil	15.85 ± 0.99	11.15a ± 0.82	26.44a ± 5.27
Abamectin	16.10 ± 0.77	14.20b ± 0.79	13.5b ± 6.65
CK* **	17.25 ± 0.86	16.25b ± 1.04	0.04b ± 6.22
P value **	0.805 NS	0.000	0.011

*: Figures within the same column with different letters differ significantly at *P value ≤ 0.05* using one way ANOVA, Fisher's pair wise comparisons.
**: NS: No significant differences at *P value* ≤0.05
***: CK = Control Treatment

Statistical analysis showed that, one week after treatment application, the number of infested leaves/plant that were recorded on both Petrolium oil (11.2) and *B.t* (11.8) treatments were significantly lower than that of either Abamactin (14.2); Neem oil (14.9); Novaluron (16.4); or even the Control treatments (16.3).

Thus, the % of decrease in infested leaves/plant that were recorded one week after treatment application, were significantly higher on *B.t* (26.7%) and Petrolium oil (26.4%) treatments than that on either Abamactin (13.5%); Neem oil (9.7%); or Novaluron (4.2%), which were without significant differences from the control treatment.

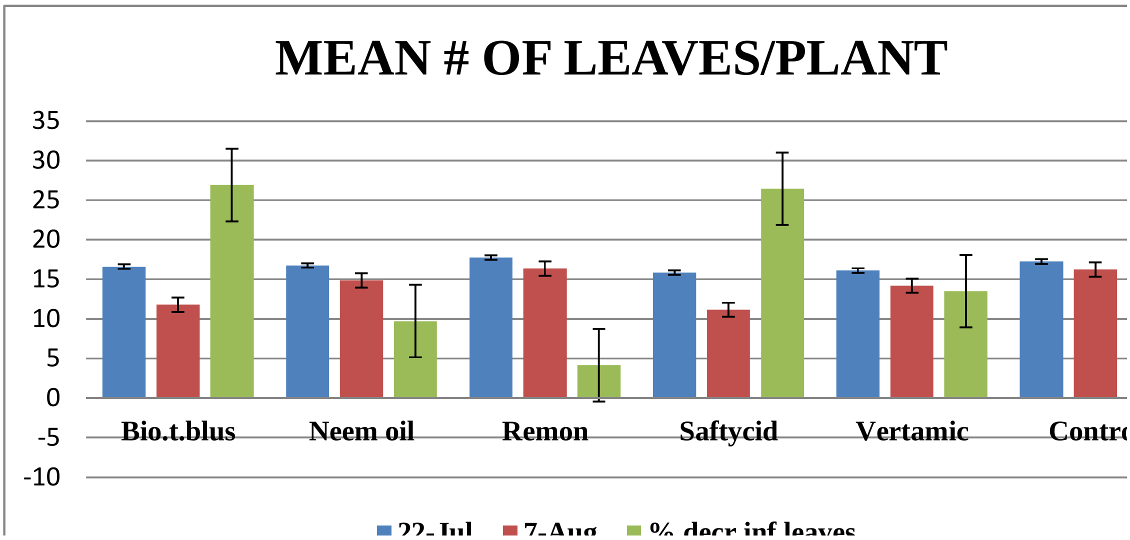

Fig 3.3: Mean numbers of tomato leaves/plant that were infested by *T. absoluta* under various common sense treatments in the open field

3.3.1.2: Mean number of *T. absoluta* mines/tomato plant that were recorded under various common sense control measures in the open field

The results presented in Table (3.14) and Fig (3.4) show the mean numbers of *T. absoluta* mines/plant that were recorded on tomato plants one week before and after application of six common sense treatments including: BIO.T. BLUS (*B.t*);

NIMEBAR (Neem oil); RIMON (Novaluron); SAF-T-SIDE (Petroilium oil); VERTIMEC (Abamactin); and Control (CK) in the Open field throughout 2012.

Table 3.14: Mean number of *T. absoluta* mines/tomato plant that were recorded under various common sense control measures in the open field. Mean* ± S.E.

Treatment (Applied on 31st July)	22-Jul (Before application)	7-Aug (After Application)	% Decrease of mines/plant
B.t	20.55 ± 1.28	15.65a ± 1.04	23.1ab ± 3.62
Neem oil	22.65 ± 1.42	18.35ab ± 1.42	19.32bc ± 3.29
Novaluron	22.15 ± 0.84	20.10b ± 0.93	16.89bc ± 2.94
Petroleum oil	21.85 ± 1.01	15.35a ± 0.81	29.1a ± 3.08
Abamectin	21.55 ± 0.97	18.55ab ± 0.99	13.18c ± 3.84
CK* **	22.70 ± 0.98	19.20b ± 1.04	13.7c ± 2.68
P value*	0.754 NS	0.008	0.006

*: Figures within the same column with different letters differ significantly at *P value* ≤ 0.05 using one way ANOVA, Fisher's pair wise comparisons.
**: NS: No significant differences at *P value* ≤ 0.05
***: CK = Control Treatment

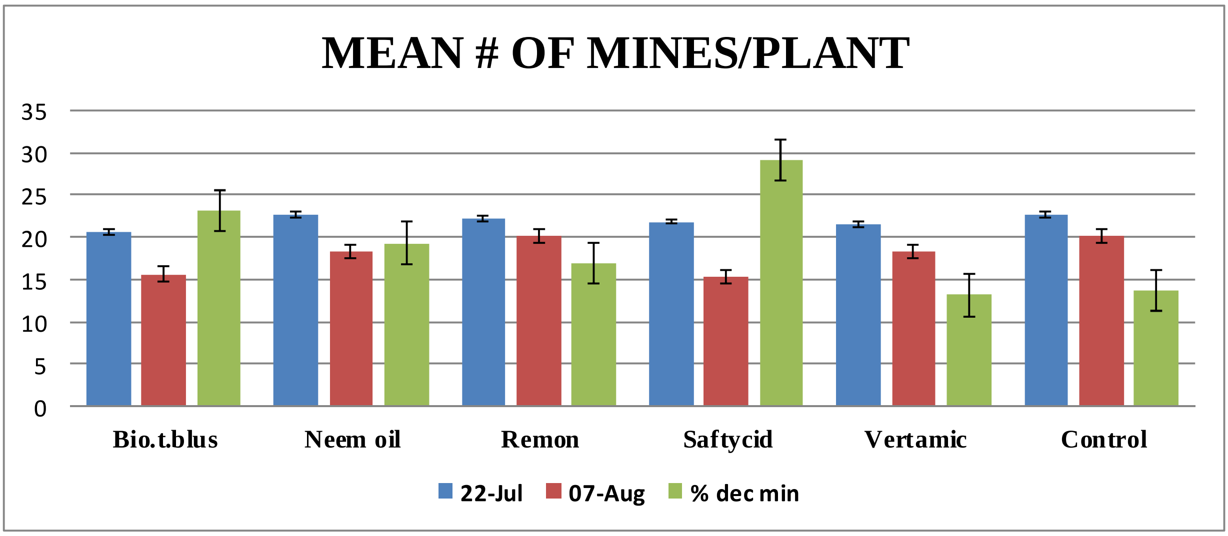

Fig 3.4: Mean number of *T. absoluta* mines/tomato plant that were recorded under various common sense control measures in the open field

Statistical analysis showed that, one week after treatment application, the number of *T. absoluta* mines/tomato plant that were recorded on both Petrolium oil (15.4) and *B.t* (15.7) treatments were significantly lower than that of either Neem oil (18.4); Abamactin (18.6); Novaluron (20.1); or even the Control treatments (19.2)**.** Thus, the % of decrease in *T. absoluta* mines/tomato plant that were recorded one week after treatment application, were significantly higher on Petrolium oil (29.1%) and *B.t* (23.1%) treatments, than that on either Neem oil (19.3%); Novaluron (16.9%); or Abamactin (13.2%) which were without significant differences from the control measure.

3.3.2: Efficiency of Mass-Trapping Technique on control of *T. absoluta* on tomato in the greenhouse:

3.3.2.1: Effect of Mass trapping technique on mean numbers tomato leaf infested by *T. absoluta* in the greenhouses

Table 3.15: Mean numbers of tomato leaves/plant that were infested by *T. absoluta* in the greenhouses. Mean *± S.E.

Treatment (N)**	**Date**		
	23/7	**8/8**	**26/8**
Mass Trapping (120)	18.26a ± 0.37	17.44a ± 0.35	16.12b ± 0.35
Control (240)	24.72b ± 0.62	27.65b ± 0.53	51.10b ± 0.82
P value	0.000	0.000	0.000

*: Figures within the same column with different letters differ significantly at *P value ≤ 0.05* using two sample t-test.
**: N = Number of Replications.

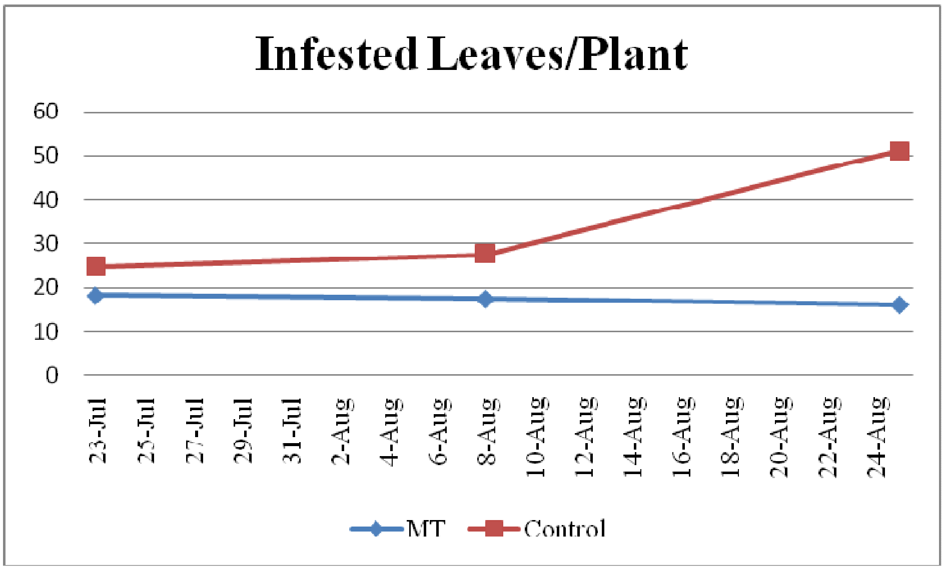

Fig 3.5: Mean number of tomato leaves/plant that were infested by *T. absoluta* in the greenhouses under Mass-trapping Technique.

The results presented in Table (3.15) and Fig (3.5) show mean numbers of tomato leaves/plant that were infested by *T. absoluta* in the greenhouses, that were recorded under mass-Trapping Technique, using four sex-pheromone yellow sticky traps/greenhouse (300 m^2), compared with control treatment which was without any control measures during 2012 season.

Statistical analysis of the results show that, the mean numbers of tomato leaves/plant that were infested by *T. absoluta* under Mass-Trapping Technique were significantly lower than that under control treatment. Furthermore, under Mass-Trapping Technique, 18.26 leaves/tomato plant were observed infested by *T. absoluta* on 23rd of July, and that declined to 17.44 on 8th August and finally to 16.12 on 25th August, meanwhile, under control treatment, the mean numbers of leaves/tomato plant that were observed infested by *T. absoluta* were 24.7 on 23rd July, and that rose to 27.65 on 8th August and finally reach to 51.1 on 26th August.

3.3.2.2: Effect of Mass trapping technique on mean number of *T. absoluta* mines/tomato plant in the greenhouses

The results presented in Table (3.16) and Fig (3.6) show mean numbers of *T. absoluta* mines/tomato plant in the greenhouses, that were recorded under mass-Trapping Technique, using four sex-pheromone yellow sticky traps/greenhouse (300 m^2), compared with control treatment which was without any control measures during 2012 season.

Table 3.16: Mean number of *T. absoluta* mines/tomato plant in the greenhouses. Mean *± S.E.

Treatment (N**)	Date		
	23/7	**8/8**	**26/8**
Mass Trapping (120)	$26.0^{a}\pm0.47$	$21.43^{a}\pm0.39$	$21.01^{a}\pm0.44$
Control (240)	$36.8^{b}\pm0.80$	$40.69^{b}\pm0.60$	$50.30^{b}\pm0.80$
P value	0.000	0.000	0.000

*: Figures within the same column with different letters differ significantly at *P value* ≤ 0.05 using two sample t-test.

**: N = Number of Replications.

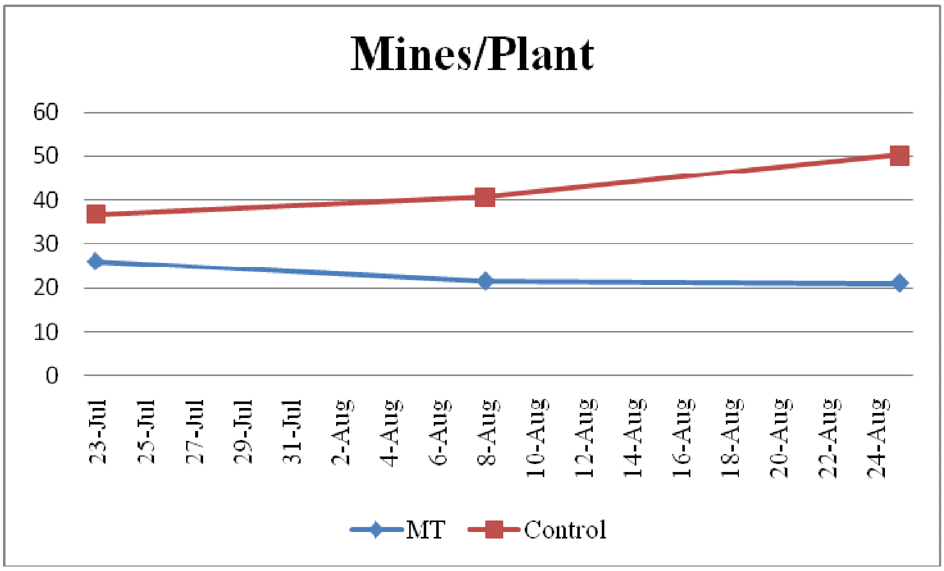

Fig 3.6: Mean number of *T. absoluta* mines/tomato plant in the greenhouses under Mass-Trapping Technique.

Statistical analysis of the results show that, the mean numbers of *T. absoluta* mines recorded per tomato plant under Mass-Trapping Technique were also significantly lower than that under control treatment. Furthermore, under Mass-Trapping Technique, on 23rd of July, means of (26) *T. absoluta* mines were recorded per tomato plant, and that declined to (21.43) on 8th August and also was (21.01) on 25th August. Meanwhile, under control treatment, the mean numbers of *T. absoluta* mines recorded per tomato plant were (36.8) on 23rd July, and that rose to (40.69) on 8th August and finally reach to (50.3) on 26th August.

Chapter Four: Discussion

Chapter 4: Discussion

4.1 Susceptibility of some solanaceous crops to *T. absoluta* infestation

Results of this study show that, tomato; eggplant and pepper plants were susceptible to *T. absoluta* infestation both in open field and in greenhouse cropping system. It was observed that, mine infestation started at the beginning of April and extended until the middle of August 2011.

Results also show that, the highest rate of infestation recorded on tomato, was significantly the highest, followed by eggplant and the lowest was on pepper plants. In addition, results show that, all investigated tomato cultivars were susceptible to *T. absoluta* infestation both in the open field and in the greenhouses. However, throughout the season, no significant differences were recorded between tomato cultivars in their rate of infestation.

T. absoluta was reported to infest most solanaseous crop plants including: Tomato, *Solanum lycopersicum* L. (*Lycopersicon esculentum* Miller) (Vargas, 1970; Fernandez & Montagne, 1990b); Eggplant, *Solanum melongena* L. (Galarza, 1984; Fernandez & Montagne, 1990b; Ministero delle Politiche Agricole Alimentari e Forestali, 2009; Viggiani et al., 2009); pepper, *Capsicum annuum* L (Ministero delle Politiche Agricole Alimentari e Forestali, 2009); potato, *Solanum tuberosum* L. (Pastrana, 1967; Vargas, 1970; Galarza, 1984; Fernandez & Montagne, 1990b; FREDON-Corse, 2009b; Maiche, 2009); and tobacco, *Nicotiana tabacum* L. (Galarza, 1984; Fernandez & Montagne, 1990b).

Infestation of tomato plants occurs throughout the entire crop cycle. Feeding damage is caused by all larval instars and throughout the whole plant. On leaves, the larvae feed on the mesophyll tissue, forming irregular leaf mines which may later become necrotic. Larvae can form extensive galleries in the stems which affect the development of the plants. Fruit are also attacked by the larvae, and the entry-ways are used by secondary pathogens, leading to fruit rot. The extent of infestation is partly dependent on the variety. Potential yield loss in tomatoes (quantity and quality) is significant and can reach up to 100% if the pest is not managed (http://www.irac-online.org/).

4.2 Flight activity of *T. absoluta* within open field and greenhouse plantation throughout the growing season

Results of this research show that the flight activity of *T, absoluta* recorded in the open field were higher than that recorded in the greenhouses throughout the growing seasons of both 2011 and 2012.

Results also show that, during 2011 season, two peaks of flight activity of *T. absoluta* were recorded in the open field, the 1st peak was recorded at 20th June and the 2nd peak was at the 20th July. However, during 2012 season, the two peaks of flight activity were respectively recorded at 6th June and at the end of August.

T. absoluta is reported to be able to complete 12 generations per year depending on environmental conditions (EPPO, 2005). In the laboratory (at a constant temperature of 25°C and 75 % R.H.), *T, absoluta* completes a generation in 28.7 days (Vargas, 1970). Given the field conditions in the Arica Valley in Chile, *T. absoluta* could complete seven to eight generations per year at that location (Vargas, 1970). Since this pest can infest hosts grown in protected situations (such as greenhouses), its rapid reproductive rate should be kept in mind. The species can over winter in the egg, pupal, or adult stage (EPPO, 2005).

4.3 Use of some common sense control measure as alternatives to chemical insecticides against *T. absoluta* in the open field

The present study investigated the efficiency of five common sense control measures compared with control treatment, that were applied against *T. absoluta* on tomato plantation in the open field, meanwhile, in the greenhouse, Mass-trapping Technique was used by inserting 4 sticky sex-pheromone traps in a 300m^2 greenhouse at the beginning of the season, and that compared with other greenhouse that was left without any control measures as control treatments.

The five common sense treatments used in the open field included: Microbial control (*Bacillus thuringiensis*); Botanical extract (Neem oil); Insect growth regulator (Novaluron); Petroilium oil, and Abamactin in comparison to Control treatment.

Results of the present study show that, the mean number of *T. absoluta* mines/tomato plant that were recorded on both Petrolium oil and *B.t* treatments were significantly lower than that on either Neem oil; Abamactin; Novaluron; or even the Control treatments**.** Furthermore, the efficiency of the control treatments measured as the % decrease in *T. absoluta* mines/tomato plant that were recorded one week after treatment application, were significantly higher on both Petrolium oil (29.1%) and *B.t* (23.1%) treatments, than that on either Neem oil (19.3%); Novaluron (16.9%); or Abamactin (13.2%) which were without significant differences from the control measure.

The strategy includes the monitoring for early detection of adults using pheromone traps and visual inspection of plants, primarily for eggs; and inundative releases of *Trichogrammatoidea bactrae*, initiated when the first adults are trapped and/or the first eggs are observed; use of *Bacillus thuringiensis* in conjunction with (or after) release of egg parasitoids to control larvae; compatible pesticides based on safe pesticide usage if necessary; crop rotation with non-host plants and cultural control practices in the greenhouse and surrounding environment (Botto, 1999; 2011). However, *Beauveria bassiana* (strain GHA 1991) was tested alone or in combination with *B. thurengiensis* for control of *T. absoluta* in open tomato fields in Ibiza, Spain, and, both treatments reduced the number and severity of fruit damage when compared to the control (Torres *et al*., 2001).

Integrated pest management (IPM) programs were developed in several countries to manage infestations of *T. absoluta*. Most IPM programs include the monitoring of pest populations; effective methods of prevention and control; and the use of pesticides when needed. Biological control is also implemented if available.

In Spain, IPM for *T. absoluta* includes the mass-trapping of adults prior to planting; clearing of crop residues from planting soil; application of imidacloprid in irrigation water 8 to10 days after planting and application of spinosad or indoxacarb when *T. absoluta* is detected; and elimination of crop residues immediately after the last fruits have been harvested (Robredo-Junco and Cardeñoso-Herrero, 2008).

In Argentina, IPM for *T. absoluta* in greenhouse tomatoes has been tested at INTA (Instituto Nacional de Tecnología Agropecuaria) over the last 10 years with positive results (Botto, 1999; 2011).

In addition, results of mass-trapping technique applied in the greenhouses show that, the mean numbers of *T. absoluta* mines recorded per tomato plant under Mass-Trapping Technique were significantly lower than that under control treatment. Furthermore, under Mass-Trapping Technique, rate of *T. absoluta* infestation on tomato plants was declining throughout the season, while that recorded on the control greenhouse was increasing.

Thus, high capture rate was ideal for mass trapping of *Tuta absoluta* particularly for protected tomato cultivation. It helps to reduce population in greenhouses particularly if insect exclusion nets and tight doors were used.
Mass trapping is a technique that involves placing a higher number of traps in the crop field in various strategic positions to remove a sufficiently high proportion of male insects from the pest population.

It is widely used in conjunction with other control measures to achieve acceptable level of damage and to reduce the reliance on insecticide treatments. Mass trapping is a potential option for open field production. However, and for practical reasons, application in protected agriculture has a higher chance of success.

Conclusions and Recommendations

Conclusions:

- Tomato; eggplant and pepper plants were susceptible to *T. absoluta* infestation both in open field and in greenhouse cropping system.
- The highest rate of infestation recorded on tomato, followed by eggplant and the lowest was on pepper plants.
- All investigated tomato cultivars were susceptible to *T. absoluta* infestation both in the open field and in the greenhouses.
- The flight activity of *T, absoluta* recorded in the open field were higher than that recorded in the greenhouses.
- Two peaks of flight activity of *T. absoluta* were recorded in the open field, the 1st peak was recorded at late June and the 2nd peak was at late July.
- Both, Petroleum oil and *Bacillus thuringiensis* treatments were significantly the highest in their efficiency for control of *T. absoluta* in the open field.
- Mass-trapping of *T. absoluta* using sex pheromone sticky traps was able to suppress the *T. absoluta* population in the greenhouse plantation.

Recommendation:

- Further study is recommended to be done on use of petroleum oil; Bt; and rate of Mass-Trapping Technique that might be used in the greenhouses.

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Arabic Abstract

دراسة حقلية حول بيولوجيا و بيئة و مكافحة عثة انفاق البندورة (*Tuta absoluta*) في المناطق الجبلية الجنوبية للضفة الغربية – فلسطين

الملخص باللغة العربية

تعتبر عثة صانعة الأنفاق في البندورة (*Tuta absoluta*) من الآفات المدمرة لمحصول البندورة, حيث أن الموطن الأصلي للحشرة هي أمريكا الجنوبية، و هي من الآفات المهاجرة عابرة الحدود و المدمرة لمحصول البندورة في الحقول المفتوحة و المحمية. فقد سجلت إصابة العثة على محاصيل العائلة الباذنجانية مثل البطاطا و الباذنجان. و علية تعتبر من الآفات الرئيسية لإنتاج البندورة في منطقة حوض البحر الأبيض المتوسط.

لقد تم تنفيذ هذا البحث في محطة العروب الزراعية الواقعة في المناطق الجبلية الجنوبية للضفة الغربية، بفلسطين خلال الفترة 2011-2012. و هدفت الدراسة إلى مراقبة النشاط الموسمي لطيران عثة أنفاق البندورة، و دراسة درجة حساسية عدد من محاصيل الغائلة الباذنجانية للإصابة بالعثة و درجة حساسية عدد من أصناف البندورة لهذه الحشرة و ذلك في الحقل المفتوح و البيوت البلاستيكية. كما هدفت الدراسة لتقييم إمكانية استخدام عدد من المركبات الكيماوية و البيولوجية و المستخلصات النباتية المقبولة بيئيا و صحيا في مكافحة العثة في الحقل المفتوح بالإضافة إلى دراسة إمكانية استخدام المصائد الفرمونية اللاصقة للصيد الكمي لذكور العثة في البيوت البلاستيكية.

أظهرت نتائج الدراسة أن نباتات البندورة و الباذنجان و الفلفل كانت حساسة للإصابة بالحشرة في الحقل المفتوح و البيوت البلاستيكية. كما أشارت نتائج الدراسة أن درجة الإصابة كانت الأعلى على نباتات البندورة تبعها الباذنجان في حين كانت الإصابة في الحد الأدنى على نباتات الفلفل في الحقل المفتوح و البيوت البلاستيكية. كما انه لم تظهر فروق معنوية في درجة الإصابة على جميع أصناف البندورة التي تم استخدامها في الحقل المفتوح أو البيوت البلاستيكية.

بالنسبة للهدف الثاني للدراسة فقد أظهرت النتائج أن نشاط طيران الحشرة سجل جيلين خلال الموسم في الحقل المفتوح و البيوت البلاستيكية حيث كان معدل نشاط الطيران للحشرة في الحقل المفتوح أعلى منه في

البيوت البلاستيكية، و قد سجلت القمة الأولى لنشاط الطيران للحشرة في الحقل المفتوح في الثلث الأخير من شهر حزيران بينما كانت القمة الثانية لنشاط الطيران في الثلث الأخير من شهر تموز.

أما بالنسبة للهدف الثالث للدراسة، فقد أظهرت النتائج أن معاملات المكافحة في الحقل المفتوح باستخدام كلا من مبيد الحشرات البكتيري (*B.t*) و الزيت البترولي كانتا الأعلى معياريا في الفعالية ضد العثة في حين كانت بقية المعاملات بفعالية منخفضة و لا تختلف معياريا عن معاملة الشاهد. في حين أن استخدام برنامج الصيد الكمي (Mass-Trapping) لذكور العثة في البيوت البلاستيكية باستخدام المصائد الفرمونية اللاصقة بمعدل 4 مصائد للبيت البلاستيكي الواحد بمساحة 300 م2 قد اظهرت نتائج مشجعة حيث تم السيطرة على درجة الإصابة بنسبة تصل إلى النصف مقارنة بمعاملة الشاهد كما أن درجة الإصابة كانت تنخفض خلال الموسم في البيت المعامل بالمصائد الفرمونية بينما كانت الإصابة تزداد في البيت الشاهد في نفس الفترة.

وعلية يمكن التوصية بضرورة تنفيذ أبحاث مستقبلية لتقييم النتائج المشجعة للسيطرة على تعداد العثة باستخدام المصائد الفرمونية و لتحديد المعدلات المناسبة للاستخدام في كل من الحقل المفتوح و البيوت البلاستيكية.