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First Estimate of the Damage of *Tuta absoluta* (Povolny) (Lepidoptera: Gelechiidae) and Evaluation of the Efficiency of Sex Pheromone Traps in Greenhouses of Tomato Crops in the Bekalta Region, Tunisia

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ABSTRACT

Monitoring *Tuta absoluta* with pheromone traps and weekly sampling in the Bekalta cropping area showed that the population dynamics of the insect on young tomato leaves can be separated into three phases: low infestation initially (from 25th March to 6th May, 2009), followed by a growing population with a dominance of eggs and of first instar larvae (from 6th May to 27th May, 2009), then a decline phase accompanied by progressive drying of tomato plants (from 27th May to 3rd June, 2009). Mass trapping in the experimental greenhouses was not efficient compared to the control. The study revealed that fruit losses do not depend on the presence or absence of a sex pheromone trap because all greenhouses in this biotope were not isolated from the external environment with an insect-proof which can prevent the entry of *T. absoluta* adults. Losses in 9 representative greenhouses were between 11.08 and 43.33% with an average deficit of 809 kg for an average total production of 4156 kg, corresponding to a 20% loss.

Keywords: infestation rate, loss, mass trapping, number of mines per leaf, population dynamics, sex pheromone lure

INTRODUCTION

A new invasive insect was detected for the first time in Tunisia in all tomato cropping areas (Anonymous 2009). It is a moth: *Tuta absoluta* (povolny) (Lepidoptera: Gelechiidae), known as the tomato leaf miner. Originally from South America (Garcia and Espul 1982; Siqueira *et al*. 2000), this pest appeared in Spain in 2006 in the province of Castellon (Valencia) (EPPO, 2007). In 2007, many outbreaks have been observed on tomato crops along the Mediterranean coast (Urbaneja *et al*. 2007). Its presence in the Balearic Islands has also been confirmed in 2007 (EPPO 2008). This moth has appeared in Algeria and Morocco in May 2008 (Guenaoui 2008). Because of its real ability to spread and proliferate, the tomato leaf miner may quickly invade all Mediterranean countries (Delgado 2007). The damage caused by the larvae affects all parts of the plant and causes considerable losses on tomato yields. This pest attacks greenhouses tomato crops as well as open-field tomato crops (Filho *et al*. 2000) and other cultivated plants from the same botanical family such as eggplant and pepper considered as potential host plants (Galarza 1984; Ramel and Oudard 2008). In South America, *T. absoluta* can cause 100% of losses in tomato crops (Souza and Reis 1992; França 1993; Torres *et al*. 2002; Delgado 2007).

The aim of this study was to estimate tomato fruit losses caused by this pest on greenhouses tomato crops using mass trapping as a tool for monitoring and controlling *T. absoluta*.

MATERIALS AND METHODS

Experimental site

The experimental site (35.62260, 11.01354) was located in the Bekalta cropping area belonging to the governorate of Monastir (East Central Tunisia). Three groups of tomato greenhouses, located one beside the other, were selected. The tomato variety used was of indeterminate growth, 'Sahel'. To evaluate the efficiency of sex pheromone water traps ("Tutasan" water traps equipped with "Pherodis" pheromone lures produced by Koppert, The Netherlands) and to monitor the population dynamics of *T. absoluta*, two of the greenhouses (S1 and S2) were equipped with one sex pheromone water traps each placed at 40 cm from the soil in the center; the third one (S3) was used as the control (**Table 1**).

On the other hand, two groups of representative greenhouses located in the same region, into which tomato plants were transplanted at the same time and equipped with water pheromone traps ("Tutasan" water traps equipped with "Pherodis" pheromone lures produced by Koppert, Nederland) installed on the same day, were selected to monitor the evolution of the number of trapped *T. absoluta* males. The first includes 13 greenhouses transplanted with

Table 1 Presentation of the experimental greenhouses in the biotope of Bekalta.

Greenhouses	Tomato variety	Surface area (m^2)	Plantation dates	Plantation density (plants/m^2)
S1	Sahel	500	December 2008	3
S2	Sahel	500	December 2008	3
S3 : control	Sahel	500	December 2008	3

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Table 2 List of Pesticides used in the studied greenhouses.

Pesticides	Active compound	Action	Number of applications	Greenhouses
Omite 57	Propargite	Miticide	1	All greenhouses
Unilax	Metalaxyl + Mancozebe	Fungicide	2	All greenhouses
Scala	Pyrimethanil	Fungicide	1	All greenhouses
Dursban	Chlorpyripos	Insecticide	2	Control

four indeterminate growth type tomato varieties ('Sahel', 'Colibri', 'Malawi' and 'Ceincara'). Pheromone traps were installed on the 18th March 2009 and pheromone lures were renewed once, on the 22nd April 2009. The second group contained 9 greenhouses transplanted with 4 indeterminate growth type tomato varieties ('Sahel', 'Murano', 'Colibri' and 'Ceincara'). Pheromone traps were installed on the 1st April 2009 and lures were renewed only once, on the 6th May 2009. It is important to note that all these studied greenhouses of the region of Bekalta are 60 m in length, 8 m wide and 2 m high tunnels with polyethylene screens and not equipped with an insect-proof; they belong to local tomato growers who were ready to cooperate with this experiment. Tomato plants in all greenhouses were cultivated in 4 double rows with a density of 3 plants/m² and conducted with conventional treatments against fungi and mites. Insecticides against leafminers and fruit borers were excluded throughout the period of the study except in the control greenhouse where two insecticide applications separated by tow weeks were carried out. All pesticides (**Table 2**) were commercialized by the agricultural service cooperative "ESSAADA".

Trapped *T. absoluta* males in all sex pheromone water traps installed in the greenhouses were counted weekly.

From 25 studied greenhouses in this biotope (3 tunnels where population dynamics were studied + the first group of 13 tunnels + the second group of 9 tunnels), the evaluation of damaged tomato fruits involved only 12 greenhouses where it was possible to weigh damaged as well as unharmed fruits.

Sampling

Sampling was done in the three greenhouses (S1, S2 and S3) from the 25th March to the 3rd June, 2009. Samples were taken from the apical part of the plants. In order to do that, greenhouses were divided into 30 experimental plots. The sampling method was totally randomized; one tomato plant was picked from each experimental plot from which one apical leaf was cut. After that, the plant was marked and not used for the next week's sampling. Leaves collected from each plant were preserved in labeled plastic bags. Thereafter, they were examined under a binocular dissecting microscope (Leica MS5) in order to count the different biological stages of *T. absoluta* (eggs, larvae, chrysalids) as well as caterpillars' mines.

RESULTS AND DISCUSSION

Mass trapping

The study of the weekly average of trapped males of *T. absoluta* in the first group of 13 greenhouses (**Fig. 1**), showed a progressive evolution during all the period of the survey. Indeed, this average was low during the first week of the study (from 18/03/2009 to 25/03/2009), starting with 156 males per trap, then gradually increased to a maximum of 315 males per trap on the 15th April 2009 four weeks after the installation of the traps, but it remained stable at that level until the renewal of the pheromone lure which occurred one week after.

Two weeks after the renewal of the pheromone lure, the number of trapped males remained constant. However, from the 13th May 2009 and due to rising temperatures, the number of trapped males was higher, reaching its second peak, four weeks after the renewal of the pheromone lure, on the 20th May 2009 with 524 males per trap. This trapping level remained around 500 males per trap until the 3rd June 2009.

Based on these data, we can conclude that the trapping level remained almost constant during two periods showing two plateaus of trapped males, the first from the 15th April

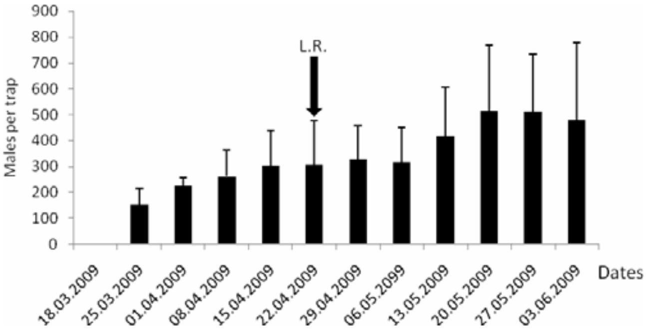

Fig. 1 Weekly evolution of the trapped males of *T. absoluta* in the first trapping system in Bekalta. L.R.: lure renewal.

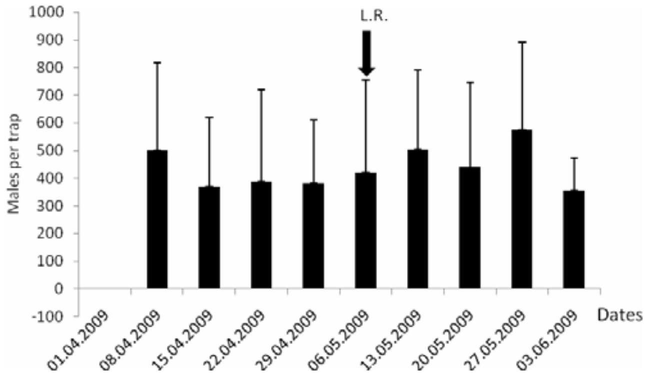

Fig. 2 Weekly evolution of the trapped males of *T. absoluta* in the second trapping system in Bekalta. L.R.: lure renewal.

2009 to the 6th of May 2009 with an average of 300 males per trap per week, and the second from the 20th May 2009 to the 3rd of June 2009 with 500 trapped males per trap per week. It is likely that the occurrence of these plateaus is closely related to the prevailing temperatures during these periods that were respectively 20.6 and 24.5°C (NIMT 2009).

These observations allowed detecting a considerable level of population which raised almost constantly to reach a maximum of 524 males per trap per week showing two periods where the number of trapped males was constant. This evolution confirms the attractiveness of the sex pheromones baits towards males of *T. absoluta.*

For the second trapping system installed since the 1st of April 2009 and covering 9 greenhouses, the results reflect a higher level of population probably associated with a higher level of infestation (**Fig. 2**). Furthermore, the attractiveness of pheromone lures has remained more or less constant during the first five weeks (from 01/04/2009 to 06/05/2009), with a weekly average of 371 and a maximum of 500 males per trap per week. After the renewal of the pheromone lure on the 6th of May 2009, the number of trapped males increased to stabilize around 500 males per trap per week for three consecutive weeks before declining to 355 in the fourth week.

This second replication of mass trapping confirms again the high level of the population of *T. absoluta* in the region of Bekalta and the great attractiveness of the sex pheromone lures whose life time was between 4 and 6 weeks.

Population dynamics

The monitoring of populations dynamics of *T. absoluta* in three greenhouses (S1, S2 and S3) in the biotope of Bekalta allowed to confirm the existence of a close relationship between various parameters (infestation rate, number of mines per leaf and population density) governing the chronology of externalization of symptoms and of damage.

The analysis of the structure of the population of *T. absoluta* in both greenhouses (S1 and S2) as well as in the control tunnel (S3) (**Fig. 3**), revealed the presence of low density of all biological stages of the pest during the end of March (week 11 after transplanting) and all the month of April (12 to 15 weeks after transplanting). This low level of infestation raised quickly during the month of May (week 16 to 19 after transplanting) from 5.5 individuals per leaf on 29/04/2009 (15 weeks after transplanting) to 31.6 on 20/05/2009 (18 weeks after transplanting) then to 40 on 27/05/2009 (19 weeks after transplanting) for the greenhouse (S1) (**Fig. 3A**), and from 7.2 to 17.4 then to 22.4 individuals per leaf on the same dates for the greenhouse (S2) (**Fig. 3B**). The greenhouse used as control (S3) showed the same evolution with a maximum density of 28 individuals per leaf

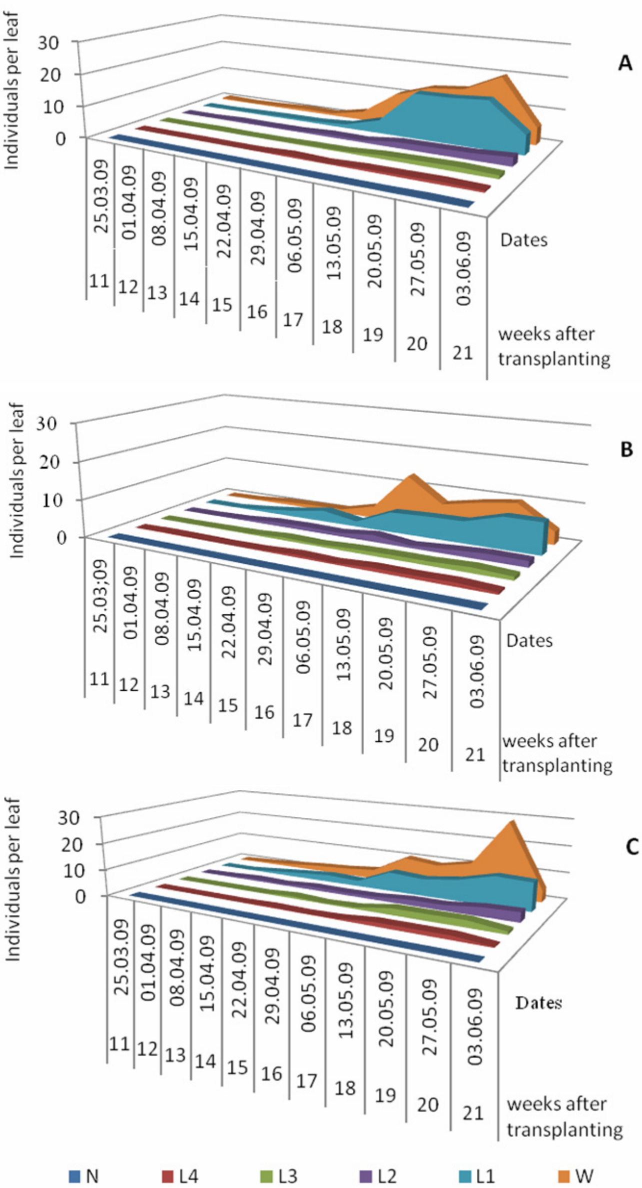

Fig. 3 Weekly evolution of the population density of *T. absoluta* per tomato ('Sahel') leaf under greenhouse conditions in the region of Bekalta in 2009. N: chrysalid, L4: fourth instar larvae, L3 third instar larvae, L2 second instar larvae, L1 first instar larvae, W: eggs, A: S1, B: S2 and C: control.

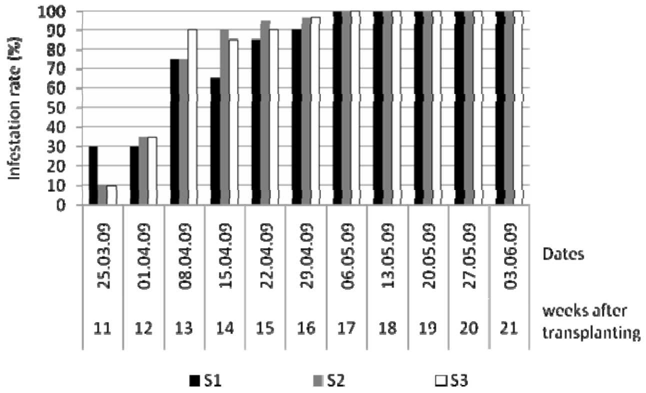

Fig. 4 Weekly evolution of the infestation rate of *T. absoluta* on young tomato ('Sahel') leaves under greenhouses conditions in the region of Bekalta in 2009. S1: first greenhouse, S2: second greenhouse and S3: control.

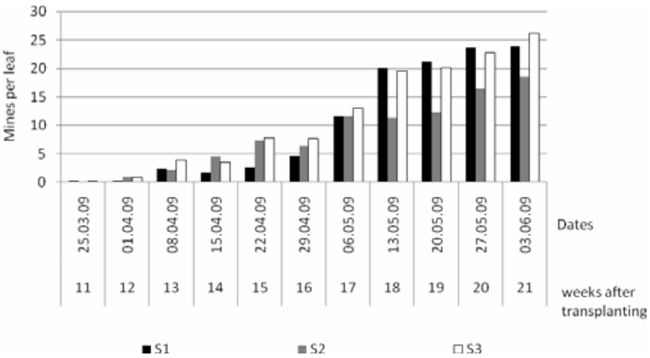

Fig. 5 Weekly evolution of the number of mines of *T. asoluta* per young tomato ('Sahel') leaf under greenhouses conditions in the region of Bekalta in 2009. S1: first greenhouse, S2: second greenhouse and S3: control.

recorded also on 27/05/2009 (**Fig. 3C**). This increase was the result of the raising temperature in this period of the year which allowed the proliferation of the pest (NIMT 2009).

As a result, the evolution of *T. absoluta* on tomato young leaves can be divided into three distinct phases. The first (from transplantation to 15 weeks after transplanting), was characterized with a low population level, low infestation rate of leaves (**Fig. 4**) and a small number of mines per leaf (**Fig. 5**) observed in the three greenhouses; followed by a second phase (16 to 19 weeks after transplanting) of growing population with dominance of eggs and first instar larvae causing an increase of the infestation rate of leaves and the number of mines per leaf. The peak of the first instar larvae in all three greenhouses was delayed by at least one week compared to that one of eggs which is consistent with the results cited by (Estay 2000) who mentioned that the period of incubation of eggs is around one week at 20°C.

The third phase was short (weeks 20 and 21 after transplantation). It was characterized by a maximum of mines, resulting from a total infestation and an increased activity of larvae which caused a general drying of leaves. The destruction of young foliage, preferential sites for oviposition, led to a decline of the population of *T. absoluta*. This last phase has severe consequences on tomato fruits, which become the preferred sites to lay eggs (sepals).

Estimation of tomato fruit losses

Tomato fruit losses in the biotope of Bekalta were relatively high. Indeed, the weight of attacked fruits in the three greenhouses (S1, S2, and control) where the monitoring of populations dynamics of *T. absoluta* was carried out has become important since the beginning of the month of May.

Table 3 Total production and loss of tomato fruit in nine greenhouses equipped with pheromone traps in the biotope of Bekalta.

Greenhouse	Tomato variety	Total production (kg)	Loss (kg)	Harvest left (kg)	Percentage of loss (%)
1	Sahel	3300	365.8	150	11.08
2	Sahel	4440	1483.2	800	33.41
3	Sahel	4750	1133.8	500	23.86
4	Malawi	4130	751	130	18.18
5	Murano	4085	487.5	125	11.93
6	Murano	5700	802.5	800	14.08
7	Colibri	3400	522	450	15.35
8	Sahel	3500	1516.5	1500	43.33
9	Sahel	4100	540.5	400	13.18
	Average	4156.11	808.62	539.44	20.06

Rising temperatures causing population growth of *T. absoluta* have largely participated in the increased fruit losses. The total loss in the greenhouse S1, equipped with the sex pheromone water trap, was about 1483.2 kg for a total harvest of 4440 kg, representing 33.40% of loss (**Fig. 6A**). As for the greenhouse S2 outfitted with the same type of trap, the damage caused by the tomato leaf miner was 1134 kg from 4750 kg of total production, representing 24% of the yield (**Fig. 6B**). In the control greenhouse (S3), the loss caused by this pest was up to 1209 kg from a total harvest of 3990 kg corresponding to a deficit of 30% (**Fig. 6C**).

It is therefore clear that losses were similar in the three greenhouses, showing that deficits do not depend on the presence or the absence of a sex pheromone water trap, because all the greenhouses in this biotope were not isolated from the external environment with an insect-proof which can prevent the entry of adults of *T. absoluta*. As consequence, the use of sex pheromone water traps must be accompanied with the use of appropriate insect proof to guarantee a maximum efficiency of mass trapping.

The estimation of the losses caused by *T. absoluta* concerned also nine other tomato greenhouses transplanted with five tomato varieties (1 'Colibri', 1 'Malwi', 2 'Murano' and 5 'Sahel') where population's dynamics of the pest were not studied. One sex pheromone water trap was installed in each greenhouse.

Losses were between 11 and 43.33%. The average deficit for all nine greenhouses was 809 kg for an average of total production of 4156 kg, corresponding to 20% of losses (**Table 3**). Attacked fruits in these greenhouses have appeared since the month of May with a maximum of damage at the end of the survey when almost all the remaining fruits were damaged (50% of total losses).

Despite the high level of the population of *T. absoluta* in the studied greenhouses, the maximum of loss was 43.33% of the production. No higher losses were recorded even if the insect can cause up to 100% of damage in South America especially on tomato crops (Souza and Reis 1986; França 1993; Torres et *al*. 2002; Delgado 2007). This level of damage can be related to the environmental and climatic conditions of the biotope and the level of adaptation of the pest with this new biotope especially that the Mediterranean countries have become new dispersion zones.

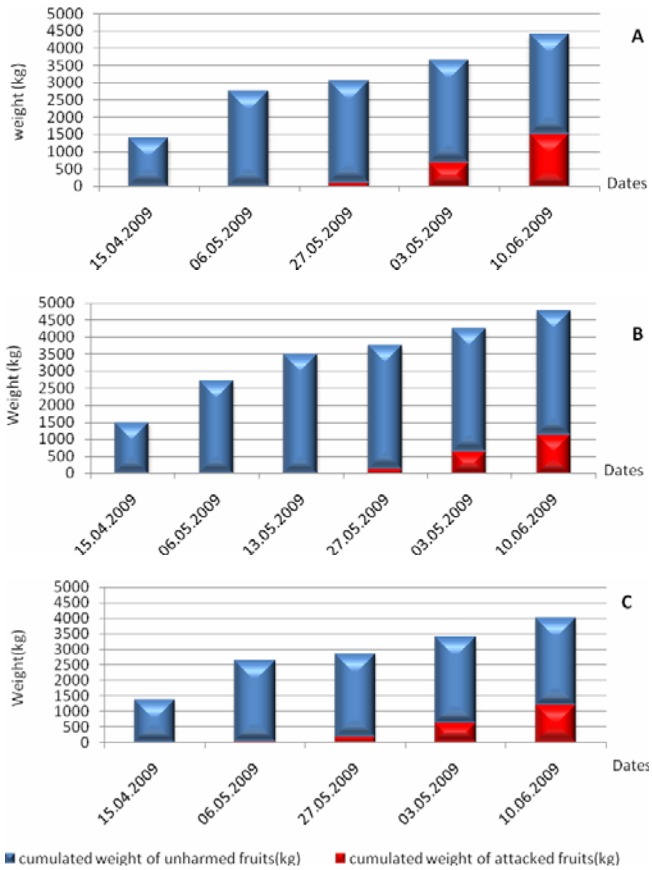

Fig. 6 Accumulated losses of tomato ('Sahel') fruits under green-house conditions in the region of Bekalta in 2009. A: S1, B: S2, C: control.

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