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On the Population Dynamics of the Tomato Leaf Miner Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae) in Egypt

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Abstract. The susceptibility of different tomato cultivars during different rotations was determined during the years 2012-2013 under Egyptian field condition. Our evaluation showed that the cultivars coded with GS and 010 appeared to be more resistant to infestation with *Tuta absoluta* in Egypt compared with other strains. Also, the rate of infestation of different host plants and the biology of *Tuta absoluta* on these hosts were investigated and the observations showed that the insect can discriminate between different host plants. It showed more preference to tomato followed by eggplant, potato and pepper and the larval duration was shorter after rearing on tomato leaves with increase in pupal weight and egg production in females previously reared on tomato leaves compared with those reared on other hosts.

Key words: *Tuta absoluta*, ecology, biology, susceptibility of tomato cultivars, host preference.

Introduction

The tomato leaf miner *Tuta absoluta* (Meyrick) has been reported in Egypt since 2009, quickly becoming one of the major pests of the tomato crop. It is a multivoltine species that mines leaves, fruits, flowers, buds and stems. The damage is produced when the larvae feed on the leaf mesophyll expanding mines, thus affecting the photosynthetic capacity of the crop with subsequent reduction of yield. Moreover, injury made directly to the fruits causes severe losses (COLOMO & BERTA, 2006).

T. absoluta is a very harmful insect pest with a strong preference for tomato plants, although *T. absoluta* is an oligophagous pest with a strong preference for tomato, it can also attack the aerial parts of Solanaceae plants (NOTZ, 1992). Tomato (*Solanum lycopersicum*) is considered as the primary host of this pest, thus no tomato cultivars are entirely resistant to this insect, but not all cultivars are equally susceptible (BORGORNI *et al.*, 2003; OLIVEIRA *et al.*, 2009; DE OLIVEIRA *et al.*, 2012). However, it can also attack other cultivated Solanaceae plants such as eggplant (*S.melongena*), potato (*S. tuberosum*), pepper (*Capsicum annuum*), sweet pepper (*S. muricatum* L.), tobacco (*Nicotiana tabacum*) and some other non-cultivated Solanaceae (*S. nigrum, S. eleagnifolium*). Also, it infests *Physalis angulata*, *Phaseolus vulgaris*, *Datura ferox* and some Chenopodiaceae plants such as *Chenopodium album* (VARGES, 1970; GARÎCA & ESPUL, 1982; FERNANDEZ & MONTAGNE, 1990).

Tomato crop is the first vegetable crop in Egypt; it is grown in four rotations and covers about 3% of Egypt's total planted area. Egypt is classified as the 5th country

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around the world and second around the Mediterranean countries in production and exportation of tomato (WPTC, 2011). According to the Egyptian Ministry of Agriculture, the tomato cultivations during 2009 -2010 was 385,243 feddans, yielding 7,158,970 tons, with the largest areas located in Beheira, Fayoum, Sharkia and Qena governorates. So, in the present study, host-plant preference and susceptibility of different tomato cultivars to infestation with *T. absoluta* was investigated under Egyptian field conditions with calculation of the thermal requirements for different stages of *T. absoluta*.

This study was designed to evaluate the susceptibility of different tomato cultivars around two seasons to infestation with *T. absoluta* and to determine the host plant preference in the field.

Material and Methods

Field experiments were carried out in Bernucht village, Al-Ayyat centre, located in the southern part of Giza governorate, Egypt; to study the preference of *T. absoluta* to its host plants judged from the rate of oviposition on the plant leaves, number of larvae and mines.

Susceptibility of some tomato cultivars to infestation with T. absoluta.

The susceptibility of different tomato cultivars to insect infestation was also determined in the field according to Harizanova *et al.* (2009); Allache & Demnati (2012); Taha *et al.* (2013). For this purpose, an area cultivated with different strains of tomato 150 m^2 was divided into separate plots, each plot 50 m^2 (5 × 10). The plants were cultivated in 2 rows. A border of one meter was left between plots without planting. Weekly visits were made and in each visit tomato leaves were collected randomly to represent the whole area. The samples were transferred to the laboratory and 60 tomato leaves were selected randomly from each sample for examination and three replicates were used.

The susceptibility of different tomato strains to infestation with *T. absoluta* was studied during 2 years (four seasons or rotations from 2012 to 2014), where the susceptibility to infestation with *T. absoluta* was measured by counting the total number of larvae, its feeding punctures (tunnels or mines) and the number of eggs deposited on the plant leaves of all tested tomato strains.

In the first year (2012), three tomato strains identified as GS, Native and Super hybrid were cultivated on January, 25th, 2012 in three separate plots to represent the early summer rotation. In the nile rotation, the two tomato strains 77 and 010 were cultivated on July, 22nd, 2012 in two separate plots.

In the second year (2013), two tomato strains GS and 2243 were cultivated on March, 14th, 2013 to represent the summer rotation. Two strains 010 and hybrid 5656 were cultivated on September, 19th, 2013 to represent the winter rotation. The same procedure was adopted during different rotations.

Host-Plant preference of T. absoluta.

To determine the host plant preference in the field, an area 200 m^2 was selected in Bernucht village, Al-Ayyat centre, Giza governorate. This area was cultivated on January, 25th, 2012 with four solanaceous host plants namely tomato (*Solanum lycopersicum*, cv GS), eggplant (*Solanum melongena*), potato (*Solanum tuberosum*) and sweet pepper (*Capsicum annuum*) in separate plots (50 m^2/plot, 5 m. length/10 m. width). A border of one meter was left between plots without planting. Weekly visits were made to this area for 4.5 months; in each visit leaves of each host plant were collected randomly using Zigzag methods and the samples were transferred to laboratory. From these samples 60 leaves were selected randomly for examination and three replicates were made. Preference was measured by recording the total number of larvae, its feeding punctures (tunnels or mines) and the number of deposited eggs on the plants (Seraj, 2000). Differences between different host plants were determined using SPSS program.

In order to determine the effect of host-plants on the biology of *T. absoluta* under laboratory conditions, three solanaceous host plants namely tomato, eggplant and potato were selected for this purpose, since these hosts were more attractive to adult moths of *T. absoluta*.

In this experiment, *T. absoluta* was reared on plant leaves of the tested hosts in separate plastic jars (2 L). The jars were lined at the bottom with filter paper, then provided with leaves of the tested hosts after being washed and dried. One hundred newly deposited eggs were placed on plant leaves of each host. All jars were incubated at room temperature with daily examination for calculating the hatching percentage. The hatched larvae were separated in new jars and divided into 3 groups as replicates to assess the effect of each host plant on different biological aspects according to PEREYRA & SÁNCHEZ (2006) as follows:

- Larval developmental time (from hatching to pupation).
- Pupation percentage and pupal weight (mg) 48 hours after pupation (15 pupae were weighted).
- Adult emergence percentage and fecundity.

Fecundity was estimated for each female. The newly emerged adults were released into rearing containers (50×60 cm) each containing a tomato pot for oviposition. The deposited eggs were counted daily until female death. Adults were fed with sugar solution (15%). The observed values were analyzed statistically to evaluate the effect of the host plants quality on some biological aspects of the insect.

Results

Susceptibility of some tomato cultivars to infestation with T. absoluta.

The susceptibility of tomato cultivars to infestation with *T. absoluta* was estimated in a series of experiments. Five tomato cultivars were cultivated during the first year (2012), in early summer and nile rotations, while four cultivars were cultivated during the second year (2013) in summer and winter rotations.

Early summer rotation (2012)

Three tomato cultivars identified as GS, native and super hybrid were cultivated in 25, January 2012 in three separated plots, 60 tomato leaves were collected randomly to represent each strain, the samples were transferred to the laboratory for examination. Eggs, larvae and tunnels or mines caused by the larvae were counted and the data are reported in Table 1.

It appears that the native strain is more attractive to *T. absoluta* than GS and super hybrid strain, 2 weeks after cultivation, where the average number of eggs was 0.73 eggs/ leaf as compared to 0.25 and 0.22 in samples collected from GS and super hybrid, respectively. The egg number increased gradually in all tested tomato strains with the increase of the plant age, where the average egg number increased to 1.6, 1.63 and 1.45 eggs/leaf of native, GS and super hybrid, respectively, in those samples collected in 20, March 2012 (plant age 8 weeks after cultivation). Then the egg number decreased gradually, while the examination of the collected samples in the first of May 2012 recorded an increase in egg number again to 2.43, 0.98 and 1.37 eggs/leaf for native, GS and super hybrid strains, respectively (when plant age was 14 weeks) and then the egg number decreased again in the following week. The maximum number of eggs was again recorded as 5.7, 2 and 3.8 eggs/leaf for native, GS and super hybrid strains, respectively in the first of June 2012. These data in general showed that the native strain was more susceptible to infestation with *T. absoluta*, where the total number of eggs around the rotation was 15.93±5.5 eggs/leaf being significantly higher as compared to GS and super hybrid, while the total number of eggs around the cycle or the rotation in both GS and super hybrid was 8.03±1.5 and 8.62±3.4 eggs/leaf, respectively. The total number of eggs in the native strain was significantly higher than the corresponding figures in GS and super hybrid strains ($F = 13$ at $df = 8$, $P < 0.05$). No significant differences were obtained between the GS and super hybrid strains with regard to the total number of eggs ($P = 0.87$).

In the meantime, the data showed that the average number of larvae in the native strain was 0.85 larvae/leaf during the first week of February, while it decreased to 0.38 and 0.15 larvae/leaf, respectively in GS and super hybrid strains. The larvae number increased gradually in the tested tomato strains with the increase of deposited eggs, where the average number of larvae increased to 1.8, 1.52 and 1.13 larvae/leaf of native, GS and super hybrid strains, respectively, in the samples collected in 3, April 2012 (plant aged 10 weeks after cultivation) then the larvae numbers were gradually decreased. Samples collected in mid of May 2012 recorded an increase in the number of larvae being 2.9, 0.42 and 1.2 larvae/leaf of native, GS and super hybrid strains, respectively, when the plant age was 16 weeks. The maximum numbers of larvae were recorded in June being 3.45, 2.45 and 1.83 larvae/leaf of native, GS and super hybrid strains, respectively. These data showed that the native strain is more susceptible to infestation with larvae where the total number of larvae around the rotation was 16.78±5.7 larvae/leaf compared to 5.73±1.9 and 8.5±2 larvae/leaf in both GS and super hybrid, respectively. Statistical analysis showed significant differences in the total number of larvae around the rotation in the native strain ($F=17$ at $df = 8$, $P < 0.05$) compared with those recorded in GS and super hybrid leaves ($P < 0.05$), but insignificant differences were recorded between GS and super hybrid ($P = 0.37$).

The number of tunnels in the leaves should be connected with the increase of the deposited eggs, hatched larvae and plant age. The results in Table 1 show that the native strain has a significantly higher number of tunnels around the rotation being 27.6±1.7 tunnels/leaf compared to 17.05±4.2 and 18.57±3.2 tunnels/leaf for GS and super hybrid strains, respectively ($F=29$ at $df =8$, $P < 0.05$). Insignificant differences were detected between the two strains GS and super hybrid ($P = 0.5$).

The nile rotation (2012)

The susceptibility of two tomato strains coded as 77 and 010 were evaluated and the data are given in Table 2 indicating that the infestation symptoms were observed 2 weeks after cultivation in the tested cultivated strains 010 and 77. The strain coded as 77 appeared to be more attractive to *T. absoluta* moths, where the average number of eggs in the collected leaves was 0.45 eggs/leaf compared to an average of 0.16 eggs/leaf in the strain 010. The egg number was increased gradually in the two tested tomato strains with the increase of the plant age, where the average number of eggs increased to 1.13 and 0.8 eggs/leaf in samples collected in 23, August 2012 from the strains 77 and 010, respectively. Following this, the egg number in the collected samples showed fluctuations around the rotation. The total number of eggs around the rotation in the strain 77 was 14.06±3.6 eggs/leaf as compared to 9.69±2.43 eggs/leaf in the strain 010. The difference is statistically significant ($t=2.26$, $df=6$, $P<0.05$).

In the meantime, the average number of the larvae was 0.06 larvae/leaf of the strain coded 77, two weeks after cultivation compared to 0.04 larvae/leaf in 010 strain. The larvae number increased gradually in the tested tomato strains with increase of deposited eggs and plant age, and the average of larvae number increased to 0.18 and 0.13 larvae/leaf of the strains 77 and 010, respectively, in samples collected in 23, August 2012 (plant aged 4 weeks after cultivation). The larvae number increased to 1.1 and 0.28 larvae/leaf of the strains 77 and 010, respectively, six weeks after cultivations. Examination of the collected samples in 23, September 2012 (8 weeks after cultivations) showed reduction in the larvae number to 0.78 and 0.21 larvae/leaf, then the larvae number increased in the next visit to 1.51 and 1.09 larvae/leaf for the strains 77 and 010, respectively. The highest number of larvae was recorded as 3.33 and 2.33 larvae/leaf of tomato strains 77 and 010, respectively, by the end of the cycle. In general, the tomato strain 77 appears to be more attractive and highly infested with *T. absoluta* larvae where the total number of larvae around the rotation was 12.41±2.4 larvae/leaf with significant difference compared to 6.23±1.6 larvae/leaf in the strain 010 ($t = 4.36$ at $df = 6$, $P < 0.05$).

The data revealed that the increase in the number of tunnels was connected with an increase of the deposited eggs, hatched larvae and plant age. It appears that the maximum number of tunnels in the tested tomato strains was 5.03 and 3.32 tunnels/ leaf of the strains 77 and 010, respectively, when the plant age was 18 weeks. The total number of tunnels around the rotation was 21.75±3.4 tunnels/leaf in strain 77 being significantly higher as compared to 14.05±2.2 tunnels/leaf in strain 010 ($t = 4.37$ at $df = 6$, $P < 0.05$).

The summer rotation (2013).

Two tomato cultivars identified as GS and 2243 were cultivated on March, 14th, 2013 in two plots, each plot 50 m^2 (5 m. length, 10 m. width) and the plants were cultivated as in early summer rotation. Visits were made to the site every 2 weeks and in each visit tomato leaves were collected randomly to represent the whole area, the samples were transferred to the laboratory for examination. Eggs, larvae and tunnels or mines caused by the larvae were counted and the data are reported in Table 3.

The data in Table 3 showed that the infestation symptoms of *T. absoluta* were observed 2 weeks after cultivation of the strains GS and 2243. The strain coded 2243 appeared to be more attractive to *T. absoluta* moths 2 weeks after cultivation where the average number of eggs in the collected leaves was 0.73 eggs/leaf compared to 0.06 eggs/leaf in the strain GS. Fluctuations in the number of eggs around the cycle were observed in both tomato strains. The maximum number of *T. absoluta* eggs was recorded by the end of July 2013 being 4.25 and 3.13 eggs/leaf for the strains 2234 and GS, respectively. These data showed that the strain coded 2234 was more susceptible to infestation with *T. absoluta* where the total number of eggs/leaf around the rotation was 17.79±3.8 eggs/leaf compared to 11.47±3.7 eggs/leaf in the strain coded GS. The statistical analysis showed significant differences between the number of eggs in both GS and 2243 ($t = 0.416$ at $df = 6$, $P < 0.05$).

Table 1. Susceptibility of three different cultivars of tomato to infestation with *T. absoluta* during the early summer rotation (2012).

Time of Examination / week	Average number ± SD / leaf								
	tunnels	larvae	eggs	tunnels	larvae	eggs	tunnels	larvae	eggs
	Super hybrid			GS			Native strain		
7/2/2012	0.43 ± 0.1	0.15 ±0.01	0.22 ±0.05	0.34 ± 0.1	0.38 ± 0.1	0.25 ±0.08	1.15 ±0.26	0.85 ± 0.54	0.73 ± 0.38
21/2/2012	1 ±0.15	0.83 ±0.07	1.17 ± 0.2	0.78 ± 0.39	0.23 ±0.02	0.58 ± 0.1	1.93 ±0.46	1.2 ± 0.53	1.05 ± 0.04
6/3/2012	1.82 ±0.12	0.57 ±0.19	0.06 ±0.01	1.1 ± 0.46	0.1 ±0.06	1.02 ± 0.2	2.25 ±0.15	1.35 ± 0.68	1.22 ± 0.72
20/3/2012	1.22 ±0.28	0.77 ±0.21	1.45 ± 1.1	1.3 ± 0.35	0.13 ±0.07	1.63 ±0.18	2.55 ±0.45	1.2 ± 0.4	1.6 ± 0.87
3/4/2012	1.3 ±0.43	1.13 ±0.21	0.15 ±0.01	1.45 ±0.11	1.52 ±0.89	0.27 ±0.06	2.87 ±0.72	1.8 ± 1.1	0.7 ± 0.04
17/4/2012	2.1 ±0.34	0.83 ±0.31	0.28 ±0.19	1.87 ± 0.18	0 .13 ±0.02	0.75 ±0.16	3.75 ±0.87	1.33 ± 0.7	0.7 ± 0.02
1/5/2012	3.6 ±0.34	1.15 ±0.07	1.37 ±0.13	2.47 ± 0.45	0.37 ±0.26	0.98 ±0.16	3.9 ±0.36	2.7 ± 1.1	2.43 ± 1.2
15/5/2012	2.8 ±0.31	1.2 ±0.34	0.12 ±0.09	2.62 ±1.52	0.42 ±0.06	0.55 ±0.11	4.35 ±0.65	2.9 ± 0.51	1.8 ± 1.1
1/6/2012	4.3 ±1.16	1.83 ±0.47	3.8 ± 1.6	5.12 ±0.62	2.45 ± 0.4	2 ±0.47	4.88 ± 0.7	3.45 ± 0.17	5.7 ± 1.08
Total	**18.57 ±3.2[e]**	**8.5 ± 2[b]**	**8.62 ± 3.4[a]**	**17.05 ± 4.2[e]**	**5.73 ± 1.9[b]**	**8.03 ± 1.5[a]**	**27.6 ±1.7[E]**	**16.78 ±5.7[B]**	**15.93 ±5.5[A]**

Means of total values followed by similar letters within the same row are not significantly different at 0.05 levels.

Table 2. Susceptibility of different strains of tomato to infestation with *T. absoluta* during the nile rotation (2012).

Time of examination / weeks	Average number ± SD / leaf					
	tunnels	larvae	eggs	tunnels	larvae	eggs
	Strain 010			Strain 77		
8/8/2012	0.05 ± 0.01	0.04 ± 0.02	0.16 ± 0.04	0.09 ± 0.04	0.06 ± 0.04	0.45± 0.23
23/8/2012	0.3 ± 0.1	0.13 ± 0.03	0.8 ± 0.19	0.47 ± 0.3	0.18 ± 0.04	1.13± 0.33
8/9/2012	1.08 ± 0.27	0.28 ± 0.08	0.31 ± 0.09	1.15 ± 0.44	1.1 ± 0.2	0.75±0.29
23/9/2012	1.23 ± 0.3	0.21± 0.06	1.43 ± 0.47	1.74 ± 0.25	0.78 ± 0.25	1.3 ± 0.21
7/10/2012	1.5 ± 0.32	1.09 ± 0.35	0.58 ± 0.23	2.5 ± 0.4	1.51 ± 0.09	1.2 ± 0.33
21/10/2012	1.72 ± 0.36	0.27 ± 0.14	1.53 ± 0.48	2.98 ± 0.37	1.4 ± 0.37	1.85± 0.32
5/11/2012	2.16 ± 0.23	1.29 ± 0.41	1.13 ± 0.37	3.48 ± 0.46	2.45 ± 0.49	1.75 ± 0.6
20/11/2012	2.69 ± 0.21	0.59 ± 0.18	1.55 ± 0.27	4.28 ± 0.4	1.6 ± 0.32	2.23 ± 0.5
5/12/2012	3.32 ± 0.37	2.33 ± 0.58	2.2 ± 0.29	5.03 ± 0.7	3.33 ± 0.58	3.4 ± 0.83
Total	**14.05 ± 2.2^{e}**	**6.23 ± 1.6^{b}**	**9.69 ± 2.4^{a}**	**21.75 ±3.4^{E}**	**12.41 ± 2.4^{B}**	**14.06 ±3.6^{A}**

Means of total values followed by similar letters within the same row are not significantly different at 0.05 levels.

Similar results were obtained with the larvae and tunnels where the data given in Table 3 indicated that the strain 2243 was more susceptible to infestation with *T. absoluta* than the strain coded GS. The total number of larvae around the rotation was 12±5.3 larvae /leaf in the strain 2243 compared to 9.48±1.8 larvae/leaf in GS strain, with no significant differences (t = 0.89 at df = 6, P = 0.07). Meanwhile, the total number of tunnels around the rotation was 19.18±4.7 tunnels/leaf in the strain 2243 compared to 17.97±2.8 tunnels/leaf in the strain GS and negatively significant differences were recorded (t = 0.42 at df = 6, P = 0.067).

The winter rotation (2013).

Two tomato strains identified as 010 and 5656-hybrid were cultivated on September, 19th, 2013 in two plots, each plot 50 m^{2} (5 m. length, 10 m. width) and the plants cultivated as in early summer rotation. Visits to the site were made every 2 weeks and in each visit tomato leaves were collected randomly to represent the whole area and the samples were transferred to the laboratory for examination. Eggs, larvae and tunnels or mines caused by the larvae were counted and the data are presented in Table 4.

The infestation symptoms of *T. absoluta* were observed 2 weeks after cultivation in both 010 and 5656-hybrid. The strain coded 5656 appeared to be more attractive to *T. absoluta* moths, where the average of egg number in the collected leaves was 0.33 eggs/leaf, compared to 0.07 eggs/leaf in samples collected from strain coded 010. The egg number increased gradually in the tested strains with the increase of the plant age. The average of egg number increased to 1.35 and 2.58 eggs/leaf in samples collected in 12, December 2013 from the strains 010 and 5656, respectively. Then the egg number decreased in the next visit to 1.2 and 1.95 eggs/leaf for the strains 010 and 5656, respectively. The maximum number of *T. absoluta* eggs recorded 2.13 and 2.8 eggs/leaf for strains 010 and 5656, respectively in the samples collected in 23, January 2014. These data showed that the strain coded 5656 appears to be more attractive and highly infested with *T. absoluta* and total number of eggs around the rotation was 14.1±5.2 eggs/leaf, compared to 10.02±3.6 eggs/leaf in the strain 010.

On the other hand, the average number of larvae was 0.11 larvae/leaf for the strain coded 5656 and decreased to 0.04 in the strain 010 at 2 weeks after cultivation. The number of larvae increased gradually in both tested strains with increase of deposited eggs and plant age, where the average number of larvae increased to 1.75 and 1.63 larvae/leaf of 5656 and 010, respectively, in samples collected in 26, December 2012, and then the larvae number decreased to 1.18 and 1.25 larvae/leaf during the next visit. The maximum number of *T. absoluta* larvae was recorded being 2.4 and 1.75 larvae/leaf of the tomato strains 5656 and 010, respectively (the plant age was 18 weeks). These data showed that the tomato strain coded 5656 appears to be more attractive and highly infested with *T. absoluta* larvae and the total number of larvae around the rotation was 10.17±5.8 larvae/leaf compared to 8.5± 3.5 larvae/leaf in strain 010.

The results in Table 4 recorded the maximum number of tunnels in the tested tomato strains in 23, January 2014 when the plant age was 18 weeks, where the average numbers of the tunnels were 3.18 and 2.35 tunnels/leaf of 5656 and 010, respectively. The tomato strain coded 5656 appears to be highly infested with *T. absoluta* where the total number of tunnels around the rotation was 16.5± 1.7 tunnels/leaf, compared with 11.76± 2 tunnels/leaf in the strain 010.

Host-Plant Preference of T. absoluta.

T. absoluta is an important tomato pest that also feeds on other host-plants from the Solanaceae family. Four solanaceous plants i.e. tomato (GS), eggplant, potato and pepper were cultivated on January, 25^{th}, 2012 in Bernucht village, Giza in an area of 200 m^2. Samples were collected weekly at random around the season (4.5 months) to evaluate the host-plant preference. Data presented in table 5 show that tomato plants were highly attractive to the female moths of *T. absoluta* in the field where the average number of deposited eggs and larvae on the tomato leaf were 8.03±1.5 and 5.73±1.9, respectively, while the number of tunnels was 17.05±4.2.

Examination of the samples of both eggplant and potato showed that the eggplant was more attractive to the insect in the field where the average number of eggs on eggplant was more than that deposited on potato being 3.8±1.4 and 2.2±0.7 eggs, respectively. The recorded larvae were 3.7±0.37 and 4.9±1.1 larvae, while the number of tunnels was 5.4±1.8 and 3.7±0.75 tunnels for both eggplant and potato, respectively, with no attractive effects of pepper leaves to the moth of *T. absoluta* since there was no eggs and larvae on pepper plants during the season with low number of tunnels (1.8±1.4 tunnels). The statistical analysis showed that tomato is a more suitable host-plant than the other hosts. It has been demonstrated that there were highly significant effects in the average number of tunnels in tomato as compared with the other hosts ($F=29.4$ at $df=11$, $P < 0.05$), while the variation in the average number of eggs was significant in tomato compared with potato and pepper ($F=32.68$ at $df=11$, $P < 0.05$), while there was negatively significant effects between the number of eggs in both tomato and eggplant ($P = 0.01$). Significant effects were also recorded when comparing the average number of larvae in tomato and pepper ($F=13.77$ at $df=11$, $P < 0.05$), but no significant effects were observed in the number of larvae in either tomato or eggplant ($P = 0.01$), and also in tomato and potato ($P = 0.44$).

The reported data in Table 5 show that tomato plants were more susceptible to infestation with *T. absoluta* than eggplant and potato under Egyptian field conditions. So, the effect of these hosts on the different biological aspects of *T. absoluta* was carried out under laboratory conditions. One hundred newly deposited eggs were exposed to plant leaves of the tested host plants (tomato, eggplant and potato) in plastic jars to evaluate the hatching rate, larval developmental time, pupation, pupal weight and adult emergency percentage and fecundity of females.

The data in Table 6 showed that the larvae which feed on tomato leaves in the laboratory had a significantly shorter developmental time than those fed on eggplant and potato and the average duration of larval development was 11.7±0.47, 13.3±1.3 and 14.7±0.45 days, respectively ($F= 6.8$ at $df = 8$, $P<0.05$). While, there was negatively significant effects between the developmental time of larvae which feed on both eggplant and potato leaves (P = 0.03).

The pupation percentage after feeding the larvae on tomato, eggplant and potato was 70.7, 65.5 and 45.3%, respectively and the pupal weight was significantly higher for individuals reared on tomato and eggplant leaves as compared with those reared on potato, being 3.31±0.54, 3.18±0.41 and 2.55±0.48 mg/pupa, respectively (F= 9.96 at df = 44 P<0.05).

The average number of eggs per female previously fed as larvae on tomato, eggplant and potato during the larval stage was 103.9, 93.2 and 81.4 eggs/female. There were no significant differences between egg production in females fed during larval stage on both tomato and eggplant (P=0.32) as compared with those fed on potato (F=14.08 at df=8, P<0.05).

Table 3. Susceptibility of different strains of tomato cultivars to infestation with *T. absoluta* during the summer rotation (2013).

Time of examination / weeks	Average number ± SD / leaf					
	tunnels	larvae	eggs	tunnels	larvae	eggs
	Strain GS			Strain 2243		
30/3/2013	0.06 ± 0.02	0.05 ±0.03	0.06 ± 0.02	0.28 ± 0.20	0.33 ±0.29	0.73 ± 0.18
14/4/2013	0.70 ± 0.30	0.13 ± 0.04	0.53 ± 0.21	0.68 ± 0.46	0.70± 0.44	1.45 ± 0.05
29/4/2013	1.17± 0.18	0.68 ± 0.33	0.94± 0.42	1.40± 0.68	0.70 ± 0.54	1.70 ± 0.19
14/5/2013	1.50 ± 0.37	1.10 ± 0.19	0.70 ± 0.46	1.53 ± 0.43	1.28 ± 0.55	1.48 ± 0.75
29/5/2013	1.85± 0.33	0.73 ± 0.31	1.35 ± 0.52	1.78± 0.42	1.00 ± 0.40	1.90 ± 0.12
13/6/2013	2.4 ± 0.37	1.35 ± 0.22	1.23 ± 0.51	2.43± 0.49	1.63 ± 0.60	1.58 ± 0.42
27/6/2013	2.96± 0.24	1.28 ± 0.19	1.63 ± 0.43	3.23± 0.55	1.45 ± 0.44	2.05 ± 0.65
11/7/2013	3.40 ± 0.43	1.88 ± 0.16	1.90 ± 0.20	3.60 ± 0.67	2.13 ± 0.87	2.65 ± 0.96
25/7/2013	3.93± 0.55	2.28 ± 0.28	3.13 ± 0.89	4.25± 0.75	2.78 ± 1.12	4.25 ± 0.49
Total	**17.97±2.8^{E}**	**9.48±1.8^{B}**	**11.47±3.7^{a}**	**19.18±4.7^{E}**	**12 ± 5.3 ^{B}**	**17.79±3.8^{A}**

Means of total values followed by similar letters within the same row are not significantly different at 0.05 levels.

Table 4. Susceptibility of different strains of tomato cultivars to infestation with *T. absoluta* during the winter rotation (2013).

Time of examination / weeks	Average number ± SD / leaf					
	tunnels	larvae	Eggs	tunnels	larvae	Eggs
	Strain 010			Strain 5656- hybrid		
3/10/2013	0.05± 0.01	0.04±0.004	0.07± 0.03	0.1 ± 0.07	0.11 ± 0.6	0.33± 0.19
17/10/2013	0.45 ± 0.1	0.083±0.02	0.87± 0.33	0.6 ± 0.24	0.13± 0.28	0.89± 0.37
31/10/2013	0.83± 0.22	0.83± 0.26	0.68± 0.26	1.13±0.083	1.18± 0.34	1 ± 0.38
14/11/2013	1.3 ± 0.21	0.93± 0.41	1.18± 0.41	1.4 ± 0.3	0.98 ± 0.4	1.05± 0.45
28/11/2013	1.28± 0.19	1 ± 0.38	1.08± 0.35	1.85± 0.27	1.1 ± 0.6	1.38± 0.54
12/12/2013	1.7 ± 0.45	1 ± 0.6	1.35± 0.55	2.23± 0.18	1.43± 0.65	2.58± 0.74
26/12/2013	2.05± 0.08	1.63± 0.53	1.2 ± 0.47	2.93± 0.16	1.75± 0.97	1.95± 0.86
9/1/2014	1.75± 0.38	1.25± 0.63	1.48± 0.55	3.08 ± 0.1	1.18± 1.05	2.075±0.83
23/1/2014	2.35 ± 0.4	1.75± 0.69	2.13± 0.64	3.18± 0.31	2.4 ± 0.87	2.8 ± 0.8
Total	**11.76 ± 2 ^{e}**	**8.5 ± 3.5 ^{B}**	**10.02±3.6^{A}**	**16.5 ± 1.7^{E}**	**10.17±5.8^{B}**	**14.1±5.2^{A}**

Means of total values followed by similar letters within the same row are not significantly different at 0.05 levels.

Table 5. Host-plant preference of *T. absoluta* under field conditions.

Host-plant	Average number ± SD / leaf		
	Tunnels	Larvae	Eggs
Tomato	17.05 ± 4.2 a	5.73 ± 1.9 A	8.03 ± 1.5 I
Eggplant	5.4 ± 1.8 b	3.7 ± 0.37 A B	3.8 ± 1.4 IJ
Potato	3.7 ± 0.75 b	4.9 ± 1.1 A B	2.2 ± 0.7 J
Pepper	1.8 ± 1.4 b	0 B	0 J

The values followed by the same letters mean that the differences were not significant at $P< 0.05$.

Table 6. Effects of host-plant on different biological aspects of *T. absoluta* under laboratory conditions.

Host plants	% of egg hatching	Larval developmental (time/day)	% pupation	Weight of pupae (mg)	% of adult emergence	Fecundity (egg/female)
Tomato	85 %	11.7 ± 0.47 a	70.7 %	3.31 ± 0.54 a	96.3 %	103.9 a
Eggplant	77 %	13.3 ± 1.3 ab	65.5 %	3.18± 0.42 ab	89.8 %	93.2 a
Potato	80 %	14.7 ± 0.47 b	45.3 %	2.55±0.48 b	91.2 %	81.4 b

Means followed by similar letters within the same vertical column are not significantly different at 0.05 level.

Discussion

T. absoluta is one of the most important lepidopterous insect pests on tomato in both greenhouses and in the open field. It prefers to lay eggs on tomato leaves and after egg deposition, larvae penetrate the leaves, stems or fruits causing mines and galleries. No tomato cultivars are entirely resistant to this insect, but not all cultivars are equally susceptible. Similar observations were recorded by BORGORNI *et al.* (2003); OLIVEIRA *et al.* (2009); PROFFIT *et al.* (2011); DE OLIVEIRA *et al.* (2012); CHERIF *et al.* (2013).

Investigations were carried out to evaluate the susceptibility of different strains of tomato during the early summer and nile rotations in 2012 and also during summer and winter rotations in 2013. It appears that the native strain was more susceptible to infestation compared to the strain GS and super hybrid in the early summer rotation of 2012. In the nile rotation, the strain 77 was more susceptible to infestation as compared to the strain 010 where the number of eggs, larvae and mines on the leaves of the strain 77 were significantly higher compared to that of the strain 010.

In the summer rotation of 2013, the strain 2243 appears to be more susceptible to infestation with *T. absoluta* as compared to the strain GS. On the other hand, the strain coded 5656 showed to be more susceptible to infestation as compared to the strain 010, judged from the number of eggs, larvae and mines (tunnels) recorded during this season on the leaves of this strain. These findings clearly indicate the variation in the susceptibility of the most dominant tomato strains cultivated in Egypt. Our results agree with observations concluded by BORGORNI *et al.* (2003) and OLIVEIRA *et al.* (2009) who studied the susceptibility of some tomato strains to infestation with *T. absoluta* and showed that no tomato cultivars are entirely resistant to *T. absoluta*, but not all cultivars are equally susceptible. In this concern, FERNANDEZ & MONTAGNE (1990) found that the tomato cultivar "Rome Gigante" was the preferred oviposition host and the best for larval development compared to different tomato variety and other hosts.

The difference in the *T. absoluta* preference between the different tomato cultivars can be attributed to differences in leaf volatile compounds (PROFFIT *et al.*, 2011; CHERIF *et al.*, 2013). Indeed, based on oviposition bioassays, PROFFIT *et al.* (2011) demonstrated that *T. absoluta* females laid more eggs in response to cvs. Santa Clara and Carmen as compared to cv. Aromata. The same authors found that overall leaf volatile composition of cv. Aromata differed significantly from cvs. Santa Clara and Carmen, due to differences in proportions of minor compounds and due to the absence of several compounds, mostly terpenes, in cv. Aromata. DE OLIVEIRA *et al*. (2012) showed that oviposition rate and damage on plants were significantly lower on tomato strains rich in one of the following allelochemicals: 2-tridecanone or zingiberene.

CHERIF *et al*. (2013) tested the susceptibility of different cultivars of tomato to infestation with *T. absoluta* and recommended that selection of lower suitability cultivars for *T. absoluta* female egg-laying in agriculture certainly provide a basis for development and implementation of effective prophylactic and environmentally-sound pest management tools against *T. absoluta*. Also, observations of GHAREKHANI & SALEK-EBRAHIMI (2014) who evaluated the damage of *T. absoluta* on eleven tomato cultivars reported that damaged leaves, active mines and damaged terminal buds were significantly different among the tomato cultivars.

T. absoluta is polyphagous, but it prefers some of its hosts such as tomato. The senses of taste and smell in lepidopterous larvae are important in host plant selection and the acceptance of the larva of *T. absoluta* to a host plant is due probably to chemical volatiles rather than purely physical factors as reported by TORRES *et al*. (2001) and PROFFIT *et al*. (2011). In this concern, Kamel (1969, Cairo University, Egypt, pers. comm.) found that the larvae of *Spodoptera littoralis* bear gustatory receptors that are localized on the labrum epipharynx.

The ecological studies showed that the tomato plants among other host plants were highly attractive to *T. absoluta* under open field conditions; this was followed by eggplant which showed to be more susceptible than potato. On the other hand, pepper was weakly susceptible with very low rates of infestation. VARGES (1970) in South America reported that *T. absoluta* feeds and develops on tomato and other cultivated and non cultivated Solanaceous plants. In Europe, the insect prefers tomato and other Solanaceous crops such as eggplant (MPAAF, 2009; VIGGIANI *et al*., 2009), potato (UNLU, 2012) and pepper (MPAAF, 2009), sweet cucumber (pepino) (FERA, 2009) and common beans (EPPO, 2009; MPAAF, 2009).

Based on these findings, the biology of *T. absoluta* is affected when reared under laboratory conditions on different host plants. Thus the larval duration was shorter when reared on tomato being 11.7±0.47 days as compared to 13.3±1.3 and 14.7±0.45 days when reared on egg plant and potato leaves, respectively. The pupation percentage was 70.7, 65.5 and 45.3% when the larvae fed tomato, eggplant and potato, respectively. Also pupal weight was significantly higher for individuals reared on tomato, eggplant as compared with those reared on potato. Egg production ranged between 103.9 eggs/female previously fed on tomato leaves and 81.4 eggs/female for those fed on potato.

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