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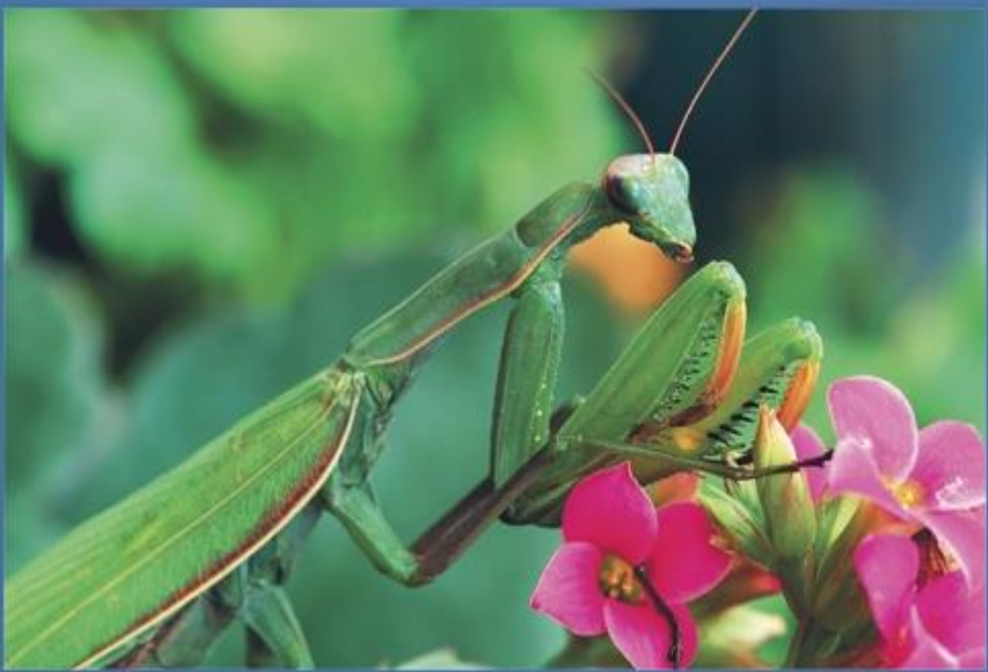

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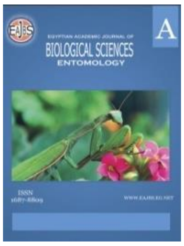

Life Table Parameters of *Tuta absoluta* (Lepidoptera: Gelechiidae) On Six Tomato Cultivars

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ABSTRACT

The tomato leaf miner (TLM), *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is a destructive insect pest of tomatoes and other solanaceous plants in Egypt and other countries all over the world. To monitor the preferred tomato cultivars for *T. absoluta*, some biological aspects, non-choice bioassay and free-choice bioassay tests were studied on six common tomato cultivars. Our results found that the tomato-86 cultivar has a superior ability to delay the development rate of TLM, while the tomato-GS cultivar accelerated the development rate. Also, results showed that *T. absoluta* larvae reared on the tomato-86 cultivar reduced the larval weight, larval survival, male and female pupal weight, mean number of laid eggs/plant and oviposition preference%. Conversely, the tomato-GS reported a highly significant increase in all non-choice and free-choice bioassay parameters. So, the results indicated that tomato-86 was the least preferred cultivar, while tomato-GS was the most preferred to *T. absoluta*. Therefore, we recommend planting the tomato-86 cultivar that could be used as a fundamental approach in integrated pest management (IPM) programs against *T. absoluta*.

INTRODUCTION

Tomatoes (*Lycopersicon esculentum* Mill.) are one of the very important food crops in the world (Portakaldali *et al.*, 2013; Bawin *et al.*, 2016, Ingegno *et al.*, 2017; Ingegno *et al.*, 2017). Egypt has a suitable climate for cultivating tomato plants and the total planted area is about 21600 feddan (=9000 ha), with annual tomato fruit production is 9204097 tons (Moussa *et al.*, 2013). Egypt is ranking 5th position of 144 countries of tomatoes producer worldwide, equivalent to 6.95% of tomatoes world production (WPTC 2011; Costa and Heuvelink 2018).

Tomato plants are infested with numerous insect pests. Among them, the destructive *Tuta absoluta* (Meyrick) is one of the biggest threats to tomatoes worldwide (Desneux *et al.*, 2011; Biondi *et al.*, 2018; Mansour *et al.*, 2018; Cherif and Verheggen 2019; Verheggen and Fontus 2019; Sadique *et al.*, 2022). In 2009, it was first detected in tomatoes in Northwestern Egypt. After that, it spread quickly to lower and upper Egypt (Moussa *et al.*, 2013; Salama *et al.*, 2015). *T. absoluta* larvae can attack tomato plants and feed on all parts except the root. So, the direct damage to tomato plants causes severe losses if not controlled (Tropea Grazia *et al.,* 2012; Soliman, 2015; Hassan, *et al*. 2017).

The present work aimed to investigate the life table parameters of *T. absoluta* on six tested tomato cultivars. The obtained results were used to know some biological aspects, non-choice bioassay test and free-choice bioassay test of *T. absoluta* on six common tomato cultivars in Egypt. Keeping in view the above facts, the present study was carried out to investigate the following points; the impact of the tested tomato cultivars on some biological and infestation parameters of *T. absoluta* using certain non-choice and free-choice bioassay tests. The present investigation aimed to determine the least preferred tomato cultivars for *T. absoluta*, so the authors recommend cultivating it within IPM programs against *T. absoluta*.

MATERIALS AND METHODS

Tested Cultivars:

Seeds of six commercially available tomato cultivars, *Lycopersicon esculentum* Mill, namely: tomato-86, tomato-Fayarouz, tomato-Omniya, tomato-036, tomato-Alissa, and tomato-GS, were obtained from El-Zahraa Farm, Sharkia Governorate. The tomato seeds were treated with 1% sodium hypochloride solution for thirty minutes and then planted in seedling trays containing peat moss under an agriculture greenhouse maintained at 25±5°C and 12:12 L:D h photoperiod. After 30 days, all seedlings were transferred to the Agriculture Faculty farm, Zagazig University and transplanted in the field after preparing and designing all the cultivated area (2100 m^2). All agricultural processes were normally conducted under natural environmental conditions without using insecticide or fertilizer. The experiment was repeated three times and designed according to a randomized complete block design.

***Tuta absoluta* Rearing:**

Field insect populations were obtained from tomato farms at Sharkia Governorate, Egypt, as larval instars. *T. absoluta* larvae were reared under laboratory conditions (26±3°C and 60±5% RH). The larvae were collected using a fine paintbrush and put directly on fresh tomato branches in glass bottles filled with tap water. The procedure continued until the larvae were pupated. Pupae were collected and put in plastic vials (2 cm × 3 cm) separately; these vials were covered with punctured covers and placed into wooden trays. Forty adults of both sexes (1:1 ♀: ♂) were introduced in a glass chimney cage supplied with a cotton swab soaked in a 10% sucrose solution and provided with fresh branches for mating and egg deposition. The glass chimney cages were covered with muslin cloth secured with bands. The tomato branches bearing eggs were taken out daily and put in plastic jars (30 cm ×10 cm). Then another fresh tomato branch was substituted. This procedure continued until the male and female adults died. The newly hatched larvae were transferred to fresh tomato branches. This rearing method for *T. absoluta* was thus continued for two successive generations to obtain rearing and adapted individuals under laboratory conditions. *T. absoluta* reared on each tomato cultivar was used for evaluating some biological aspects, non-choice and free-choice bioassay tests on the tested tomato cultivars.

Biological Aspects of *Tuta absoluta*:

Five pairs of newly emerged adults (within 24 hours) of *T. absoluta* were introduced into glass chimney cages (one pair for each glass chimney cage) containing one fresh branch/each of the tested tomato cultivars. In all treatments, newly emerged adults (female and male) were paired in glass chimney cages with 10% sucrose solution in impregnated cotton. The glass chimney cage was covered with black muslin cloth tightened with a rubber band. Each chimney cage was placed on a 9 cm Petri dish with filter paper on the bottom. The chimney cages were inspected daily to count the laid egg numbers/female. The tested branches bearing eggs were put in glass jars (50 ml) and then substituted daily with fresh branches until the adults died. Hatchability percentage, male longevity and female longevity (Pre-oviposition, oviposition, and post-oviposition periods), sex ratio and mean generation period were calculated. These procedures were carried out on all six tested cultivars and The experiment was repeated five times and designed according to a completely randomized design.

Non-choice Bioassay Test:

Six different tomato cultivar plantings were put inside glass jars banded with wilting cotton which were replicated three times and designed according to a completely randomized design for a non-choice assay test. All plantings of the six tomato cultivars were infected with 1st larval instar. Daily, the larvae were inspected until reaching the 4th larval instar and weighted the live larvae/planting. After pupating, Ten pupae were weighed of each tested cultivar. The tunnel area of the tomato cultivar leaves was also measured by KOIZUMI PLACOM KP-90N digital Planimeter. The live larvae percentages were calculated**.**

$$\text{Live larva\%} = \frac{\text{No.of the live larvae}}{\text{Total No.of larvae/ six tomato cultivars}} \times 100$$

Free-choice Bioassay Test:

Six tomato cultivar plantings were put inside glass jars (500 mL capacity), covered with a muslin cloth, tied with its bands, and kept at 26 ± 3°C and 60 ± 5% RH. Three replicates and designed according to a completely randomized design were used. Eight pairs of *T. absoluta* adults were put inside the glass jars, then daily inspected the six plantings of tomato cultivars, and counted the eggs laid by the tested insect. The plantings were changed per two days until finishing the laid oviposition and counting the laid egg numbers per cultivar. The Oviposition preference% was calculated as the following:

$$\text{Oviposition preference\%} = \frac{\text{No.of laid eggs on the tested cultivar}}{\text{Total No.of laid eggs/six tomato cultivars}} \times 100$$

Statistical Analysis:

The obtained data was subjected to Analysis of Variance (ANOVA) techniques and treatment means with significant differences were separated by Duncan multiple range test (Duncan 1955) at 1% and 5% probability levels. The computer package software SPSS 14.00 (SPSS, Inc. Chicago, Il, USA) statistical was employed (Hendy 1969).

RESULTS

Biological Aspects of *Tuta absoluta*::

The incubation period varied highly significantly between the six tested tomato cultivars(F= 5.16**; *P*<0.0024). The incubation period was the longest on the tomato-86 cultivar, followed by tomato-Fayrouz and tomato-Omniya (4.00±0.00, 3.80±0.17 and 3.80±0.17 days, respectively) and the shortest period was observed on tomato-GS (3.00±0.00 days) (Table 1).

Regarding hatchability, it was noticed that there were highly significant variations in hatchability % on the different tested tomato cultivars(F= 4.66**; *P*<0.0041). It was found that the highest hatchability% was recorded on the tomato-036 (94.50±0.75%), while the lowest was recorded on the tomato-86 (85.50±2.33%) (Table 1). The larval duration on tomato-86 (11.40±0.21 days) was longer than those on the other cultivars, while the shortest was 5.20±0.17 days on tomato-036 (Table 1). The pupal duration was 6.40±0.21, 6.20±0.33 and 6.00±0.00 days on tomato-GS, tomato-Omniya and tomato-036, respectively, while the shortest duration was detected on both tomato-86 and tomato-Fayrouz (5.20±0.17 and 5.20±0.17 days, respectively) Table (1).

Table 1. Biological aspects of *Tuta absoluta* on the tested tomato cultivars under laboratory conditions.

Tomato cultivar	Incubation period (day)	Hatchability (%)	Larval duration (day)	Pupal duration (day)	Developmental period (day)	Pupation (%)	Adult emergence (%)	Generation period (day)
	Mean±SE							
Tomato-86	4.00±0.00^{a}	85.50±2.33^{c}	11.40±0.21^{a}	5.20±0.17^{c}	20.00±0.40^{a}	61.10±2.81^{c}	83.54±2.55^{c}	37.40±0.45^{a}
Tomato-Alissa	3.40±0.21^{bc}	93.41±1.04^{ab}	6.80±0.33^{b}	5.40±0.21^{bc}	16.00±0.40^{b}	87.40±2.43^{a}	88.30± 0.81^{b}	32.40±0.21^{c}
Tomato-Fayrouz	3.80±0.17^{ab}	89.78±1.43^{bc}	6.80±0.17^{b}	5.20±0.17^{c}	16.20± 0.33^{b}	90.33±2.03^{a}	80.85±1.01^{c}	31.20±0.33^{cd}
Tomato-Omniya	3.80±0.17^{ab}	92.10±0.89^{ab}	6.20±0.17^{b}	6.20±0.33^{a}	16.40±0.35^{b}	80.16±2.81^{b}	89.59±1.01^{b}	34.80±0.33^{b}
Tomato-036	3.20±0.17^{c}	94.50±0.75^{a}	5.20±0.17^{c}	6.00±0.00^{ab}	14.40±0.21^{c}	92.45±2.49^{a}	90.12±0.81^{ab}	30.20±0.52^{d}
Tomato-GS	3.00±0.00^{c}	92.10±0.83^{ab}	6.80±0.17^{b}	6.40±0.21^{a}	15.60±0.35^{b}	93.50±1.98^{a}	94.20±0.56^{a}	30.00±0.28^{d}
F- value	5.16**	4.66**	77.07**	4.99**	23.21**	25.09**	10.88**	48.89**
P-Value	0.0024	0.0041	0.00000	0.0028	0.0000	0.0000	0.0000	0.0000

**: means with different letters within the same column are highly significant (*P*<0.01)

Respecting the mean developmental period, it was found that there were highly significant variations in this period for tested tomato cultivars (F= 23.21**; *P*<0.0000). The longest mean developmental period was observed on tomato-86 (20.00±0.40 days), whereas the shortest was 15.60±0.35 and 14.40±0.21 days on tomato-GS and tomato-036 cultivars, respectively (Table 1). Pupation and adult emergence percentages showed highly significant differences. The highest pupation percentage on the tomato-GS cultivar was 93.50±1.98%, and the lowest on tomato-86 was 61.10±2.81% (F= 25.09**; *P*<0.0000) (Table 1). The adult emergence percentage showed the highest emergence percentage, 94.20±0.56%, on the tomato-GS cultivar. In contrast, the lowest was 80.85±1.01% and 83.54±2.55% on tomato-Fayrouz and tomato-86, respectively (F= 10.88**; *P*<0.0000) (Table 1). The different tested tomato cultivars had highly significant differences in mean generation period (F= 48.89**; *P*<0.0000). The longest mean generation period was recorded for tomato-86 (37.40±0.45 days), while the tomato-GS cultivar recorded the shortest one (30.00±0.28 days) (Table 1).

The tested cultivars' mean number of laid eggs/female was influenced by the highest number on tomato-GS cultivar (179.60±3.30 eggs/female). In contrast, the lowest value was recorded on tomato-86 (97.80±3.19 eggs/female). Highly significant variations were found among them (F= 76.12**; *P*<0.0000) (Table 2). Variations in the pre-oviposition period between the females resulted from larvae that reared on the six tested cultivars, significantly varied between each other detected (F= 2.77*; *P*<0.0409). The tomato-GS, tomato-036 and tomato-Alissa had the shortest pre-oviposition period (2.80±0.17 days) on the three tomato cultivars, while the pre-oviposition period was the longest on tomato-86 (3.60±0.21 days) Table 2. The oviposition period was the longest on tomato-Omniya and tomato-Fayrouz (5.80±0.17 and 5.00±0.00 days, respectively); being highly significantly different from all other cultivars (F=7.71**; *P*<0.0002) and the shortest one was 4.20±0.17 days on tomato-86. The longest post-oviposition period was 8.60±0.21 days recorded on tomato-Alissa, whereas the shortest was 7.40±0.21 days on tomato-036, with highly significant varied between the tested cultivars (F=3.97**; *P*<0.0091). The tested cultivars and total female longevity differed highly significantly (F=5.89**; *P*<0.0011) and the longest was 17.40±0.21 days on tomato-Omniya, whereas the shortest was 14.80±0.52 and 15.60±0.21 days on tomato-036 and tomato-86, respectively (Table 2).

Table 2. Laid egg number and adult longevity of *T. absoluta* on the tested tomato cultivars under laboratory conditions.

Tomato cultivar	Laid eggs/female (Mean±SE)	Adult longevity (day) (Mean±SE)					Sex ratio (as female) % (Mean±SE)
		Female				Male	
		Pre-oviposition	Oviposition period	Post-oviposition period	Total		
Tomato-86	97.80±3.19^{e}	3.60±0.21^{a}	4.20±0.17^{c}	7.80±0.17^{bc}	15.60±0.21^{bc}	15.20±0.33^{a}	52.27±3.30^{c}
Tomato-Alissa	117.60±1.93^{d}	2.80±0.17^{b}	4.80±0.17^{bc}	8.60±0.21^{a}	16.20±0.17^{b}	14.20±0.17^{b}	64.55±1.74^{a}
Tomato-Fayrouz	126.60±2.96^{cd}	3.40±0.21^{ab}	5.00±0.00^{b}	7.60±0.21^{bc}	16.00±040 ^{b}	15.00±0.28^{a}	61.60±3.02^{ab}
Tomato-Omniya	128.40±2.27^{c}	3.40±0.21^{ab}	5.80±0.17^{a}	8.20±0.17^{ab}	17.40±0.21^{a}	15.40±0.21^{a}	65.26±2.68^{a}
Tomato-036	158.20±3.97^{b}	2.80±0.17^{b}	4.60±0.21^{bc}	7.40±0.21^{c}	14.80±0.52^{c}	14.20±0.17^{b}	54.13±0.78^{bc}
Tomato-GS	179.60±3.30^{a}	2.80±0.17^{b}	4.80±0.17^{bc}	8.20±0.17^{ab}	15.80±0.17^{bc}	15.20±0.17^{a}	54.60±1.87^{bc}
F- value	76.12**	2.77*	7.71**	3.97**	5.89**	4.04**	4.58**
P-value	0.0000	0.0409	0.0002	0.0091	0.0011	0.0084	0.0045

* & **: means with different letters within the same column are significant (*P*<0.05) and highly significant (*P*<0.01), respectively.

The male longevity resulting from larvae reared on the tested cultivars varied significantly against tested tomato cultivars (F=4.04**; *P*<0.0084). The longest male longevity was 15.40±0.21 days observed on tomato-Omniya cultivar, while the shortest was 14.20±0.17 days on tomato-036 and tomato-Alissa (Table 2). There were highly significant variations in the sex ratio (as female) of the moths resulting from larvae that were reared on the tested tomato cultivars (F= 4.58**; *P*<0.0045). The highest sex ratio was 65.26±2.68% for tomato-Omnyia, while the lowest was 52.27±3.30% for tomato-86 (Table 2).

Non-choice Bioassay Test:

There were highly significant differences between some infestation parameters with TLM on the six tested cultivars under the non-choice bioassay test (Table 3). It was found that the highest live larva weight was recorded on the tomato-GS cultivar (23.27±2.58 mg), while the lowest one (1.28±0.62 mg) was recorded on the tomato-86 cultivar, being highly significantly different (F= 25.45**; *P*<0.0000). The live larva percentage of *T. absoluta* differed significantly on the tested tomato cultivars. The highest live larval percentage was 99.67±7.84, 99.67±6.33 and 99.67±5.55 % on the three tomato cultivars (tomato-GS, tomato-036 and tomato-Omniya, respectively) and the lowest live larva percentage was 20.33±1.76% on the tomato-86 cultivars, being highly significantly different from all other tested cultivars (F= 38.43**; *P*<0.0000) (Table 3).

Regarding pupa weight of the tested insect pest, there were highly significant variations between the tested cultivars. The highest pupa weight, which resulted from larvae fed on the tomato-GS cultivar, was 10.18±1.16 mg, whereas the lowest pupa weight was 0.31±0.06 mg, which was recorded on tomato-86; being a highly significant difference with all other tested cultivars (F= 27.29**; *P*<0.0000) (Table 3). There was a highly significant difference between the tested tomato cultivars in the tunnel area/leaflet (mm^2) (F= 6.43**; *P*<0.0040). The highest tunnel area/leaflet was 8.21±1.14 mm^2 on the tomato-GS cultivar and the lowest one (1.25±0.61 mm^2) was recorded on the tomato-86 (Table 3).

Table 3. Effect of the tested tomato cultivars on some infestation parameters of *T. absoluta* under non-choice bioassay test.

Tomato cultivar	Live larva weight (mg)	Live larva (%)	Pupa weight (mg)		Tunnel area/leaflet (mm²)
			Male	Female	
	Mean±SE				
Tomato- 86	1.28±0.62[c]	20.33±1.76[d]	0.31±0.06[c]	0.60±0.12[c]	1.25±0.61[c]
Tomato- Alissa	5.70±0.89[c]	52.78±3.47[c]	1.91±0.57[c]	3.16±1.18[c]	3.93±0.61[bc]
Tomato- Fayrouz	17.09±1.70[b]	80.00±4.36[b]	8.01±0.58[ab]	8.00±1.15[b]	6.47±1.17[ab]
Tomato- Omniya	18.43±1.60[ab]	99.67±5.55[a]	6.18±0.50[b]	9.49±1.23[ab]	7.31±1.14[a]
Tomato- 036	19.08±2.06[ab]	99.67±6.33[a]	9.07±1.12[a]	7.99±1.15[b]	6.14±1.16[ab]
Tomato- GS	23.27±2.58[a]	99.67±7.84[a]	10.18±1.16[a]	11.79±1.11[a]	8.21±1.14[a]
F-value	25.45**	38.43**	27.29**	15.24**	6.43**
P-value	0.0000	0.0000	0.0000	0.0001	0.0040

**: means with different letters within the same column are highly significant ($P<0.01$)

Free-choice Bioassay Test:

The six different tomato cultivars highly significantly affected the mean number of oviposited eggs number/plant by *T. absoluta* females. The most laid egg numbers by females were on leaves/plant of the tomato-GS cultivar, followed by the tomato-036, the tomato-Omniya, the tomato-Fayrouz, the tomato-Alissa and the tomato-86 (70.00±2.88, 53.33±4.40, 41.67±4.40, 35.00±4.04, 32.00±4.35 and 18.33±2.03 eggs/plant); being highly significant varied in numbers between each other (F= 22.45**; $P<0.0000$). The oviposition preference percentages of the six selected tomato cultivars descendingly as 29.59±1.58, 19.49±1.74, 15.52±1.14, 12.42±1.15, 11.63±0.66 and 7.22±0.60% for tomato-GS, tomato-036, tomato-Omniya, tomato-Fayrouz, tomato-Alissa and tomato-86, respectively; being highly significantly different between each other (F= 41.43**; $P<0.0000$) (Table 4).

Table 4. Laid eggs and oviposition preference% of *T. absoluta* on the tested tomato cultivars under free-choice bioassay test.

Tomato cultivar	laid eggs/plant	Oviposition preference (%)
	(Mean±SE)	
Tomato-86	18.33±2.03[d]	7.22±0.60[e]
Tomato-Alissa	32.00±4.35 [c]	11.63±0.66[d]
Tomato-Fayrouz	35.00±4.04[c]	12.42±1.15[cd]
Tomato-Omniya	41.67±4.40[bc]	15.52±1.14[c]
Tomato-036	53.33±4.40[b]	19.49±1.74[b]
Tomato-GS	70.00±2.88 [a]	29.59±1.58[a]
F-value	22.45**	41.43**
P-value	0.0000	0.0000

**: means with different letters within the same column are highly significant ($P<0.01$)

DISCUSSION

The present results clarify the different impacts of the six commonly grown tomato cultivars on the growth, mortality and Laid eggs of TLM, *T. absoluta*. The present results agree with other findings on TLM (Pereyra and Sanchez 2006; Erdoğan and Babaroğlu 2014; Gharekhani and Salek-Ebrahimi 2014; Khatami *et al.*, 2022). All studies revealed the profound effect of various cultivars of tomato on TLM performance. The various cultivars influenced the incubation period of tomato leaf miner. The present results agree with (Ghaderi *et al.,* 2017). Tomato cultivar Cal JN3 demonstrated that in comparison to the other tested cultivars, larval and pupal stages of *T. absoluta* was the shortest period, and exhibited that this cultivar contains the nutritional contents for larvae requirement. The two tomato varieties, namely, Cobra 26 F1 and Kanon F1 cultivars, have superior abilities to delay the development rate of TLM (Sawadogo *et al.,* 2021). On the other hand, the growth time of tomato leaf miner on the Urbana Y cultivar was the longest compared with the other tested cultivars. *T. absoluta* adult longevity varied significantly between the selected cultivars, with the shortest and longest adult longevity. Urbana Y cultivar had low susceptibility to TLM, which might be attributed to tested tomato plants' biochemical or physical properties. The mean fecundity of TLM ranged between 97.73 to 132.78 eggs/female on the tested Solanaceae plants (Pereyra and Sanchez 2006), while it reached 141.16 eggs/female on the tested tomato plants (Erdoğan and Babaroğlu 2014). While mean fecundity was recorded on different potato cultivars (25.5 and 50.6 eggs/female) Caparros Megido *et al.,* 2013).

Our results indicated a highly significant difference in all non-choice bioassay test parameters due to variations in the six tested tomato cultivars. *T. absoluta* larvae reared on the least preferred cultivars in a non-choice bioassay test showed a reduction in the weight of larvae, survival larvae and pupae Dos Santos *et al.*, 2011; Mphahlele 2021). Conversely, there was no influence in some non-choice bioassay test parameters (weight pupae) by the kind of tomato line (Thomazini *et al.,* 2001; Borgoni and Carvalho 2006).

In our investigation, the variations of the oviposition preference of the insect tested on the different tested cultivars may be attributed to plant leaf chemicals variance (El-Sitiny 2022). Also, depending on oviposition preference, TLM females preferred more oviposition on Carmen and Santa Clara tomato cultivars than on Aromata cultivars (Proffit *et al.,* 2011).

CONCLUSION

The obtained data might provide basic information for selecting the tomato cultivars that were the least preferred host to TLM infestation, which can used for implementing protection management strategies against *T. absoluta* by studying the life table parameters on six commonly tested tomato cultivars in Egypt.

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