Research Article

Population Dynamics of the Leaf Miner *Tuta absoluta* (Lepidoptra: Gelechiidae) and its Parasitoids on Tomato Crop in Beni-Suef, Egypt

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Abstract | Tomato (*Solanum lycopersicum*) is the most common vegetables all over the word. In Egypt, tomato is extensively cultivated and considered one of the key pillars in the agricultural vegetables production. Pests are the main obstacle facing the tomato production worldwide. The tomato leaf miner, *Tuta absoluta* is one of the recent devastating exotic pests that is able to cause severe damage to the tomato crop and is very difficult to control. Therefore, the present study was aimed to evaluate seasonal population dynamics of the tomato leaf miner *Tuta absoluta* and its parasitoids as well as the rate of parasitism, the parasitoids assemblages and the relative impact of parasitoids on its population over two seasons on tomato in the experimental farm of the Agriculture Research Center, Sids in Beni Suef Governorate, Egypt. During first plantation in the first plantation, The results revealed that *T. absoluta* started to appear after one month from the plantation on the 3rd August week and increased gradually to show 5 peaks in the 7th September, 2nd November, 30th November, 28th December and 11th January. During second plantation in the first season, the population of *T. absoluta* started very weak in 12th April and showed five peaks in 17th May, 31st May, 28th June, 12th July and 26th July. During first plantation in the second season, this pest revealed 5 peaks in 13th September, 4th October, 18th October, 20th and 31th January. During second plantation in the second season, *T. absoluta* exhibited five peaks in 17th April, 1st May, 29th May, 12th June and 10th July. The samples of *T. absoluta* collected in the present study were parasitized by *Bracon* sp., *Pteromalus* sp. and *Eulophus* sp. with maximum rate of parasitism reached to 51% with 5 peaks similar to these of *T. absoluta*. Therefore, we suggest that these parasitic species could be used in biological control of *T. absoluta*.

Keywords | *Solanum lycopersicum*, Biological control, Parasite, Prevalence

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INTRODUCTION

Solanaceous plants especially tomatoes have great economic importance in Egypt (Hassan et al., 2022). Tomato leaf miner *Tuta absoluta* (Meyrick) is a devastating insect pest causing severe loss of tomato production in many countries either in open field or greenhouses (Hassan et al., 2022). In South America for example, *Tuta absoluta* considered is main destructive pest for tomato crops (EPPO, 2010). *Tuta absoluta* is present throughout the crop duration; larvae can infest leaves, flowers, stems and fruits, causing severe crop losses of up to 100 % when no control measures are present (EPPO, 2008; Youssef, 2015). Although tomato is the major host for *T. absoluta* and has

a better nutritive quality than other hosts (Desneux et al., 2010; Bawin et al., 2015), it can invade many economically important families of vegetable crops (Pereyra and Sánchez, 2006; Shehata et al., 2016) and weeds (Portakaldali et al., 2013; Sabry and Ragaei, 2015; Abbes et al., 2016).

The tomato leaf miner, invaded Egypt in the nearest Governorate to Libya (Matrooh) in 2009 and by 2010 it was reached to Giza, coming well established in all Governorates of Egypt and reaching to the border and north part of Sudan on June 2011 (Tamerak, 2011; Gaffar, 2012). Since that time, this pest spread quickly in all tomato growing areas in Egypt, destroying entire open fields and tomato in plastic houses. Ramirez et al. (2010) reported that the damage by *T. absoluta* can be 100% in unprotected crops and it was considered in its region distribution area as a significant tomato insect pest (Leite et al., 2001). Nowadays, *T. absoluta* becomes one of the most damaging pests and severe threat to tomato production in Egyptian agroecosystem (Hassan et al., 2022).

The current study was carried out in Sids Research Station to estimate the population dynamics, seasonal abundance and number of generations per annum of *T. absoluta* for two successive seasons of tomato plantation (2014/2015 and 2015/2016).

MATERIALS AND METHODS

This study was carried out in Sids Research Station for two successive cultivation seasons of tomato; 2014/2015 and 2015/2016. During two seasons, normal practices were followed and chemical control was neglected. Sampling took place as soon as the true newly vegetative growth was completely appeared in the experimental area and continued weekly until harvest.

Incidence of *T. Absoluta*

To estimate the population abundance of *T. absoluta*, cultivate two plantations, first plantation in 1/2 feddan (2100 m^2) with 23 variety at the beginning of July and second plantation in 1/2 feddan with 23 variety at beginning of March. Sampling started after one month of seedling. Twenty-five 25 compound leaves were collected weekly during the two experimental seasons. These leaves were kept in polyester bags, taken to laboratory, carefully to be examined. The development stages (eggs and larvae) were calculated and recorded. A survey of parasitoids was carried out in Beni-Suef Governorate throughout a period of two seasons. Samples of infested leaves with several insects were randomly collected in different months of the season. Immediately after collection, the samples were packed in paper bags, taken to the laboratory for examination. These specimens were carefully examined, and a needle was used to remove all the insects except only the desired species of insects which its natural enemies were desired to be surveyed. Those examined parts of plants were enclosed in plastic jars of 15 cm. diameter and 20 cm. height covered with muslin held in position by a rubber band and kept for securing any emerging parasitoids. The pupae of leaf-miners were placed on wetted filter paper in Petri-dishes of 9 cm and kept under preferential conditions until emergence of adult parasitoids according to Eid (1998).

Parasitoids species

All emerged parasitoids were collected, sorted into species and preserved in vials containing 70% ethanol and 5% glycerin, the slide mounting of represented specimens, was conducted as well. The labeled data included; location, date of collection, host insect and host plant. The parasitoids species were identified at Biological Control Research, Department of Plant Protection, Research Institute, Ministry of Agriculture, Giza, Egypt. The rate of parasitism in or on different stages of leaf miners infesting each of the mentioned host plants were estimated throughout two successive years extending from 2014 to 2016.

Efficiency of the parasitoid on the tomato leaf miners

To estimate the efficiency of the parasitoid on the tomato leaf miners *T. absoluta* random samples of the insect were collected weekly from tomato plants and kept in the laboratory in Petri dishes and fed on tomato leaves until pupation. Newly formed pupae were put in other Petri dishes till the emergence of fly adults or its parasitoids. The emerged parasitoids were determined in the two successive seasons. Each parasitoid specimen was put on a slide and covered with a water film, to be examined under a stereo-microscope, and classified as following: alive un-parasitized, parasitized leaf-miner having larvae, pupae of parasitoids or emergence holes. The percentage of parasitism was calculated.

RESULTS

The fluctuation in the population density of tomato leaf miner *T. absoluta*

Data illustrated in Figure 1 summarize the change in the population density of the tomato leaf miner, *T. absoluta* as indicated by the weekly counts of leaf miner per 25 compound leaves during two seasons. During first plantation in the first season (2014/2015), infestation started after one month from plantation on 3rd August with 4 individuals/ 25 leaves. This pest had 5 peaks. The number of larvae has increased gradually to reach to the first peak in 7th September with 19 individuals/ 25 leaves with maximum temperature 33.6°C and minimum temperature 22.3°C with average humidity of 63.79%. The second peak

was in 2nd November with 68 individuals/ 25 leaves. The third peak was in 30th November with 43 individuals/ 25 leaves. The fourth peak was in 28th December with 88 individuals / 25 leaves. The fifth peak was in 11th January with 76 individuals/ 25 leaves.

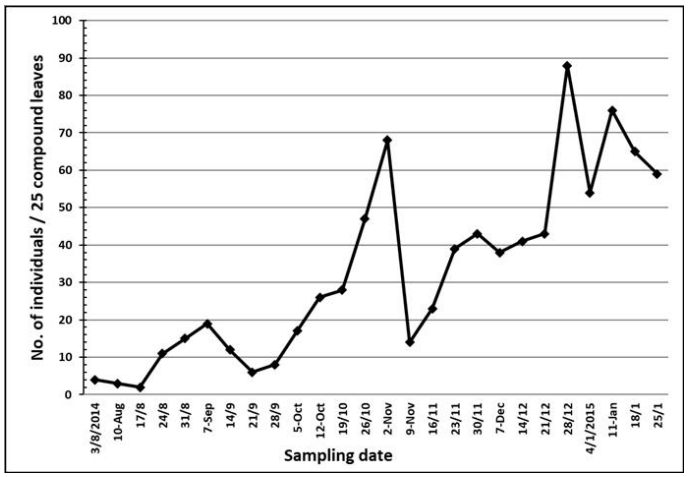

Figure 1: The fluctuation in the weekly counts of *T. absoluta*/ 25 compound leaves at Beni-Suef Governorate during first plantation in 2014/2015 season.

During second plantation in the first season, the population of *T. absoluta* started very weak in the 12th April with 8 individuals/ 25 leaves. *T. absoluta* showed five peaks during second plantation; the first peak occurred in 17th May with 83 individuals/ 25 leaves, the second peak occurred in 31st May with 98 individuals/ 25 leaves, the third peak occurred in 28th June with 187 individuals/ 25 leaves, the fourth occurred in 12th July with 137 individuals/ 25 leaves while the fifth peak occurred in 26th July with 106 individuals/ 25 leaves (Figure 2).

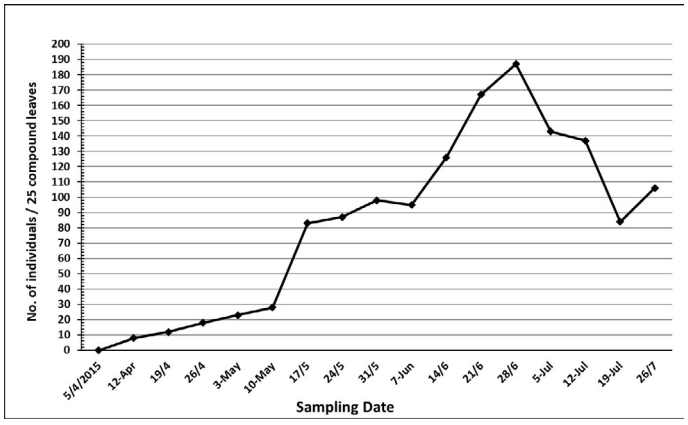

Figure 2: The fluctuation in the weekly counts of *T. absoluta*/ 25 compound leaves at Beni-Suef Governorate during second plantation in 2014/2015 season.

During first plantation in the second season (2015/2016), this pest revealed 5 peaks. The first peak in 13th September with 26 individuals/ 25 leaves with max. temperature 35.5°C, min. temperature 24.4°C and average humidity 67.97%. The second peak was in 4th October with 34 individuals/ 25 leaves. The third peak was in 18th October with 56 individuals/ 25 leaves. The fourth peak was in 20th December with 87 individuals/ 25 leaves. The fifth peak was in 31th January with 338 individuals/ 25 leaves (Figure 3).

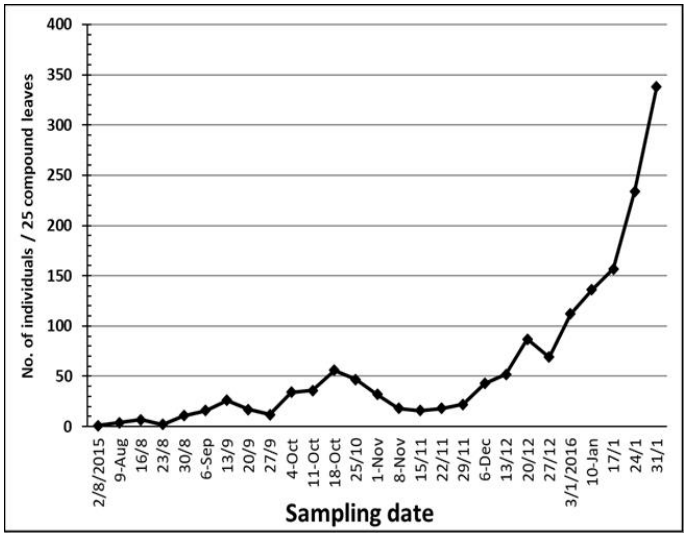

Figure 3: The fluctuation in the weekly counts of *T. absoluta*/ 25 compound leaves at Beni-Suef Governorate during first plantation in 2015/2016 season.

During second plantation in the second season, *T. absoluta* exhibited five peaks during second plantation; the first peak occurred in 17th April with 25 individuals/ 25 leaves, the second peak occurred in 1st May with 38 individuals/ 25 leaves, the third peak occurred in 29th May with 97 individuals/ 25 leaves, the fourth occurred in 12th June with 56 individuals/ 25 leaves while the fifth peak occurred in 10th July with 87 individuals/ 25 leaves (Figure 4).

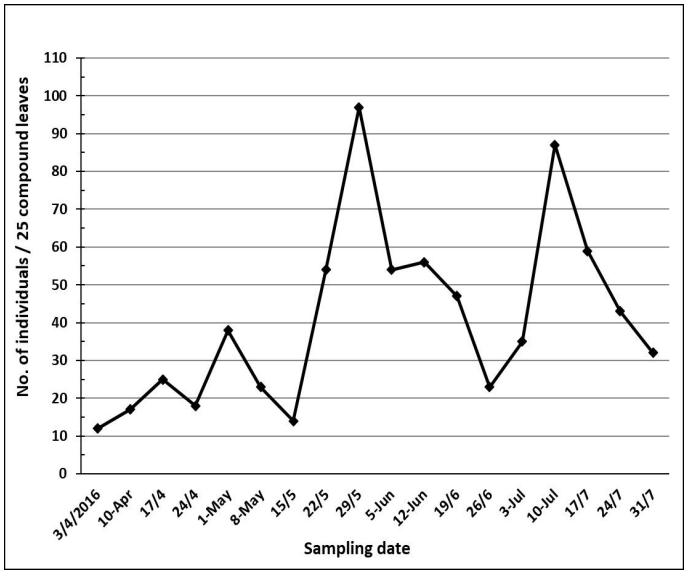

Figure 4: The fluctuation in the weekly counts of *T. absoluta*/ 25 compound leaves at Beni-Suef Governorate during second plantation in 2015/2016 season.

Table 1: Statistical analysis of the total count of immature stages of *T. asoluta* on tomato in two plantations as affected by weekly means of Max. and Min. temperatures, percentage of relative humidity (%R.H.) (partial correlation (r), regression coefficient (B), t-values (t) and analysis of variance (F- test and percentage of explained variance E.V. %) throughout two successive seasons 2014/2015 and 2015/2016 at Beni-Suef Governorate.

Y factor	season		X factor	Analysis of partial regression			Analysis of variance	
				r	B	t	F	E.V. %
T. asoluta	1st season 2014/ 2015	1st plantation (Y_1)	X_{11}	0.84	-1.2	-2.25	17.33**	70.4
			X_{21}		0.28	0.54		
			X_{31}		-0.37	-2.64		
		2nd plantation (Y_2)	X_{12}	0.84	0.03	0.08	10.4**	70.6
			X_{22}		0.75	1.78		
			X_{32}		0.21	0.92		
	2nd season 2015/ 2016	1st plantation (Y_3)	X_{13}	0.7	-0.36	-0.54	7.47**	49.4
			X_{23}		-0.34	-0.54		
			X_{33}		-0.51	-2.55		
		2nd plantation (Y_4)	X_{14}	0.49	-0.68	-0.75	1.49	24.2
			X_{24}		1.1	1.25		
			X_{34}		0.05	0.18		

** Highly significant at probability level 0.01; X1= Max. T; X2 =Min. T; X3= R.H. %; Y: Total count of immature stages.

esults presented in Table 1 showed that Max. T., Min. T., R. H. % had great effect on the activity of the total count of immature stages (larvae) of *T. asoluta* on tomato in two plantations throughout two successive seasons 2014/2015 and 2015/2016 at Beni-Suef Governorate. During the first season of investigation, the statistical analysis of data indicated that, the simple correlation and regression coefficient were highly significant at probability level 0.01 in the two plantations. The correlation coefficient values were 0.84 for the two plantations, in case of the total population of immature stages. The regression equations of total population of *T. asoluta* (Y_1) and (Y_2) with all factors under study were:

$Y_1 = 4.3 - 1.2\ X_{11} + 0.28\ X_{21} - 0.37X_{31}$ for first plantation in the first season

$Y_2 = 0.03X_{12} + 0.75X_{22} + 0.21X_{32} - 0.85$ for second plantation in the first season

That means that for first plantation the total population of *T. asoluta* immature stages decreased 1.2, 0.37and 0.03 when max. T. increased 1°C and R.H. increased 1% in air and increased 0.28 as min. T. increased 1°C respectively.

While in second plantation the total population of *T. asoluta* immature stages increased 0.03, 0.75 and 0.21 as max and min. T. increased 1°C and R.H. increased 1% in air, respectively.

On the other hand, the accurate effect of the calculated percentage of explained variance values of the combined effect of these factors were 70.4% and 70.6% in the two plantation, respectively, in case of the total population of immature stages.

While the second season of investigation, the statistical analysis of data indicated that, the simple correlation and regression coefficient were highly significant at probability level 0.01 in first plantation, but insignificant in second one.

The correlation coefficient values were 0.7 and 0.49 for the two plantations respectively, in case of the total population of immature stages.

The regression equations of total population of *T. asoluta* (Y_3) with all factors under study were:

$Y_3 = 2.99 - 0.36\ X_{13} - 0.34X_{23} - 0.51X_{33}$ for first plantation in the second season

That means that the total population of *T. asoluta* immature stages decreased 0.36, 0.34 and 0.51 when max. T. and min. T. increased 1°C, and R.H. increased 1% in air for second plantation in the second season, respectively.

On the other hand, the accurate effect of the calculated percentage of explained variance values of the combined effect of these factors were 70.4%, 70.6%, 49.4% and 24.2% in the two seasons, in case of the two plantations of the total population of immature stages, respectively.

The remaining unexplained variance as assumed to be due to the influences of other unconsidered factors such as speed of wind or total amount of rainfall in addition to the experimental error affecting on the population density

of *T. asoluta* immature stages during the two seasons of investigation.

Survey of parasitoids

The samples of *T. absoluta* collected in the present study from tomato leaves during the two seasons (2014/2015) and (2015/2016) showed three species of hymenopterous parasitoids. These species are *Bracon* sp. (Braconidae), *Pteromalus* sp. (Petromalidae), *Eulophus* sp. (Eulophidae).

Rate of parasitism

Data in Figure 5 indicate that, *T. absoluta* parasitoids were presented almost all year around, the percentage of parasitism on *T. absoluta* ranged between 1-41 % during the first season (2014/2015) and between 1-51 % during the second season (2015/2016).

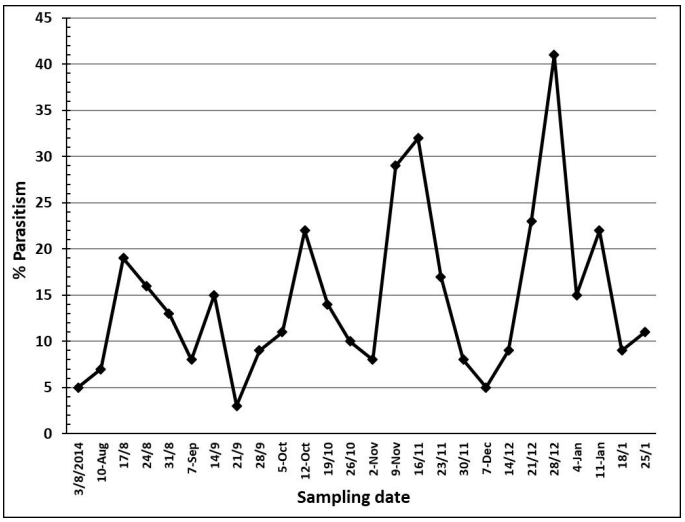

Figure 5: Weekly percentage of parasitism among *T. absoluta* infesting tomato at Beni-Suef Governorate at first plantation during 2014/2015.

During first plantation in the first season (2014/2015), percentage of parasitism had six peaks on *T. absoluta* larvae and pupae. The first peak (19%) was recorded at 17th August, 2014 the second peak (15%) was observed at 14th September, the third peak (22%) at 12th October, the fourth peak (32%) was observed at 16th November, the fifth peak (41%) was observed at 28th December and the sixth peak (22%) at 11th January 2015.

During second plantation in the first season (2014/2015) percentage of parasitism ranged between 1-35%. Four peaks on *T. absoluta* larvae and pupae first peak was recorded at 3th May, 2015 (7%), the second peak (13%) was observed at 24th May, the third peak (17%) at 14th June and the fourth peak (35%) was observed at 19th July (Figure 6).

During first plantation in the second season (2015/2016) percentage of parasitism had six peaks on *T. absoluta* larvae and pupae. The first peak was recorded at 16th August, 2015 (37%), the second peak (12%) was observed at 13th September, the third peak (45%) at 4th October, the fourth peak (31%) was observed at 18th October, the fifth peak (15%) was observed at 20th December and the sixth peak (11%) at 17th January 2016 (Figure 7).

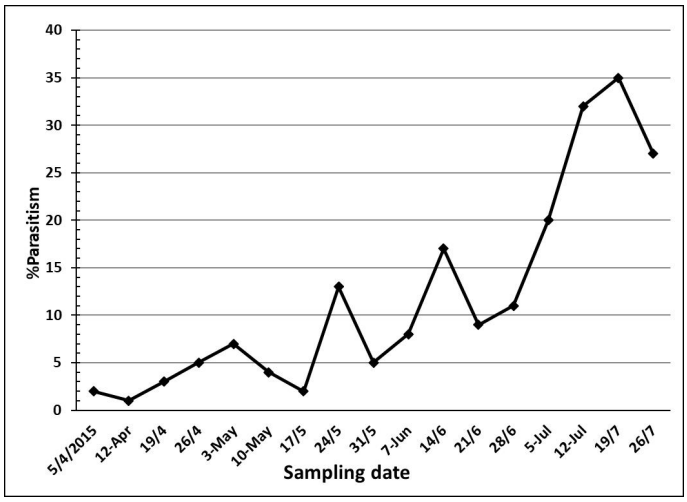

Figure 6: Weekly percentage of parasitism among *T. absoluta* infesting tomato at Beni-Suef Governorate at second plantation during 2014/2015.

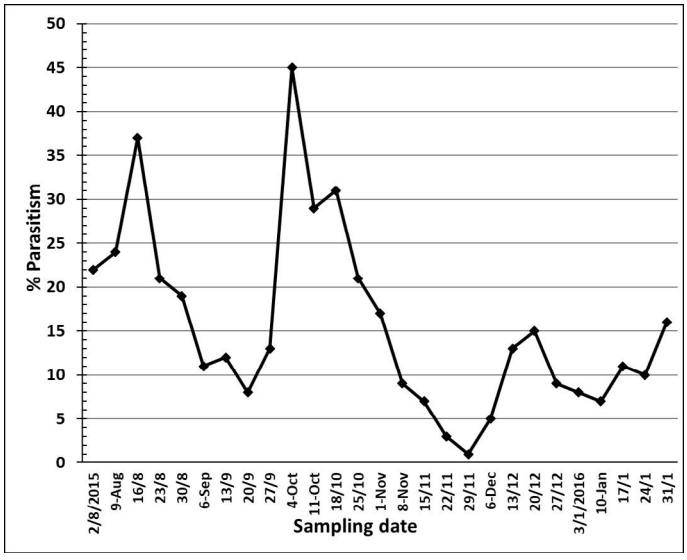

Figure 7: Weekly percentage of parasitism among *T. absoluta* infesting tomato at Beni-Suef Governorate at first plantation during 2015/2016.

During second plantation in the second season (2015/2016) percentage of parasitism ranged between 6-51%. Four peaks on *T. absoluta* larvae and pupae first peak was recorded at 1st May, 2016 (25%), the second peak (51%) was observed at 20th June, the third peak (39%) at 3th July and the fourth peak (45%) was observed at 17th July (Figure 8).

DISCUSSION

Tomato leaf miner *Tuta absoluta* is a major threat pest for tomato production in Egypt (Abd-Elmaksoud et al., 2016).

It was first detected in 2009 in tomatoes in Marsa Matrouh (northwestern Egypt), then the pest rapidly spread to the upper and lower regions of Egypt (Moussa et al., 2013; Salama et al., 2015). In Egypt, several tomato producing areas surfed from 100% damage due to the infestation with this insect (Moussa et al., 2013). Therefore, the study of its population density under field conditions is considered as foremost step to plan effective management strategies. Our results explained the occurrence of 5 peaks in each plantation season during 2014/2015 and 2015/2016. This similar to the result of Cherif and Lebdi-Grissa (2017) as this pest was able to achieve 4-5 flight peaks in Takelsa and Bou Slim locations, Tunisia, respectively. Also, Polat et al. (2016) declared that *T. absoluta* may accomplish 5 generations in Çanakkale province, Turkey, through summer-winter growing season. In addition, previous studies indicated that *T. absulata* has up to 11 generations per year with three generations during each growing season of spring, summer and autumn (Tabikha and Hassan, 2015). In another study carried out in open-field tomatoes in Assiut region (Upper Egypt), it was shown that *T. absoluta* can have 13 generations per year (Mohamed, 2011).

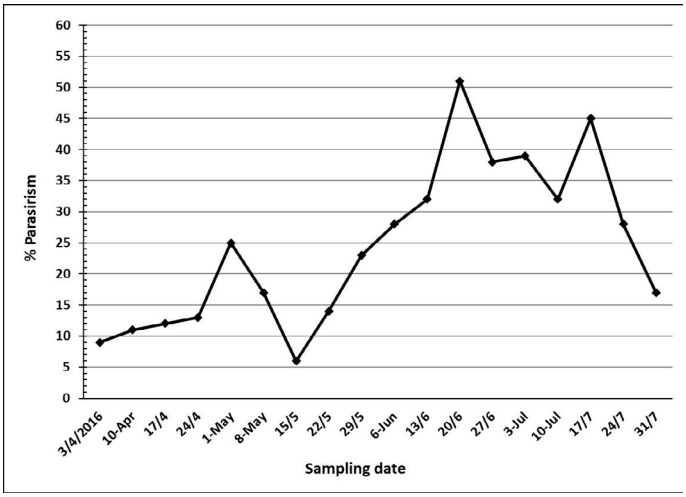

Figure 8: Weekly percentage of parasitism among *T. absoluta* infesting tomato at Beni-Suef Governorate at second plantation during 2015/2016.

In first plantation season, the number of pest beginning to increase from 7th, 13th Sep. and the population density reached to the highest-level during 28th, 20th Dec. and 11th, 31th Jan. during 2014/2015 and 2015/2016, respectively. From Sep. to Jan the temperature values ranged from 22.3 to 28.3c and humidity 60-80. Mahmoud et al. (2015) noticed that, *T. absoluta* has four peaks in winter plantations, the highest peak occurred in the fourth week of Jan.

Regarding to second plantation season, the first Peak appeared at 17th May and the highest-Peak during 28th June and 12th, 26th July in 2014/2015. During 2015/2016, the first Peak appeared at 17th April and reach the highest-Peak during 1st, 29th May, 28th June and 10th July with temperature values ranged from 30.3 to 32.3c. This population peaks have been attributed to the appropriate weather factors during May-July. As, the duration of the *T. absoluta* developmental cycle greatly depends on temperature (Cuthbertson et al., 2013), host availability and quality depend on crop growth cycle towards crop flowering (Torres et al., 2010). Similarly, Awad et al. (2018) found that *T. absoluta* male population increased with warm weather and moderate temperatures during May then decreased with higher temperatures. Also, the greatest population growth of *T. absoluta* was observed in spring/early summer and in late summer/autumn with a period of respite in mid-summer (Cuthbertson et al., 2013). Salama et al. (2014) recorded high level of *T. absoluta* in summer growing seasons in the March, May, and the first week of June. Also, (El-Ghany et al. 2016) recorded 3 population peaks with outbreak started on the 1st week of May at Qaliobeya governorate, Egypt. In addition, Hassan et al. (2022) recorded the highest population density *of T. absoluta* during May. Furthermore, Bayram et al. (2017) reported similar results as the highest (163) number of *T. absoluta* adults trap-1 were observed in Diyarbakır province during July when temperature was 31.7 °C. Also, Berxolli and Shahini (2017) reported that the first generation of *T. absoluta* appears in the first ten days of March; it reaches the maximum at April 4, and finish at April 8. The second generation appears at the April 18; it reaches the maximum at May 9, and finish at May 14. The third generation appears at the May 23; it reaches the maximum at June 13 and finish at June 18. The fourth generation appears at the June 27, it reaches the maximum at July 18, and finish at July 25.

Our survey revealed the presence of three species of Hymenopterous parasitoids on *T. absoluta* during the two seasons (2014/2015) and (2015/2016). These species are *Bracon* sp. (Braconidae), *Pteromalus* sp. (Petromalidae), *Eulophus* sp. (Eulophidae). Previously, three genera of Hymenopterous parasitoids, *Diglyphus* sp. (Eulophidae), *Elasmus* sp. (Elasmidae) and *Telenomus* sp. (Scelionidae) were record in Egypt (Abd-Elmaksoud et al., 2016). *Bracon nigricans Szépligeti* and *Trichogramma euproctidis Girault* other parasitoid of *T. absoluta* were also found in Egypt (Zappalà et al., 2013; El-Arnaouty et al., 2014). In addition, two indigenous larval ectoparasitoid species were found developing on *T. absoluta*; *Bracon* sp. (Hymenoptera: Braconidae) attacking mature larvae, and *Necremnus* sp. (Hymenoptera: Eulophidae) attacking first, second and third instar larvae (Abbes et al., 2014). Guenaoui et al. (2011a, b) reported the eulophid parasitoids, *Hemiptarsenus zilahisebessi* and *Necremnus artynes*, which was the most abundant parasitoid species developing or feeding on *T. absoluta* in tomato crops in northwestern Algeria. Furthermore, Al-Gerrawy (2013) mentioned

five Hymenopterous parasitoids on *T. absoluta*; They were namely: two egg parasitoids *Trichogramma pintoi* (Trichogrammatidae) and *Telenomus* sp. (Platygastridae); two larval parasitoids *Bracon* (Habrobracon) sp. (Braconidae) and *Closterocerus* sp. (Eulophidae); pupal parasitoid *Proconura* sp. (Chalcididae). However, few research suggests Braconids, Chalcidids, Eulophids and Ichneumonids as potential pupal parasitoids for *T. absoluta*. In first plantation season, there are six peaks of parasitism on *T. absoluta* larvae and pupae. The highest Peak was recorded in Nov. (32%) and Dec. (41%) during 2014/2015. In 2015/2016, the highest Peak was noticed in August. (37%) and October (45%, 31%). In second plantation season, there are four peaks of parasitism on *T. absoluta* larvae and pupae. Two Peak on May (7%, 13%), one Peak in June (17%), and one in July (35%) during 2014/2015. In 2015/2016, the four Peak distributed one in May (25%), one in June (51%), and two in July (39%, 45%). This similar to Nannini et al. (2014) as the highest rates of parasitism were recorded in spring and summer, with a peak in July (4.8%). From the illustrated result the peaks of *T. absoluta* similar to peaks of its parasitism therefore, we suggest that these parasitic species could be used in biological control of *T. absoluta*.

Conclusively, *Bracon* sp. (Braconidae), *Pteromalus* sp. (Petromalidae), *Eulophus* sp. are naturally occurred on the tomato crop and this suggests a close interaction among these species with their tomato leaf miner host. However, the nature of this relationship need further studies to evaluate the impact of these parasitoids on the insect pest population. Since these parasitoids are natural enemies of insect pests, the possibility of their use as biological control agents in the tomato crop could be investigated.

NOVELTY STATEMENT

Since the recorded parasitoids are natural enemies of *Tuta absoluta*, these parasitoids can be alternative way for the biological control this pest.

AUTHOR'S CONTRIBUTION

All authors contributed equally.

Conflict of interest

The authors have declared no conflict of interest.

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