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(Original Article)

Impact of Climate and Plant age on Tomato leaf Miner Population Patterns, Tomato Leaf Miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae)

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Abstract

Field experiments were carried out in two seasons (2020 and 2021) to investigate the population fluctuation of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) under some selected climatic factors [temperatures in (°C): Maximum Temperature (Max.T) and Minimum Temperature (Min.T); temperature in the soil (°C): Soil Maximum Temperature (SMax.T) and Minimum Temperature (SMin.T); relative humidity in (%): relative Maximum humidity (RMax.H) and Minimum humidity (RMin.H); wind speed in (Km/hr.): maximum wind speed (Max.ws) and Minimum wind speed (Min.ws)]. as well as tomato age. The population grew gradually, reaching four peaks in the first season and five in the second, with the infestation starting on March 7th, fifteen days after the transplant date. March and April marked the high points of both seasons, with a minor decline in infestation in May and June until the end of the season. There is a clear and substantial negative association between the *T. absoluta* population (mean number of larvae per 10 plants per replicate) and plant age, air temperatures (Max.T and Min.T), and soil temperatures (SMax.T and SMin.T). On the other hand, the population of *T. absoluta* exhibited a non-significant positive correlation with the minimum humidity (RMin.H) and a significant positive correlation with the maximum humidity (RMax.H). Lastly, the population of *T. absoluta* showed a non-significant positive connection with wind speed (Max.ws and Min.ws).

Keywords: *Leaf miners, T. absoluta, Tomato crop, Climatic factors, Population*

Introduction

The tomato, *Lycopersicon esculentum* Mill., is a popular vegetable consumed raw all over the world because of its high nutritional value, which includes minerals, vitamins, proteins, and antioxidants. Moreover, it has phytosterols (β-sitosterol, campesterol, and stigmasterol), carotenoids (lycopene and β-carotenoids), and mono-unsaturated fatty acids (linoleic and linolenic

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acids). Tomato fruits include essential amino acids such arginine, leucine, threonine, valine, histidine, and lysine (Ali *et al*. 2020). In Egypt, the production of tomato in 2019 and 2020 reached to 6.81 M tons of tomato, represented 33.3% of total vegetable production (approximately 20.44 M tons), according to Agricultural Statistics of Egyptian Ministry of Agriculture and Land Reclamation (Agricultural 2019). *Tuta absoluta* (Meyrick) posed a serious threat to tomato cultivation in Europe in 2006 when it first appeared in Eastern Spain. From there, it quickly expanded to the Mediterranean region, Africa, and Asia (Terzidis *et al.* 2014). It became a serious pest threatening tomato cultivations in Egypt since 2009, (Moussa *et al.* 2013). It started to invade tomato and potato plantations in Marsa Matrooh as it is the nearest Egyptian governorate to Libya, it had reached Giza governorate in 2010, then spread in all governorates to reach border of Sudan (Tamerak 2011). According to Guenaoui *et al*. (2010), *T. absoluta* is a multivoltine species that grows quickly in climates that are conducive to its life cycles. One female can generate between 230 and 260 eggs when she is in optimal reproductive condition, according to Barritos *et al*. (1998). The environmental climatic factors such as temperature and relative humidity are the main factors that influence infestation rates due to its effect on insect physiology and behavior causing substantial losses in yield (Abolmaaty *et al.* 2010). The population fluctuation studies of *T. absoluta* in Egypt have not enough records and needs further researches by (Gaffar *et al.* 2017).The purpose of this research is to examine how *T. absoluta* fluctuates in response to a few key climatic factors: The temperature values are expressed as follows: [temperatures in degrees Celsius: Maximum Temperature (Max.T) and Minimum Temperature (Min.T); temperature values in degrees Celsius: Soil Maximum Temperature (SMax.T) and Minimum Temperature (SMin.T); relative humidity values in percentage: relative Maximum humidity (RMax.H) and Minimum humidity values (RMin.H); wind speed values expressed in kilometers per hour: Maximum wind speed (Max.ws) and Minimum wind speed (Min.ws)] and the age of tomatoes.

Material and Methods

1. Experimental design

Mill Variety Tomato*, Lycopersicon esculentum* Ellisa was planted on January 20 in a greenhouse, and in the field in an area approximately 400 m^2 the seedlings cultivated on 22[th] of February in 2020 and 2021 seasons. The area separated into five plots; each plot approximately 80 m^2, at the Experimental Farm of Plant Protection Department, Faculty of Agriculture, Al-azhar University, Assiut, Egypt. The recommended agricultural practices were performed with no insecticide applications during the seasons of study.

2. Sampling and counting method

After fifteen days from the date of cultivation, samples were randomly collected once a week. Ten plants, each individually packed in a polyethylene bag, made up the sample, which was analyzed in a lab setting with binoculars. Using the direct count approach, the total number of larvae in each plant part—

leaves, stems, and end buds—was counted and recorded in relation to the age of the plant at various growth stages.

3. Meteorological data

The climatic factors data [temperatures in (°C): Maximum Temperature (Max.T) and Minimum Temperature (Min.T), Soil temperature in (°C): Soil Maximum Temperature (SMax.T) and Minimum Temperature (SMin.T); relative humidity in (%): relative Maximum humidity (RMax.H) and Minimum humidity (RMin.H) and Wind speed in (Km/hr.): maximum wind speed (Max.ws) and Minimum wind speed (Min.ws)] were obtained from the Meteorological Station at the Experimental Farm, Faculty of Agriculture, Assiut University.

4. Statistical analysis

Data were subjected to simple correlation analysis by the Advanced Statistical Analysis Package of the computer program SPSS version 22.

Results and Discussion

1. The population fluctuation of *T. absoluta* larvae

The population fluctuation of *T. absoluta* larvae in the 1st season (2020)

At the beginning of the season, the mean numbers of larvae per 10 plants per replication were comparatively low. After that, the means gradually increased to have four peaks in frequency. There were two peaks in the moderate mean numbers that were seen on March 14 and 28 (35.2 and 40.2 mean numbers of larvae/10 plants/replica, respectively). The highest mean number of larvae was recorded in April 11 (54.8 mean numbers of larvae/ 10 plants/ replicate). In the meantime, May 23rd marked the lower peak (26.4 mean counts of larvae/ 10 plants/ replicate). The infestation started at 7 of March with gradual increase to form the first peak with means of (35.2 larvae/10 plants/replicate) in 14 of March. Following that, the larvae fluctuated between 17.9 mean numbers of larvae per 10 plants/replica on March 21 and 40.2 mean numbers of larvae/10 plants/replicate on March 28, when it grew once more to reach the second peak. However, on April 11, the population scored the greatest peak with mean numbers of (54.8 larvae/10 plants/replicate), then the number of larvae decreased slightly till the end of April. In May, only one peak occurred on May 23 when the number of larvae reached to (26.4 mean numbers of larvae/10 plants/replicate), with slight fluctuation and no peaks occurred in all weeks of June.

The population fluctuation of *T. absoluta* larvae in the 2nd season (2021)

T. absoluta larvae population line (Fig. 2) began the season with a low number and grew steadily to show five peaks. There were two peaks on April, 11 and 25, (24.8 and 27.8 mean numbers of larvae/10 plants/replicate, respectively), and two smaller peaks on May, 9 and 30 (20.2 and 15.3 mean numbers of larvae/10 plants/replicate, respectively). The first peak happened on March 28 (25.9 mean numbers of larvae/10 plants/replicate). The infestation also started on March 7, then increased gradually to form the first peak on March 28 with means of (25.9 larvae/10 plants/replicate). Afterwards, the larvae means scored two peaks on April 11 and 25 (24.8 and 27.8 mean numbers of larvae/10 plants/replicate, respectively for 11 and 25 of April). However, two smaller peaks were recorded on May 9 and 30 when the mean numbers of larvae/10 plants/replicate decreased to 20.2 and 15.3, respectively. Afterwards, the means of larvae continues decreasing till the end of the season.

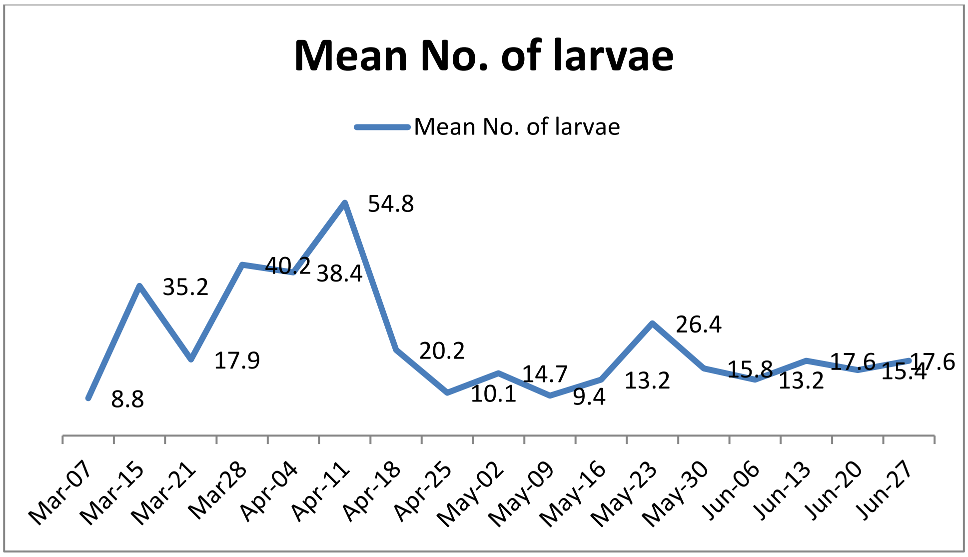

Fig. 1. The fluctuation of *T.absoluta* larvae during the 1st season (2020) under prevalent climatic factors.

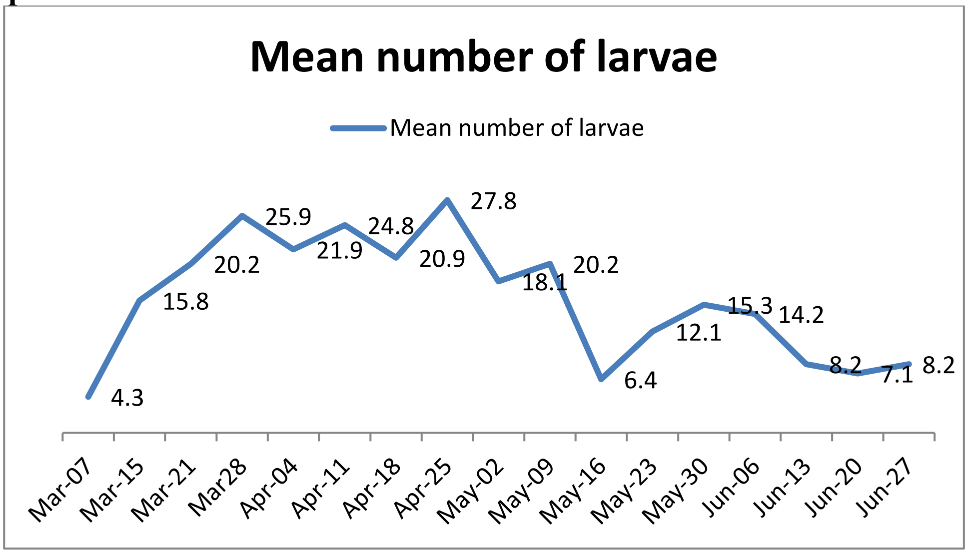

Fig. 2. The fluctuation of *T.absoluta* larvae during the 2nd season (2021) under prevalent climatic factors.

Similar findings were reported by Mahmoud *et al*. (2015), who found that *T. absoluta* infestation caused four peaks in the fluctuation curve line throughout the winter season at Giza Governorate, Egypt; the peaks happened in January, February, March, and April. On the other hand, *T. absoluta* infestation in summer plantations showed three peaks: one in July, one in August, and two curve line peaks in September. However, Inas *et al*. (2023) carried out an open field experiments at summer season and found two peaks of *T. absoluta* infestation curve line in tomato fruits at summer season. (Salama *et al*. (2014) investigated different variations in the moth population density throughout a two-year period, 2012–2014, and during various tomato rotations. found that eight peaks of abundance occurred during the year 2012, including three peaks in early summer plantations and four peaks in Nile plantations and an additional peak between the two rotations. In 2013, five peaks were recorded in the summer plantations and three peaks in winter plantations. The rate of increase in insect population reached a high index in March-April when the average temperature ranged between 16.19 and 21.13˚C.

2. The population fluctuation of *T. absoluta* larvae in relation to plant age and climatic factors

The population fluctuation of *T. absoluta* larvae in the 1st season (2020)

A substantial negative link was found in the correlation statistical analysis of the first season (Table 1) between the mean number of larvae per 10 plants and the highest soil temperature (Max.T and Min.T). On the other hand, the mean number of larvae per 10 plants per duplicate was positively correlated with both the minimum soil temperature and relative humidity (RMax.H and RMin.H). Wind speed, however, showed a non-significant positive connection (Max.ws and Min.ws).

Table 1. Population fluctuation of *T. absoluta* larvae in relation to plant age and climatic factors in the 1st season (2020)

Sampling Date	Larvae (mean no.)	Plant age (days)	Air temperature (°C)		Soil temperature (5 cm) (°C)		Humidity %		Wind speed (km/h)	
			Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Mar 07	8.8	22	29	8.6	37.2	14.2	76	24	28	15
Mar 15	35.2	30	28.6	12.6	38.2	18.4	77	30	24	0
Mar 21	17.9	40	40	17	35.4	21.3	43	11	26	0
Mar28	40.2	25	25	10.4	35	17.4	76	31	31	15
Apr 04	38.4	51	32.6	8.6	33.6	17.6	71	14	28	11
Apr 11	54.8	58	25.8	7.6	30.5	18.9	76	35	31	17
Apr 18	20.2	65	40.7	17.2	48.1	26.9	43	15	28	0
Apr 25	10.1	72	43	16.6	48.1	26.4	63	17	28	9
May 02	14.7	79	42.2	20	52	29	31	11	26	13
May 09	9.4	86	47	23	55.9	31.8	49	12	28	6
May 16	13.2	93	43	20	54	30.2	52	15	30	0
May 23	26.4	100	33.8	18.4	45.4	31.4	68	27	30	19
May 30	15.8	107	42	21	51.8	31.3	44	18	22	0
Jun 06	13.2	115	40.2	24.2	53.8	34.6	73	26	33	9
-Jun13	17.6	122	38.4	24.2	53.4	34.6	35	20	26	7
Jun 20	15.4	129	38.2	22.6	51.6	33.2	41	13	17	0
Jun 27	17.6	136	41.4	22.8	54.4	33.4	57	18	30	11

Statistical analysis

Factor	Plant age	Temperature		Soil temp. (5 cm)		Humidity %		Wind speed	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Larvae	-0.408	-0.778**	-0.676**	-0.738**	0.545*	0.519*	0.639**	0.219	0.357

*. Correlation is significant at the 0.05 level. **. Correlation is significant at the 0.01 level.

The population fluctuation *T. absoluta* larvae in the 2nd season (2021)

Data obtained from correlation analysis (Table. 2) indicated that Plant age, maximum air temperature and maximum soil temperature showed same trend as first season, they recorded a significant negative correlation with Mean numbers of *T .absoluta* larvae/10 plants/replicate. However minimum air temperature and minimum soil temperature demonstrated a non-significant negative correlation with the mean numbers of larvae/ 10 plants/ replicate. Meanwhile, relative humidity (RMax.H. and RMin.H) and Wind speed (Max.ws and Min.ws) showed a non-significant positive correlation with the mean numbers of larvae/10 plants/replicate.

Table 2. Population fluctuation T. absoluta larvae in relation to plant age and climatic factors in the 2nd season (2021)

Date	Larvae (mean no.)	Plant age (days)	Air temperature (°C)		Soil temperature (5 cm) (°C)		Humidity %		Wind speed (km/h)	
			Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Mar 07	4.3	22	26.8	6.8	38	16	71	33	20	0
Mar 15	15.8	30	27	11.8	38	17.6	64	44	19	0
Mar 21	20.2	40	21.8	6.2	35.8	15	71	37	26	7
Mar28	25.9	25	27.2	12.2	39.4	21.4	88	41	28	17
Apr 04	21.9	51	34.2	11	42.6	21.2	47	15	33	4
Apr 11	24.8	58	27	10	42	20.6	58	27	26	11
Apr 18	20.9	65	31.4	15.6	43.9	23	77	38	33	19
Apr 25	27.8	72	28.6	15.6	44	26	82	32	28	19
May 02	18.1	79	40	18.2	49.6	27.8	52	31	19	0
May 09	20.2	86	30.6	16.4	47	30	64	29	33	15
May 16	6.4	93	45	22.2	52.8	30.6	61	20	28	0
May 23	12.1	100	38	21.4	51.4	33.2	57	32	33	6
May 30	15.3	107	33.4	18	47.6	28.6	60	21	33	17
Jun 06	14.2	115	39.6	20.8	52.2	30	47	26	19	19
-Jun13	8.2	122	43.8	23.4	54.4	33.2	36	17	26	4
Jun 20	7.1	129	37.2	21	51.4	31.6	44	27	30	13
Jun 27	8.2	136	37	23	51.4	33	78	28	28	15
					Statistical analysis					
Factor	**Plant age**	**Temperature Max.**	**Temperature Min.**	**Soil temp. (5 cm) Max.**	**Soil temp. (5 cm) Min.**	**Humidity % Max.**	**Humidity % Min.**	**Wind speed Max.**	**Wind speed Min.**	
larvae	-0.467*	-0.553*	-0.457	-0.494*	-0.392	0.388	0.310	0.186	0.419	

*. Correlation is significant at the 0.05 level. **. Correlation is significant at the 0.01 level.

The population fluctuation *T. absoluta* larvae of the two seasons in sequence (2020 and 2021)

Correlation analysis of the two seasons in sequence (Table. 3) showed that Plant age, air temperature (Max.T and Min.T) and Soil temperature (SMax.T and SMin.T) recorded significant negative correlations with the mean numbers of larvae/ 10 plants/ replicate. However, maximum relative humidity recorded significant positive correlation with the mean numbers of larvae/ 10 plants/ replicate. The mean number of larvae per 10 plants per duplicate was shown to have a non-significant positive connection with minimum relative humidity and wind speed (Max.ws and Min.ws).

Table 3. Fluctuation of *T. absoluta* larvae in relation to plant age and climatic factors of the two seasons in sequence (2020 and 2021)

Factor	Plant age (days)	Air temperature (°C)		Soil temperature (5 cm) (°C)		Humidity %		Wind speed (km/h)	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
larvae	-0.399*	-0.548**	-0.523**	-0.646**	-0.450**	0.398*	0.259	0.187	0.306

*. Correlation is significant at the 0.05 level. **. Correlation is significant at the 0.01 level.

Similar study by Ata and Megahed (2014) reported that the insignificant positive correlations between the climatic factors such as daily range, air temperature and relative humidity with insect population activities except air temperature recorded significant positive correlation. Plus, Bacci *et al*. (2021) investigated the effects of tomato phenology, climatic factors, and insecticide on the population dynamics of *T. absoluta* infestation in tomato open field cultivation, found that *T. absoluta* life cycles influenced by Insecticide, host plant, and climatic conditions over time, resulting in shifts of peaks in the pest curve line. de Barros, R. P., 2018) found that rainfall, relative humidity, and solar radiation have great influence on population dynamics due to its effect on the development stages of *T. absoluta*. Also, the impact of temperature on *T. absoluta* was studied by Martins *et al*. (2016). Moreover, they stated that the optimum temperature for *T. absoluta* was 30 °C and concluded that Temperature is one of the main climatic factors that influence insect populations.

Abolmaaty *et al*. (2010) predicted the future climate and *T. absoluta* population fluctuations in a different study. In comparison to EL Beheira, Giza, and Fayoum governorates, the results showed that Qena governorate produced the greatest number of generations in the *T. absoluta* population under the current climate. The number of *T. absoluta* generations increased due to climate change, especially in the governorates of Qena. It is anticipated that in 2050 and 2100, there may be 12–14 and 13–15 generations year, respectively.

Conclusion

To sum up, the infestation of *T. absoluta* in the first season, the fluctuation line showed four peaks, and in the second, five peaks. Therefore, plant age and climatic conditions may be associated to peak shifting in both seasons. The mean numbers of larvae per 10 plants each replication and the environmental and climatic parameters were correlated with the age of the plants. The mean numbers of larvae per 10 plants per replication were significantly correlated negatively with air temperature (maximum and minimum), soil temperature (maximum and minimum), and plant age, according to a correlation analysis of the two seasons in order. Nonetheless, there was a non-significant positive association found between the mean numbers of larvae/ 10 plants/replica and lowest humidity, while there was a significant positive correlation found between the two. Lastly, the mean numbers of larvae per 10 plants per replication and wind speed (maximum and minimum) showed non-significant positive relationships.

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تــأثير العوامــل المناخيــة وعمــر النبــات علــى تذبــذب تعــداد صــانعة أنفــاق أوراق الطمــاطم *Tuta absoluta* (Meyrick)

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الملخص

يتأثر تعداد يرقات حشرة توتا ابسليوتا على نبات الطماطم بعمر النبـات والعوامـل المناخيـة (درجة الحرارة الجوية - درجة حرارة التربة – الرطوبة - سرعة الرياح) للمنطقة المزروع بها، ولهذا الغرض تم اجراء تجربتين حقليتين في مزرعة كلية الزراعة بجامعة الأزهر لمـدة موسـمين مختلفين (2020 م و2021 م).

بدأت الاصابة يوم 7 مـارس بعـد 15 يـوم مـن الشـتل، أتبـع ذلـك زيـادة فـي متوسـط تعـداد اليرقات/ 10 نباتات/ مكررة مما أدي الي وجود قمم في منحني متوسط تعداد اليرقات/ 10 نباتـات / مكررة حيث بلغت هذه القمم 4 في الموسم الأول وخمسة في الموسم الثاني، وحدثت القمم العالية في شهري مارس وابريل ثم انخفضت في مايو ويونيو حتى نهاية الموسم.

وسـجل التحليـل الاحصـائي وجـود علاقـات طرديـة معنويـة بـين درجـة الحـرارة الجويـة (العظمى والصغرى) ودرجة حرارة التربة (العظمى والصغرى) وعمر النبات مع متوسط تعـداد اليرقات/ 10 نباتات/ مكررة بينما سجلت درجة الرطوبة العظمي علاقة ايجابية معنوية مع متوسط تعداد اليرقات / 10 نباتات / مكررة، وسجل كـل مـن درجـة الرطوبـة الصـغرى وسـرعة الريـاح (العظمى والصغرى) علاقة ايجابية غير معنوية مع متوسط تعداد اليرقات/10 نباتات / مكررة.