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RESEARCH ARTICLE

Monitoring of the whitefly populations on cucumber plants in a greenhouse in Luxor region of South Egypt

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Abstract

Experiments were conducted on cucumber plants under greenhouse conditions (Barracuda cultivar) at Armant district, Luxor Governorate, Egypt, throughout two successive growing seasons (2021 and 2022) to study the population dynamics of the whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae). The effect of temperature, relative humidity, and plant development on the oscillations of *B. tabaci* was studied. The results cleared that the number of *B. tabaci* individuals was detected on cucumber plants during the period from January 23rd till April 17th, i.e., the insect infestations appeared on plants that were eight weeks old after emergence (WAE) in 2021 season. While, it appeared during the interval from March 6th until July 9th, i.e., the injuries discovered on plants that were thirteen weeks old after emergence (WAE) in 2022 season. Furthermore, the total estimates of *B. tabaci* during the first growing season (2021) were smaller than those during the second growing season (2022). In the two seasons, a gradual increase in the numbers of *B. tabaci* on cucumbers was observed during the month of April, indicating that the management of the pest should begin before it reaches its highest level, during the seedling and flowering stages. The results indicated that the influences of weather circumstances and plant development on *B. tabaci* abundance were highly significant over the two seasons studied and that these variables varied from season to another. As well, the percentages of explained variance were 98.05 and 93.43% in the two seasons, respectively. This information can help establish a greenhouse whitefly management and monitoring programme.

Keywords: *Bemisia tabaci*; cucumber plants; environmental conditions; plant age; seasonal abundance.

1. Introduction

Cucumber (*Cucumis sativus*) is one of the most important vegetable crops planted all over the word. It occupies a significant position among vegetable crops in Egypt (Abdelatef *et al*., 2022). Cucumber plants are subjected to infestation by several major insect pests (Hegab, 2017; El-Shazly *et al*., 2019; Awadalla *et al*., 2020). The whitefly, *Bemisia tabaci* (Genn.) (Hemiptera: Aleyrodidae), is regarded as a devastating pest on cucumber plants, is a deleterious insect (Basu, 1995), is a piercing-sucking pest (Li *et al*., 2022), is a cosmopolitan pest (Ramesh *et al*., 2023), and is highly polyphagous (Abd-El-Kariem *et al*., 2015). It infests the cucumber plants, and it caused him serious trouble, and because it feeds directly on the sap from the plant leaf and consumes enormous quantities of phloem sap and excretes a large amount of honeydew, which would reduce plant vitality, growth, and production, that's because of its high numbers of insects, low movement, and confined and congregational feeding of nymphs stage (Stansly *et al*., 2009; Vav Doorn *et al*., 2015). It also contributes to the spread and transmission of

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disease pathogens. Rao *et al*. (2008) mentioned that the cucurbit yellow dwarfism virus and the whitefly-transmitted closterovirus significantly affect cucurbit plants. Mansour and Al-Mousa (2008) mentioned that adult suffices to transmit the virus.

Insects exhibit various trends in their incidence as well as in the type and degree of damage they cause to crops due to fluctuations in the climatic circumstances of different seasons (Pareek *et al*., 2017). Additionally, a number of other well-known and little-known elements are equally crucial in determining the prevalence and dominance of a pest (Walther *et al.*, 2002; Janu and Dahiya, 2017).

The abundance of piercing-sucking pest's diverse on the host plant altered depending on the season, the plant phenology, and maybe other aspects of climatic factors (Bakry *et al*., 2020).

The goal of this current investigation was to understand the relationship between whitefly abundance, environmental parameters, and plant development throughout the two seasons, in order to create a program to whitefly management under greenhouses.

2. Materials and methods

2.1. Population estimates of the whitefly, Bemisia tabaci on cucumber plants

Weekly investigations into greenhouse-grown cucumber plants (Barracuda cultivar) were performed to estimate the total number of whiteflies per leaf. Greenhouse size about 175 cm^2, the seeds was sown on the appropriate sowing date (first week of December each season). From six to nine a.m. in the morning, the examination was carried out. Once germination appeared on the soil surface, sampling was initiated at weekly intervals and continued until the crop of cucumbers was harvested.

In four plots of the greenhouse, from each plot, ten cucumber plant leaves were randomly selected every week from different cucumber plant levels (lower, middle, and higher) and from the northern, central, and southern parts of the greenhouse throughout the two seasons for tracking the population estimates. These leaves were gathered, packaged in different polythene bags, and transported to the lab. Under a stereo binocular microscope, the total count of whiteflies (nymphs and adults) was counted and estimated for each leaf to display seasonal fluctuations. The direct assessment of whiteflies was performed on the same day of inspection as reported by Aboul-Saad (2008).

Agricultural practices were used in the experimental area (greenhouse) without the use of any pesticides.

2.2. Assessment of the whitefly-days and the cumulative whitefly-days

Whitefly days are an indication of the overall counts of whiteflies that would have been observed if sampling had taken place each day and the results had been summed up. It presupposes a straight line between the first and the following specimens. This equation offered by different authors was used to compute this approach (El-Defrawi and El-Harty, 2009; Bakry and Fathipour, 2023).

Whitefly-days= [7 x [(d_1+d_2) / 2]

Where:

d_1= Average whitefly count/leaf on the preceding checking time

d_2= Average whitefly count /leaf on the following checking time

Cumulative whitefly-days= Whitefly-days from the last assessment + Whitefly-days from the current assessment, for every sampling period to take out a running, cumulative overall.

As for the rate of increase in whiteflies count, it was estimated according to (Bakry *et al.*, 2020; Bakry and Fathipour, 2023) as follows:

$R = (a / A)$

Where:

R = Rate of increase

a = Average whitefly count / leaf on the present examination date.

A= Average whitefly count / leaf on the preceding examination date.

2.3. Combined effects of the weather parameters and biotic variable on whiteflies abundance attacking cucumber plants

Seasonal abundance of the whitefly, *B. tabaci*, was associated with weather variables and biotic parameter over two seasons (2021 and 2022). The weather variables viz., maximum temperature, minimum temperature, and mean of percentage of relative humidity, were evaluated inside the greenhouse. The daily registers of these variables were recalculated to gain the daily averages within seven days of the whitefly estimate. As for the biotic variable as plant development, i.e. [(intervals after emergence, in weeks) (WAE)] assessed at the date of the whitefly estimate. This relationship was evaluated by the nonlinear equation of the third degree, *i.e.*, $Y= a+ b_1X+ b_2X^2+ b_3X^3$. Bakry and Abdel-Baky (2023) employed this technique.

The data obtained were statistically analyzed by applying different models of correlation and regression to detect the relationships between weather variables and biotic variable on the whitefly, *B. tabaci*, incidence according to the formula (Fisher, 1950). The multiple correlation, coefficient of determination, and explained variance percentage in the numerical abundance of the whitefly, *B. tabaci*, were elucidated by every independent factor estimated using SPSS Program software (1999). As well, the data was calculated and estimated graphically by applying Microsoft Excel 2007.

3. Result and discussion

3.1. Population density of B. tabaci

The weekly counts of *B. tabaci* that infested cucumber plants under greenhouse (Barracuda cultivar) at Armant district, Luxor Governorate, throughout two growing seasons (2021 and 2022). As well, weekly mean records of weather conditions and plant phenology for cucumber plants during the two growing seasons of investigation are tabulated in Tables (1 and 2) and Figures (1 and 2). The effects of the weather factors and plant phenology of cucumber plants on the population density of *B. tabaci* were estimated based on the average number of individuals (nymphs and adult individuals) estimates per leaf in the consecutive inspection dates. The results cleared that the number of *B. tabaci* individuals was detected on cucumber plants thought the period from January 23rd till April 17th, *i.e*., the insect infestations appeared on plants that were eight weeks old after emergence (WAE) in 2021 season. While, it appeared during the interval from March 6th until July 9th, *i.e*., the injuries discovered on plants that were thirteen weeks old after emergence (WAE) in 2022 season. As well, the total estimates of *B. tabaci* during the first growing season (2021) were smaller than the second growing season (2022). The general average of *B. tabaci* counts throughout the whole season was 28.56 ± 2.52 and 32.56 ± 2.28 individuals per leaf over the first and second growing seasons, respectively.

As for the cumulative numbers of *B. tabaci* were 370.44 and 618.57 individuals per season in the two seasons, respectively. These results were coincided with those obtained by Hegab (2017) mentioned that one peak of *B. tabaci* on cucumber leaves was recorded at the third week of July. Kamel *et al*. (2000) recorded that the infestation by *B. tabaci* increasing progressively from mid-June until the end of July 1996.

On the contrary, Ahmed (1994) mentioned that three peaks of *B. tabaci* were appeared on summer cucumber plantations per season.

3.2. Cumulative whitefly-Days

Data exhibited in Tables (1 and 2) and illustrated in Fig. (1), indicated the whitefly-days and the cumulative whitefly-days for *B. tabaci* on cucumber plants to illustrate the overall impact of a continuously changing individuals through time. These results revealed that the effect of *B. tabaci* population on cucumber plants was higher in the second season (4147.03 cumulative whitefly-days) as compared to the first season (2465.39 cumulative whitefly-days).

3.3. Rate of increase in B. tabaci counts

The rate of increase (R) in *B. tabaci* counts on cucumber plants were estimated (Tables, 1 and 2). The rate of increase in the population is an indicator of the appropriate week for the activity of the insect, expressed as the week of the highest increase in the number of this insect during the season. When R >1 it means more activity, <1 means less activity and =1 means no variation in insect activity (Bakry and Abdel-Baky, 2023).

Data as recorded in Table (1), it seems that the favorable weeks for the increase in *B. tabaci* numbers are from Jan., 30th to March 19th and April, 3rd and 10th throughout the first season (2021), when the rates of increase were greater than one. Whereas, during the second season (2022), the favorable times for increasing *B. tabaci* numbers occurred in the intervals from March, 27th through April 24th, May, 8th, and from May 29th through July 9th, as shown (Table, 2).

So, the gradual rise in *B. tabaci* numbers on cucumber throughout these periods suggests that management of the pest should begin before it reaches its highest level, during the seedling and flowering stages. These results are consistent with El-Shazly *et al.* (2019).

It was obvious that increment in *B. tabaci* numbers during the inspection times, which is greater than 1, was clearly seen as an indication that weather variables were more favorable to *B. tabaci* development. The present results agree with those of Ahmed (1994) mentioned *B. tabaci* were observed in the 2nd week of May, 1st week of June and throughout July 1993 on summer cucumber plantations.

3.4. Influence of certain weather factors and plant development on B. tabaci abundance on cucumber plants

3.4.1. Effect on certain weather factors

A- Effect of daily mean maximum temperature

Data in Table (3) indicated that the simple correlation between this factor and the *B. tabaci* counts was highly significantly positive (+0.71and +0.87) in the two seasons, respectively. As well as, the simple regression showed that a 1˚C increase in this factor, would increase the counts by 1.97 and 2.70 insects per leaf for the two seasons, respectively (Table, 3). As for the partial regression values for the effects of this factor on the *B. tabaci* counts had a significant negative (P. reg. value; -1.82) in the first season and significant positive (P. reg. value; 1.92) in the second season.

B- Effect of daily mean minimum temperature

Data in Table (3), showed that the simple correlation values had highly significantly positive correlations between this variable and *B. tabaci* counts (r values; +0.71 and +0.89) during the both seasons, respectively. In same time, the regression coefficient (b) indicated that every 1˚C increase in this variable, would increase the counts by 2.65 and 2.74 insects per leaf during the two seasons, respectively.

The effects of this factor on *B. tabaci* counts had insignificantly negative (P. reg. values; -1.32 and -1.80) during the two seasons, respectively (Table, 3).

C- Effect of the mean relative humidity

Data in Table (3), revealed that the correlation between this factor and *B. tabaci* counts was highly significant negative (r value was -0.82) in the first season and insignificant negative (r value was -0.34) in the second season. Also, the simple regression indicated that an increase by 1% in this factor, would decrease the counts by -1.46 and -0.97 insects per leaf during the two seasons, respectively (Table, 3). The present results agree with those of El-Shazly *et al.* (2019) mentioned that counts of *B. tabaci* increased with decreasing relative humidity. The effect of this variable exhibited from the partial regression values which indicated that the effect had significantly negative (P. reg. value was -1.18) in the first season and significant positive (P. reg. value was 0.90) in the second season (Table, 3).

D- Effect of the plant development

Data in Table (3) revealed that the relationship between of the plant development and *B. tabaci* counts was highly significantly positive (r-value; 0.92) in each season. As well as, this factor indicated that for every day increase in the development of cucumber plant, the estimates of *B. tabaci* would increase by 3.73 and 2.85 insects per leaf for the two seasons, respectively (Table, 3). Abdel Hamed *et al.* (2011) observed a significant positive correlation between the okra plant age and *B. tabaci* incidence.

The impact of cucumber plant development on *B. tabaci* counts was determined by the partial regression values (Table, 3), which were highly significantly positive (P. reg. values; 4.89 and 3.41) in the two seasons, respectively (Table, 3).

E- The combined effect of certain weather factors and plant development on B. tabaci counts

Data in Table (3), the combined effect of certain weather factors and plant development on *B. tabaci* counts during the two growing seasons was highly significant where the "F" values were 34.19 and 41.17 respectively. The explained variance percentages were 94.47 and 92.16% for the two seasons, respectively.

3.4.2. Effect of plant development

This relationship was evaluated by the nonlinear equation of the third degree, *i.e.*, $Y= a+ b_1X+ b_2X^2+ b_3X^3$. It observed highly significant relation to the changing in the counts of *B. tabaci*. The explained variance percentages were 97.59 and 92.51% for the two seasons, respectively (Table, 3). The regression equation was presented in Fig. (3):

First season (2021):

$Y_1 = -0.0002 X^3 + 0.0549 X^2 – 3.7378 X + 78.763$

$R^2= 0.9757$

Second season (2022):

$Y_1 = -0.0032 X^3 - 0.3874 X^2 + 15.134 X – 141.23$

$R^2 = 0.9251$

Also, the combined effect of these factors on *B. tabaci* estimates was highly significant where the "F" values were 121.34 and 61.76 during the two seasons, respectively (Table, 3).

3.4.3. Effect of all tested variables on B. tabaci counts

Results exhibited that the combined impact of the all tested variables (three weather factors and plant development) on *B. tabaci* counts. The combined effect of all these factors on *B. tabaci* counts have highly significant where the «F» value was 50.37 and 28.45 during the both seasons (Table, 3). As well, the percentages of explained variance were 98.05 and 93.43% in the two seasons, respectively (Table, 3).

It is clear that the effects of weather factors and plant development on the *B. tabaci* counts were very important during the two seasons, and these factors changed from one season to another.

The ecological needs of various pests of vegetable crops have been increasingly important in pest management research plans lately. However, some research has been done on the influence of climatic conditions on population fluctuations in damage, losses, and pest control for vegetable crops, according to Abou-Zaid (2003). Adam *et al*. (1997) they mentioned a significant positive correlation between the temperature & relative humidity and *B. tabaci* populations on cucumber plants in greenhouse. Bharadia and Patel (2005) also reported that the maximum population of whitefly was in the fourth week of October. Abdel-Hamed *et al.* (2011) mentioned that the weather factors (maximum, minimum, mean temperature) and okra plant age had significant positive effect on population of *B. taba*ci, while the relative humidity had negative significant effect on population of *B. tabaci* in 2009 and 2010 seasons. As well, the percentage of explained variance of these factors seasons were 91.50; 94.60% during the two, respectively. Ammar and Abolmaaty (2016) stated that the daily mean temperature and RH% are the most important abiotic factors influencing *B. tabaci* incidence. Kumar and Gupta (2016) mentioned that *B. tabaci* occurrence in potato plants decreased gradually with the decrease in the maximum and minimum temperatures.

Table 1. Population fluctuations, cumulative whitefly-days and rate of increase of *Bemisia tabaci* infesting cucumber plants with the corresponding means of main weather conditions at Armant district, Luxor region over the first season (2021

Inspection time		Weeks after emergence	Whitefly estimates / leaf ± S.E.	Cumulative counts / leaf	% Cumulative	Whitefly-days	Cumulative whitefly - days	Rate of increase	Max. temp.	Min temp.	% R.H.
Jan.,	23	8	2.13 ± 0.09	2.13	0.58	7.47	7.47	—	19.76	10.08	58.10
2021	30	9	8.23 ± 1.27	10.37	2.80	36.28	43.75	3.86	22.38	6.19	55.07
	6	10	9.90 ± 1.61	20.27	5.47	63.47	107.22	1.20	23.41	8.02	52.93
	13	11	14.00 ± 1.73	34.27	9.25	83.65	190.87	1.41	21.43	8.65	50.56
	20	12	18.00 ± 2.31	52.27	14.11	112.00	302.87	1.29	25.56	11.03	49.86
Feb.	27	13	30.67 ± 2.73	82.67	22.32	169.41	472.28	1.69	22.06	9.68	53.64
	5	14	36.67 ± 3.18	119.56	32.28	235.53	707.81	1.21	28.10	11.03	43.44
	12	15	40.00 ± 1.15	159.71	43.11	269.65	977.45	1.09	29.84	14.13	36.09
	19	16	42.33 ± 2.96	202.45	54.65	290.12	1267.57	1.06	23.90	9.68	49.91
March	26	17	41.00 ± 2.08	243.19	65.65	292.17	1559.74	0.95	28.57	13.89	40.96
	3	18	45.00 ± 1.35	287.74	77.68	298.52	1858.27	1.09	30.56	19.05	34.54
	10	19	46.67 ± 1.76	333.96	90.15	317.68	2175.94	1.04	35.41	16.54	32.50
April	17	20	36.67 ± 4.48	370.44	100.00	289.44	2465.39	0.79	38.73	19.59	34.99
Total			370.44			2465.39					
General average			28.56 ± 2.52						26.90	12.12	45.58

Table 2. Population fluctuations, cumulative whitefly-days and rate of increase of *B. tabaci* infesting cucumber plants with the corresponding means of main weather conditions at Armant district, Luxor region over the second season (2022).

Inspection time		Weeks after emergence	Whitefly estimates / leaf ± S.E.	Cumulative counts / leaf	% Cumulative	Whitefly-days	Cumulative whitefly - days	Rate of increase	Max. temp.	Min temp.	% R.H.
March, 2022	6	13	4.43 ± 0.24	4.43	0.72	15.52	15.52	—	24.47	12.44	44.71
	13	14	3.57 ± 0.13	8.00	1.29	28.00	43.52	0.80	32.30	12.13	35.14
	20	15	3.43 ± 0.37	11.43	1.85	24.50	68.02	0.96	31.00	14.34	33.43
	27	16	6.83 ± 0.64	18.27	2.95	35.93	103.95	1.99	34.01	18.14	38.00
April	3	17	16.23 ± 0.90	34.50	5.58	80.73	184.68	2.38	26.27	12.27	41.00
	10	18	20.27 ± 0.26	54.77	8.85	127.75	312.43	1.25	33.94	14.16	35.29
	17	19	30.47 ± 0.68	85.23	13.78	177.57	490.00	1.50	31.67	15.63	39.29
	24	20	40.73 ± 0.37	125.97	20.36	249.20	739.20	1.34	40.73	21.93	37.14
May	1	21	40.20 ± 0.83	166.17	26.86	283.27	1022.47	0.99	38.31	20.49	38.29
	8	22	45.47 ± 0.15	211.63	34.21	299.83	1322.30	1.13	42.47	23.69	37.57
	15	23	41.77 ± 0.15	253.40	40.97	305.32	1627.62	0.92	40.51	24.27	42.00
	22	24	37.23 ± 0.93	290.63	46.98	276.50	1904.12	0.89	40.31	23.93	40.00
	29	25	41.10 ± 0.74	331.73	53.63	274.17	2178.28	1.10	37.43	24.90	42.00
June	5	26	43.37 ± 1.79	375.10	60.64	295.63	2473.92	1.06	42.34	29.34	45.14
	12	27	45.77 ± 1.93	420.87	68.04	311.97	2785.88	1.06	40.59	23.99	35.86
	19	28	45.97 ± 1.11	466.57	75.43	320.13	3106.02	1.00	40.63	25.83	30.00
	26	29	48.97 ± 0.64	515.53	83.34	331.33	3437.35	1.07	41.06	24.47	28.00
July	2	30	50.77 ± 2.46	566.30	91.55	349.07	3786.42	1.04	42.42	26.70	26.00
	9	31	52.27 ± 1.85	618.57	100.00	360.62	4147.03	1.03	42.34	26.81	22.29
	Total		618.57			4147.03					
General average			32.56 ± 2.28						36.99	20.81	36.38

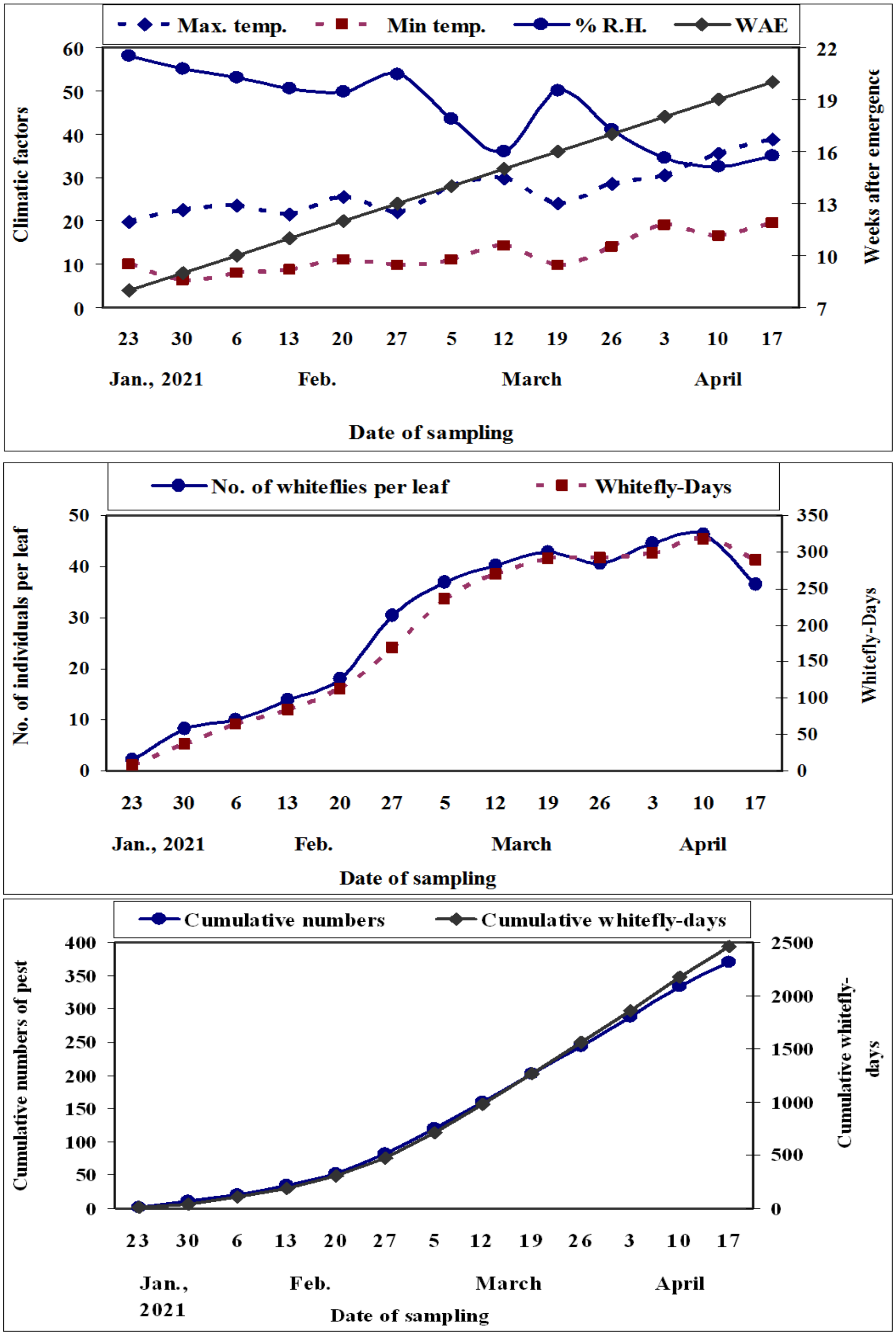

Figure 1. Population fluctuations and cumulative whitefly-days of *B. tabaci* infesting cucumber plants with the corresponding means of main weather conditions at Armant district, Luxor region over the first season (2021).

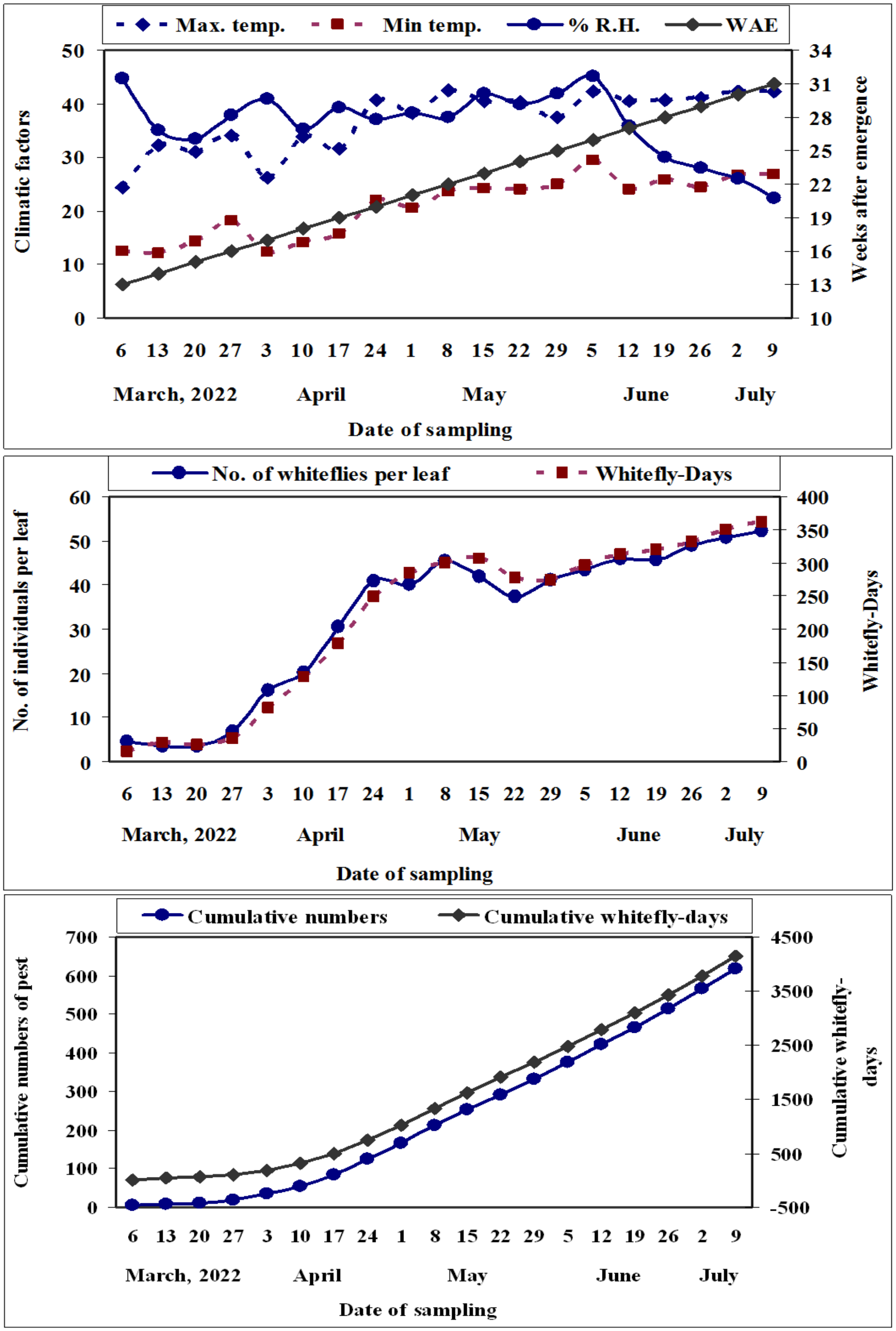

Figure 2. Population fluctuations and cumulative whitefly-days of *B. tabaci* infesting cucumber plants with the corresponding means of main weather conditions at Armant district, Luxor region over the second season (2022).

Table 3. Multiple linear regression models between population fluctuations of *B. tabaci* and weather parameters and biotic variable over the two seasons (2021 and 2022).

Season	Tested Variables	Simple correlation and regression values				Partial regression values			Analysis variance			
		Simple correlation	Simple regression	Standard error	t-test	Partial regression	Standard error	t-test	F values	Multiple correlation	Coefficient of determination	Explained variance %
2021	Max. temp (X_1)	0.71	1.97	0.59	3.33 **	-1.82	0.66	-2.77 *	34.19 **	0.97	0.94	94.47
	Min. temp (X_2)	0.71	2.65	0.80	3.32 **	-1.32	0.77	-1.72				
	R.H.% (X_3)	-0.82	-1.46	0.30	-4.83**	-1.18	0.45	-2.63 *				
	Plant age (X_4)	0.92	3.73	0.48	7.77 **	4.89	0.82	5.98 **				
	Plant ages (X_4, X_4^2, X_4^3)								121.34 **	0.99	0.98	97.59
	Combined effect (X_1 to X_4^3)								50.37 **	0.99	0.98	98.05
2022	Max. temp (X_1)	0.87	2.70	0.37	7.37 **	1.92	0.67	2.85 *	41.17 **	0.96	0.92	92.16
	Min. temp (X_2)	0.89	2.74	0.34	8.07 **	-1.80	1.04	-1.74				
	R.H.% (X_3)	-0.34	-0.97	0.64	-1.51	0.90	0.35	2.60 *				
	Plant age (X_4)	0.92	2.85	0.30	9.65 **	3.41	0.78	4.34 **				
	Plant ages(X_4, X_4^2, X_4^3)								61.76 **	0.96	0.93	92.51
	Combined effect (X_1 to X_4^3)								28.45 **	0.97	0.93	93.43

** Significant at P ≤ 0.05* *** Highly significant at P ≤ 0.01*

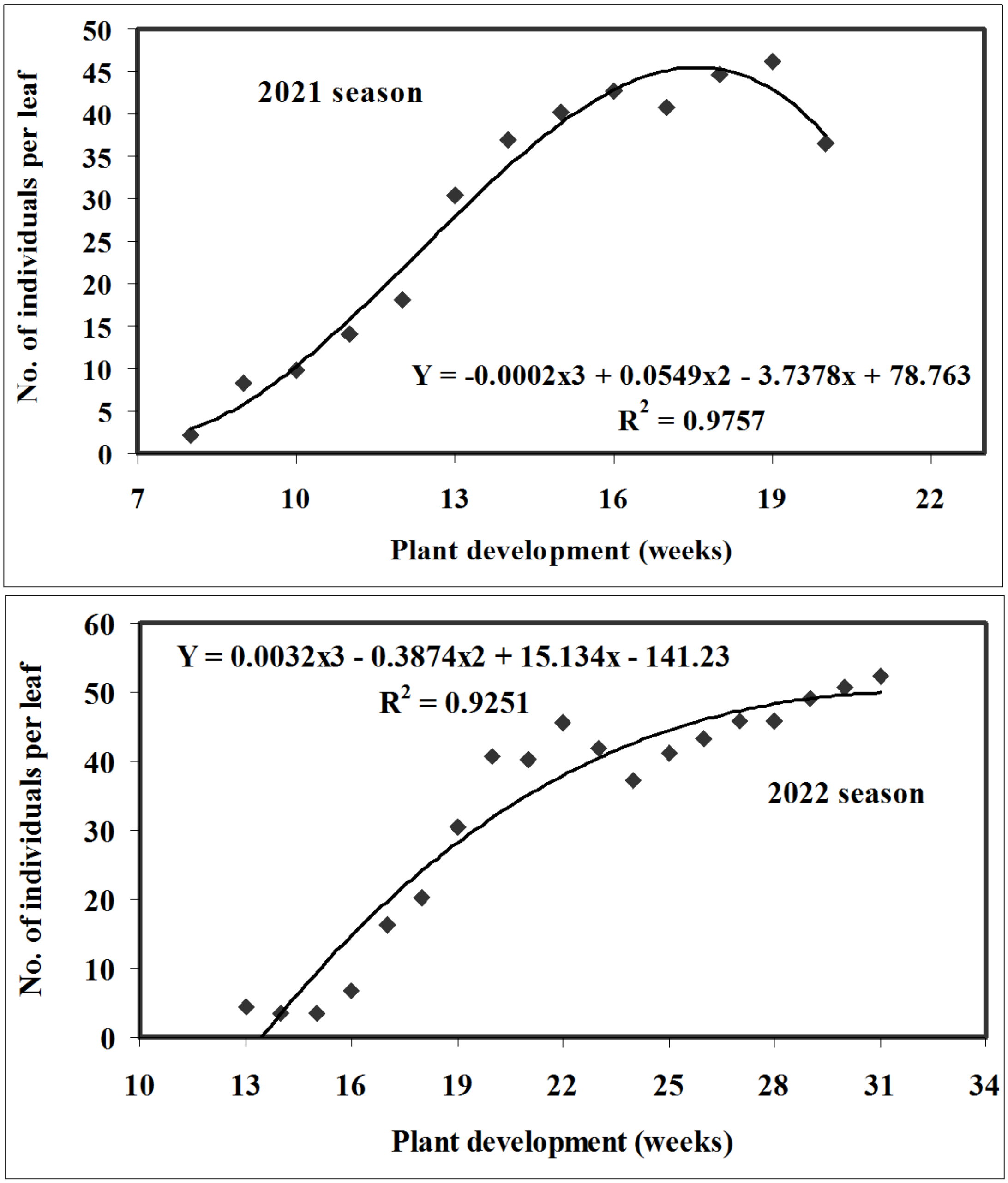

Figure 3. The nonlinear relationship between plant development and the population estimates of *B. tabaci* throughout the two seasons (2021 and 2022).

Hegab (2017) mentioned that the weather factors influenced *B. tabaci* fluctuation 21.5 and 67.2 % (as percentages of explained variance) during the two seasons (2016 and 2017), respectively. Moanaro and Choudhary (2018) revealed a positive correlation between whitefly population with minimum and maximum temperature on capsicum. El-Shazly *et al.* (2019) reported that numbers of *B. tabaci* raise with increasing the temperatures per season, and mean counts also increased with decreasing relative humidity. As well as, the combination of temperature and humidity was impacting *B. tabaci* activity. Kataria *et al.* (2019) reported that whitefly counts indicated negative correlation for minimum and maximum temperature, while, positive correlation with relative humidity. Ghongade *et al.* (2021) also revealed significantly positive correlation between whitefly population with minimum and maximum temperature and insignificant negative influence with relative humidity on cucumber plants.

On the contrary, Kumar *et al.* (2023) mentioned that *B. tabaci* incidence did not show any significant correlation with weather factors.

4. Conclusions and recommendations

In order to established a program for whitefly management in greenhouses, the objective of the current investigation was to comprehend the relationship between whitefly occurrence, environmental variables, and plant development over the two seasons. The findings demonstrated that the seasonal activity of *B. tabaci* was detected on cucumber plants during the period from January 23rd till April 17th, i.e., the insect infestations exhibited on plants that were eight weeks old after emergence in 2021 season. However, it appeared during the interval from March 6th until July 9th, i.e., the injuries discovered on plants that were thirteen weeks old after emergence in 2022 season. During the two seasons, a gradual increase in the numbers of *B. tabaci* on cucumbers was observed during the month of April, indicating that the management of the pest should begin before it reaches its highest level, during the seedling and flowering stages. In addition, the impacts of weather circumstances and plant development on *B. tabaci* abundance were highly significant over the two seasons studied and that these variables varied from season to another. As well, the percentages of explained variance were 98.05 and 93.43% in the two seasons, respectively. It may be possible to adjust the insecticide application schedule to focus on the most affected areas. But to verify the validity of these notions; many studies must be carried out.

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Institutional Review Board Statement

All Institutional Review Board Statements are confirmed and approved.

Data Availability Statement

Data presented in this study are available on fair request from the respective author.

Ethics Approval and Consent to Participate

Not applicable

Consent for Publication

Not applicable.

Conflicts of Interest

The authors disclosed no conflict of interest starting from the conduct of the study, data analysis, and writing until the publication of this research work.

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