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Original Research

Occurrence of the Whitefly *Bemisia tabaci* on Pepper Plants in a Greenhouse in Saudi Arabia

Badriah M.K. Asiri°*

Department of Biological Sciences, College of Science, University of Jeddah, Jeddah, Saudi Arabia

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Abstract

Bemisia tabaci (Gennadius), the scientific name for the whitefly, is an insect pest of economic importance that threatens crops worldwide. This study aimed to assess the population abundance of *B. tabaci* on pepper plants (*Capsicum annuum*) during two seasons (2022/2023 and 2023/2024) in the Al-Qassim Region, Kingdom of Saudi Arabia. We also investigated the impact of weather factors and plant age on *B. tabaci* abundance using simple correlation coefficients, multiple regression, and principal component analysis. We additionally assessed the association between essential nutrients in pepper leaves and *B. tabaci* counts. Data showed that *B. tabaci* individuals were recorded on pepper plants from October 6 to April 14 in each season. The variability in *B. tabaci* counts explained by the multiple regression model was 84.17% and 78.48% across the two seasons, respectively. A principal component analysis was undertaken to analyze the meteorological variables and *B. tabaci* counts to evaluate the correlation between them. Over the two seasons, *B. tabaci* counts were negatively correlated with potassium content in pepper leaves and positively correlated with nitrogen, phosphorus, and carbohydrate contents.

Keywords: *Bemisia tabaci*, *Capsicum annuum*, population density, climatic conditions, biotic factors

Introduction

Pepper (*Capsicum* spp.), a popular vegetable and spice crop globally, is known for its color, flavor, pungency, scent, and taste [1]. Sweet pepper, which belongs to the genus *Capsicum* and the family Solanaceae [2], is grown in plastic houses in Saudi Arabia and is considered one of the best sources of health-promoting components [3]. Pepper plants, found in Asia, Southeast Asia, South and Central America, and Africa, are a rich source of antioxidants, vitamins A and B, and other nutrients [4]. Cooked, *Capsicum* leaves are eaten alongside fruits, with *Capsicum* spp. being the main food source in the nightshade family [5].

Red sweet pepper fruit contains health-promoting substances like carotenoids, phenolics, and antioxidants [6]. Customers evaluate fruit quality based on weight, thickness, color, and nutritional content, choosing mature, nutrient-dense fruit [7]. Sweet peppers can be infested by various insect pests, including the economically significant whitefly, *Bemisia tabaci*, which poses a significant threat to agricultural hosts worldwide [8]. *B. tabaci*, a polyphagous whitefly, is a dangerous pest that can colonize various crops [9], including sweet pepper plants [10], by removing sap from leaves, causing wilting, yellowing, and reduced development [11].

*e-mail: bmasiri@uj.edu.sa
°ORCID iD: 0009-0002-2090-9679

Additionally, it exudes honeydew, a sticky material that can encourage the formation of sooty mold [12]. Severe infestations of whitefly can weaken and harm pepper plants, causing viral infections, seedling mortality, and reduced plant growth and production [13].

B. tabaci, a destructive insect, poses a significant threat to pepper plants globally, becoming resistant to traditional pesticides, necessitating immediate control measures [14]. Climate, physical characteristics, growth climate, and season all influence the number and extent of insects and their harm to plants [15]. Understanding insect pest ecology requires understanding phenology, which is influenced by factors like location, weather, and management techniques, which can impact its severity and frequency [16].

Understanding pest population patterns in relation to weather conditions is crucial for designing effective pest management strategies [17]. Understanding weather patterns and the impact of mineral nutrients on whitefly populations is crucial for developing integrated pest management plans for *Capsicum*, with N fertilizer levels significantly affecting growth and yield [18].

Pepper plants respond differently to insect epidemics based on leaf chemistry [19]. Factors like weather, trichome type, plant vigor, N and K levels, and natural enemies influence whitefly population density. Potassium levels can cause plant resistance to insects, while antifeedant potassium reduces host suitability for pests [20]. Phosphorus treatment led to a significant decrease in Hemiptera pest populations, affecting other insect pests like *Empoasca* sp. and *Frankliniella occidentalis* [21]. This suggests that biochemical components and genetic modifications could serve as defense mechanisms against pests [22].

Principal Component Analysis (PCA) is a multivariate method that uses axes to represent data, with the first principal component explaining more variance [23]. Correlation-based PCA is preferred for different scales, and eigenvalues determine the ideal number of principal components [24].

The goal of the present study was to estimate whitefly populations on pepper plants over the two seasons. The association between plant age, meteorological conditions, and the number of whiteflies during the two seasons was also estimated. The relationship between *B. tabaci* numbers and essential elements in pepper leaves was also evaluated.

Materials and Methods

Population Studies of *B. tabaci* on Pepper Plants

Abundance of B. tabaci

The current study was conducted on a private farm in the Al-Qassim area of the Kingdom of Saudi Arabia. The trial was conducted during the 2022/2023 and 2023/2024 growing seasons. Pepper seeds of the "Barbero" cultivar were planted in the second week of September, followed by the transfer of seedlings at 25 days old to greenhouses (approximately 600 cm^2). The seedlings were arranged in a completely randomized block design. Any seedlings that died were replaced with new seedlings of the same age within one week of the initial planting. All agronomic practices, except for chemical controls, were used. Sampling of leaves was initiated just after the first week of October, when the infestation first began, and continued each week until the crop was completely harvested. The total number of whiteflies (adults and nymphs) on each leaf was counted using 10x magnification; samples were taken weekly from eight different areas in each replicate throughout the two seasons and from various strata of the pepper plants in the greenhouse. The total number of samples collected during the two crop seasons was 2240 pepper leaves, consisting of 56 individual sampling sessions (28-sample replicates × 4-sample replicates × 10 leaves × 2 seasons). Each season had 1120 leaves.

Damaged Leaf Percentages by B. tabaci

The number of *B. tabaci* on pepper leaves was estimated, and the percentages of damaged leaves were assessed according to Bakry and Abdel-Baky [25].

$$A = (n / N) \times 100$$

Where A is the proportion of damaged leaves, n represents the number of damaged leaves in the sample, and N is the total number of examined leaves (undamaged and damaged) for each examined date.

The study analyzed *B. tabaci* numbers and leaves damaged by the pest in the two research seasons using one-way ANOVA. Means were compared using the least significant difference (LSD) test at the 5% probability level.

Accumulated Numbers of B. tabaci Population

The weekly average of *B. tabaci* per 10 pepper leaves was calculated to compare seasonal population abundance. This strategy involved counting individuals at weekly sampling intervals. The total number of *B. tabaci* recorded on each sampling day was then summed to calculate the accumulated number of *B. tabaci* per 10 leaves on each sampling date. The percentages of the cumulative numbers relative to the total number of *B. tabaci* in each season were then computed. Next, Bakry [26] used odd-number percentages to highlight the overall population density.

The Rate of Increase in B. tabaci Counts

To assess the rate of increase in population size at weekly examination variations, the average *B. tabaci* count at the current examination time was divided by that at the preceding examination time [27].

Two Models Evaluated the Effect of Some Weather Factors and Plant Age on the Occurrence of *B. tabaci*

By Applying the Multiple Regression Method

The occurrence of *B. tabaci* numbers per 10 leaves was related to climatic factors and biotic characteristics across two seasons (2022/2023 and 2023/2024). Weather variables – mean temperature, mean relative humidity, and sunshine duration – were measured in the greenhouse. Daily data for these factors were averaged over the seven days corresponding to *B. tabaci* counts. The biological characteristic of plant age was measured weekly and documented at each sampling date. The collected data were statistically assessed using multiple correlation and regression analyses to identify the relationships between the examined biotic and abiotic factors and the population density of *B. tabaci*. To provide a basic understanding of the level of variability in population fluctuations under these criteria, the percentage of explained variance was also estimated. STATISTICA Software [28] was used to perform statistical analysis on the data. All of the data were computed and graphically presented in Microsoft Excel 2010. Simple correlation values among several independent variables and *B. tabaci* counts were computed and displayed using R software [29]. The association between plant age (in days) and the number of *B. tabaci* per 10 leaves was determined using a third-degree polynomial regression approach. Asiri and Bakry [30] adopted this strategy.

By Applying the Principal Component Model

Principal Component Analysis (PCA) is a multivariate analytic approach used to reduce the dimensionality of data.

A scatterplot utilizing principal component analysis and the PAST program version 1.62 [31] was used to illustrate the multidimensional relationships of meteorological influences and plant age on *B. tabaci* occurrence.

The Correlation between Essential Nutrients in Pepper Leaves and B. Tabaci Counts

Essential nutrients contained in pepper leaves are thought to either promote or inhibit insect infestation and susceptibility in plants. Consequently, plant nutrient elements, including potassium, phosphorus, nitrogen, and carbohydrates, were selected for analysis, along with their respective concentrations within the pepper leaves. For this experiment, a sample of pepper leaves was collected at random (excluding other parts of the plant) by selecting 10 leaves from each replicate, specifically from the fifth leaf (i.e., the fifth leaf from the terminal bud of developing pepper plants). Once harvested, the fresh leaf samples were washed with tap water and then distilled water to remove any contaminants, dirt, etc. [32]. The clean samples were dried in a 70ºC electric oven for 48 h. Fresh and dry weights were recorded [33]. Dried leaves were ground into powder using an electric mill and stored in a container for later analysis [34]. The plant samples were digested using an H_2SO_4 solution following the procedure outlined by Sumner [34]. Analyses were conducted on a dry weight basis.

Sumner [34] used flame photometry to determine potassium (K), ascorbic acid as a colorimetric indicator of phosphorus (P), and the micro-Kjeldahl method to quantify total nitrogen (N) in ground samples. The anthrone method was used for the colorimetric determination of total carbohydrates from dried pepper leaves, while A.O.A.C. [35] colorimetry was performed using 240 nm as the wavelength of interest.

Statistical analysis of the chemical constituents of dried pepper leaves and the estimated mean counts of whitefly (*B. tabaci*) per 10 leaves per season was conducted using R software [36]. This analysis aimed to determine the regression coefficient and calculate the simple correlation. Data were also subjected to ANOVA analysis, and the means were compared by the least square difference test (LSD) at $P \leq 0.05$. The association of key elements within dried pepper leaves and *B. tabaci* data was assessed using Pearson's correlation coefficient and Haar's principal components analysis to further support the correlation analysis performed using R Core Team [37].

Results

Weekly studies were conducted on greenhouse-grown pepper plants (Barbero cultivar) in the Qassim region of Saudi Arabia to assess the number of *B. tabaci* per 10 leaves, analyze climatic and biotic parameters, and evaluate seasonal changes during the two seasons (2022/2023 and 2023/2024).

Occurrence and Damaged Leaves Percentages by *B. tabaci* on Pepper Plants

Population Abundance

According to the data, *B. tabaci* counts on pepper plants were recorded for each season between October 6 and April 14 (Tables 1 and 2 and Figs 1 and 2). Overall estimates of *B. tabaci* counts for the two seasons were 2782.25 and 2789.50 individuals, respectively. Additionally, during the two seasons, the average number of *B. tabaci* per leaf was 99.37±5.88 and 99.63±6.06 individuals, respectively (Tables 1 and 2 and Figs 1 and 2). Variations in climatic conditions and other variables throughout the two-season period resulted in fluctuations in the numbers of *B. tabaci* individuals on pepper leaves during each season.

Statistical analysis showed that there were highly significant differences between *B. tabaci* individuals analyzed on different dates throughout each season. Data showed that the coefficient of variation values reached 9.18 in 2022/2023 and 5.80 in 2023/2024, while the L.S.D. values reached 7.10 and 6.10 in the two seasons, respectively. In this case, there was no statistically significant difference in the number of individuals between the two seasons. The data collected and the results of the statistical analysis generally supported the results across the two seasons, indicating that *B. tabaci* counts fluctuated between sampling dates within the two seasons.

Damaged Leaves Percentages

Four maximum peaks of abundance were recorded for the percentages of damaged leaves by *B. tabaci* on pepper plants during the 2022/2023 season. These were on October 27, November 24, January 14, and February 11. The results showed, respectively, 25.00±2.89, 32.50±6.29, 40.00±4.08, and 47.50±2.50%. However, the lowest percentages of damaged leaves were recorded on October 6, 2022, as shown in Table 1 and Fig. 1.

The seasonal oscillations of the percentages of damaged leaves by *B. tabaci* over the 2023/2024 season showed four maximum peaks, with 25.00±6.45, 35.00±9.57, 40.00±7.07, and 45.00±5.00% on November 3, December 15, January 14, and February 18, respectively, as presented in Table 2 and illustrated in Fig. 2. On October 6, 2023, however, the lowest percentages of damaged leaves were recorded, as shown in Table 2 and Fig. 2.

Fluctuations in the percentages of pepper leaves damaged by *B. tabaci* during the two-season period are caused by changes in the climate and other variables. Statistical analysis revealed that there were highly significant differences in the percentages of pepper leaves damaged by *B. tabaci* inspected at different time points during each season.

In this context, the L.S.D. values were 3.96 and 3.39 in the two seasons, respectively, while the coefficient of variation values were 7.50 in 2022/2023 and 6.80 in 2023/2024.

According to the results, the average percentage of pepper leaves damaged by *B. tabaci* throughout the two seasons was 30.80±1.17 and 28.75±1.14%, respectively. In the first season (2022/2023), the percentage of pepper leaves damaged by *B. tabaci* had a greater impact than in the second season (2023/2024). The percentages of pepper leaves damaged by *B. tabaci* also varied significantly between the two seasons; the L.S.D. was 0.86, and the coefficient of variation was 9.07.

B. tabaci Weekly Abundance, Accumulation, and Proportion to Seasonal Total

To depict the overall pattern of population density, the percentages of cumulative numbers for every week

Table 1. Average weekly numbers of *B. tabaci* individuals per 10 leaves and the rate of increase in numbers on sweet pepper plants, with biotic and abiotic factors influencing them in the Qassim region of Saudi Arabia during the first season (2022/2023).

Sampling date		No. of individuals per 10 leaves ± S.E.	% No. of individuals of total population	Cumulative numbers	% Cumulative No.	Rate of increase	% Attacked leaves	Mean temp	R.H. %	Sunshine (h)	Plant age (in days)
Oct., 2022	6	2.75±0.63	0.10	2.75	0.10	------	5.00±2.89	29.17	72.93	11.00	30.00
	13	3.50±0.29	0.13	6.25	0.22	1.27	17.50 ± 4.79	31.42	75.17	11.00	37.00
	20	11.25±0.48	0.40	17.50	0.63	3.21	22.50±6.29	33.66	68.44	11.00	44.00
	27	24.50±0.96	0.88	42.00	1.51	2.18	25.00±2.89	33.66	72.93	11.00	51.00
Nov.	3	45.00±2.04	1.62	87.00	3.13	1.84	22.00±2.50	33.66	72.93	11.50	58.00
	10	48.25±4.70	1.73	135.25	4.86	1.07	27.50±6.29	34.78	72.93	11.50	65.00
	17	53.25±4.70	1.91	188.50	6.78	1.10	30.00±4.08	33.66	72.93	11.50	72.00
	24	73.00±0.91	2.62	261.50	9.40	1.37	32.50±6.29	35.90	72.93	11.50	79.00
Dec.	1	86.25±3.71	3.10	347.75	12.50	1.18	30.00±4.08	31.42	75.17	11.00	86.00
	8	84.50±2.22	3.04	432.25	15.54	0.98	30.00±4.08	28.05	75.17	11.00	93.00
	15	92.00±1.08	3.31	524.25	18.84	1.09	32.50±4.79	22.44	75.17	11.00	100.00
	22	114.50±2.22	4.12	638.75	22.96	1.24	35.00±6.45	24.68	75.17	11.00	107.00
	29	122.00±3.08	4.38	760.75	27.34	1.07	35.00±2.89	20.20	71.81	8.50	114.00

Jan., 2023	7	158.25±3.33	5.69	919.00	33.03	1.30	37.50±4.79	19.07	70.69	8.50	121.00
	14	165.75±3.45	5.96	1084.75	38.99	1.05	40.00±4.08	20.20	71.81	8.50	128.00
	21	171.00±3.42	6.15	1255.75	45.13	1.03	37.50±2.50	20.20	69.56	8.50	135.00
	28	177.00±2.65	6.36	1432.75	51.50	1.04	42.50±4.79	20.20	63.95	10.50	142.00
Feb.	4	191.50±3.59	6.88	1624.25	58.38	1.08	45.00±2.89	19.07	65.08	10.50	149.00
	11	203.00±4.36	7.30	1827.25	65.68	1.06	47.50±2.50	21.32	66.20	10.50	156.00
	18	194.25±5.14	6.98	2021.50	72.66	0.96	45.00±5.00	23.56	67.32	10.50	163.00
	25	171.75±4.80	6.17	2193.25	78.83	0.88	42.50±2.50	24.68	79.66	10.50	170.00
	27	140.00±9.13	5.03	2333.25	83.86	0.82	37.50±2.50	30.29	83.03	10.50	177.00
Mar.	3	120.00±10.99	4.31	2453.25	88.18	0.86	35.00±2.89	31.42	78.54	10.50	184.00
	10	107.50±5.80	3.86	2560.75	92.04	0.90	30.00±4.08	32.54	79.66	10.50	191.00
	17	88.00±3.74	3.16	2648.75	95.20	0.82	25.00±2.89	37.03	88.64	11.00	198.00
	24	62.00±5.03	2.23	2710.75	97.43	0.70	20.00±4.08	38.15	80.78	11.00	205.00
April	7	45.75±3.90	1.64	2756.50	99.07	0.74	17.50±2.50	31.42	89.76	11.00	212.00
	14	25.75±5.11	0.93	2782.25	100.00	0.56	15.00±2.89	32.54	90.88	11.00	219.00
Total		2782.25	100								
General average		99.37±5.88					30.80±1.17	28.37	74.97	10.57	124.50

Table 2. Average weekly numbers of *B. tabaci* individuals per 10 leaves and the rate of increase in numbers on sweet pepper plants, with biotic and abiotic factors influencing them in the Qassim region of Saudi Arabia during the second season (2023/2024).

Sampling date		No. of individuals per 10 leaves ± S.E.	% No. of individuals of total population	Cumulative numbers	% Cumulative No.	Rate of increase	% Attacked leaves	Mean temp	R.H. %	Sunshine (h)	Plant age (in days)
Oct., 2023	6	4.00±0.41	0.14	4.00	0.14	------	7.50±2.50	40.00	76.66	11.00	30.00
	13	9.50±0.65	0.34	13.50	0.48	2.38	15.00±2.89	40.00	79.99	11.00	37.00
	20	15.75±1.65	0.56	29.25	1.05	1.66	17.50±2.50	38.89	77.77	11.00	44.00
	27	32.00±1.41	1.15	61.25	2.20	2.03	20.00±4.08	38.89	76.66	11.00	51.00
Nov.	3	50.50±0.96	1.81	111.75	4.01	1.58	25.00±6.45	34.44	72.22	11.00	58.00
	10	27.25±1.25	0.98	139.00	4.98	0.54	22.50±4.79	34.44	72.22	11.00	65.00
	17	32.25±1.25	1.16	171.25	6.14	1.18	25.00±6.45	35.55	74.44	11.00	72.00
	24	72.25±1.65	2.59	243.50	8.73	2.24	27.50±2.50	38.89	68.88	11.00	79.00

Dec.	1	85.00±3.49	3.05	328.50	11.78	1.18	30.00±4.08	35.55	77.77	11.00	86.00
	8	111.50±2.87	4.00	440.00	15.77	1.31	32.50±4.79	34.44	75.55	11.00	93.00
	15	119.00±2.12	4.27	559.00	20.04	1.07	35.00±9.57	35.55	73.33	11.00	100.00
	22	118.00±2.16	4.23	677.00	24.27	0.99	32.50±7.50	36.66	79.99	11.00	107.00
	29	125.50±2.50	4.50	802.50	28.77	1.06	35.00±5.00	35.55	63.33	11.50	114.00
Jan., 2024	7	164.50±5.91	5.90	967.00	34.67	1.31	37.50±2.50	36.66	68.88	11.50	121.00
	14	172.00±4.60	6.17	1139.00	40.83	1.05	40.00±7.07	36.66	67.77	11.50	128.00
	21	170.50±4.11	6.11	1309.50	46.94	0.99	30.00±4.08	36.66	69.99	11.50	135.00
	28	185.25±2.06	6.64	1494.75	53.58	1.09	30.00±4.08	35.55	63.33	10.50	142.00
Feb.	4	191.50±3.30	6.87	1686.25	60.45	1.03	32.50±2.50	37.77	64.44	10.50	149.00
	11	203.00±3.42	7.28	1889.25	67.73	1.06	35.00±6.45	36.66	65.55	10.50	156.00
	18	194.25±2.72	6.96	2083.50	74.69	0.96	45.00±5.00	36.66	66.66	10.50	163.00
	25	171.75±2.39	6.16	2255.25	80.85	0.88	42.50±2.50	32.22	78.88	10.50	170.00
	27	144.50±2.33	5.18	2399.75	86.03	0.84	35.00±6.45	30.00	82.21	10.50	177.00
Mar.	3	116.00±5.42	4.16	2515.75	90.19	0.80	32.50±4.79	30.00	77.77	10.50	184.00
	10	87.50±4.79	3.14	2603.25	93.32	0.75	30.00±5.77	28.89	78.88	10.50	191.00
	17	60.75±6.87	2.18	2664.00	95.50	0.69	27.50±2.50	30.00	87.77	10.00	198.00
	24	58.50±1.89	2.10	2722.50	97.60	0.96	25.00±2.89	28.89	79.99	10.00	205.00
April	7	43.50±3.86	1.56	2766.00	99.16	0.74	20.00±4.08	27.78	88.88	10.00	212.00
	14	23.50±5.07	0.84	2789.50	100.00	0.54	17.50±2.50	28.89	89.99	10.00	219.00
Total		2789.50	100								
General average		99.63±6.06					28.75±1.14	34.72	74.99	10.79	124.50

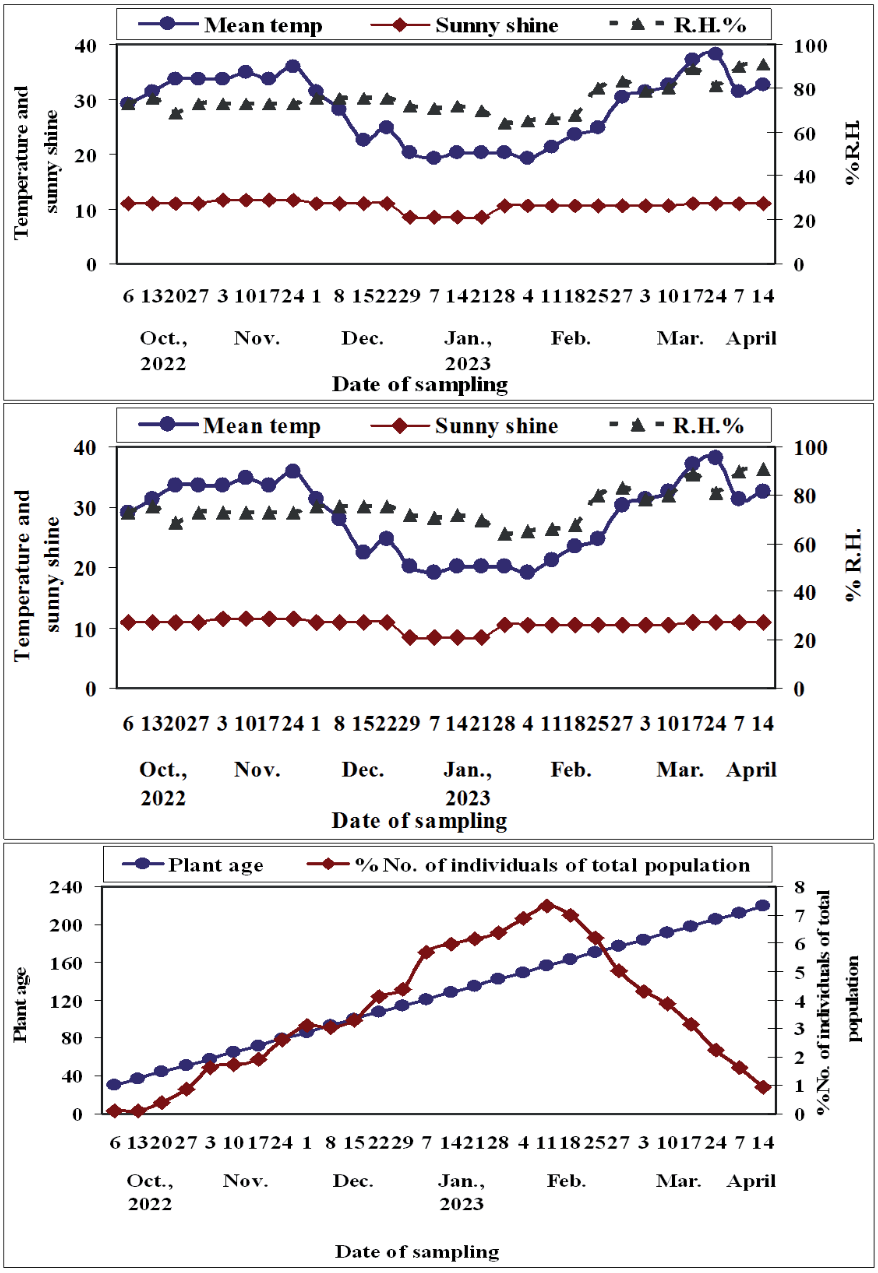

Fig. 1. Abundance of *B. tabaci* individuals per 10 leaves on pepper plants, with weather factors and plant age influencing them in the Qassim region of Saudi Arabia during the first season (2022/2023).

were also connected to the total seasonal number, as seen in Tables 1 and 2.

According to the data in Tables 1 and 2, the greatest percentages of *B. tabaci* individual counts on pepper leaves during the two seasons were recorded on January 14.

This might be due to optimal climatic conditions at that time of year. The total estimates of *B. tabaci* populations for the two growing seasons were 2782.25 and 2789.50 individuals, respectively, according to the data in Tables 1 and 2. As the number of sampling times during the growing season increased, so did the percentages of cumulative counts of *B. tabaci* individuals on pepper leaves.

Rate of Increase in B. tabaci Counts

The projected rate of increase in *B. tabaci* counts on pepper plants, with the timing of insect activity predicted by population change, is shown in Tables 1 and 2. According to the explanations given by Bakry and Tolba [38], an increase rate of more than one indicates increased activity, a rate of less than one indicates decreased activity, and a rate equal to one indicates no change in insect activity. *B. tabaci* counts on pepper plants showed a significant rise in 2022/2023 beginning on October 13 and continuing through December 1 and then continuing from December 15 through February 11 (Table 1). Starting on October 13 and continuing

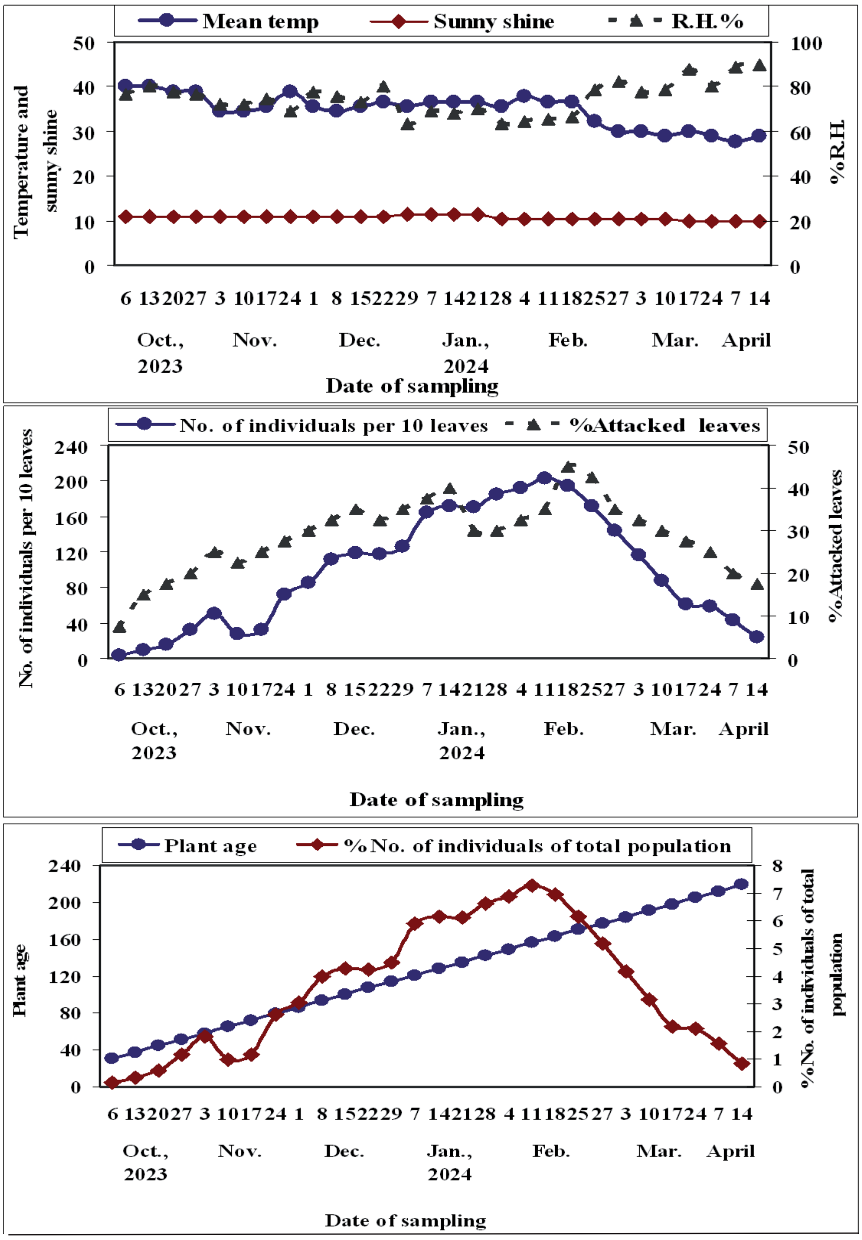

Fig. 2. Abundance of *B. tabaci* individuals per 10 leaves on pepper plants, with weather factors and plant age influencing them in the Qassim region of Saudi Arabia during the second season (2023/2024).

through November 3, November 17 through December 15, December 29 through January 14, and February 4 through February 11, the rates of increase were greater than one for 2023/2024. This suggests that *B. tabaci* activity was supported by favorable environmental conditions during these periods (Table 2).

The Different Third-Order Nonlinear Relationships

Between the B. tabaci Counts and the Percentages of Damaged Pepper Leaves

The relationship between *B. tabaci* estimates (X) and the percentages of damaged pepper leaves (Y) was estimated. The equations are as follows:

First season (2022/2023):

$$Y = 5^{-6}X^3 - 0.0019X^2 + 0.3214X + 12.745 \quad R^2 = 0.8687 \qquad (1)$$

Second season (2023/2024):

$$Y = 3^{-6}X^3 - 0.0018X^2 + 0.3668X + 10.497 \quad R^2 = 0.8492 \qquad (2)$$

For both seasons, the explained variance proportions were 86.87% and 84.92%, respectively, as shown in Equations (1) and (2).

Between the Plant Age (in Days) and B. tabaci Estimates

The relationship between pepper plant age (X) and the number of *B. tabaci* (Y) was estimated. The equations are as follows:
First season (2022/2023):

$$Y = -0.0002 X^3 + 0.0411X^2 - 1.6197X + 18.066 \quad R^2 = 0.9535 \qquad (3)$$

Second season (2023/2024):

$$Y = -0.0002 X^3 + 0.0394X^2 - 1.3292X + 9.4173 \quad R^2 = 0.9289 \qquad (4)$$

The explained variance proportions for both seasons were 95.35% and 92.89%, respectively, as shown in Equations (3) and (4).

Between Plant Age (in Days) and Percentages of Damaged Pepper Leaves

The relationship between pepper plant age (X) and the percentages of damaged leaves (Y) was estimated as illustrated in Fig. 3. The equations are as follows:
First season (2022/2023):

$$Y = -0.00002X^3 + 0.0027X^2 + 0.1832X + 6.2313 \quad R^2 = 0.8906 \qquad (5)$$

Second season (2023/2024):

$$Y = -0.000007X^3 + 0.00009X^2 + 0.3896X - 0.2496 \quad R^2 = 0.8386 \qquad (6)$$

The findings showed that 89.06% and 83.86%, respectively, were the proportions of explained variance for both seasons, as shown in Equations (5) and (6).

Effect of Certain Weather Factors and Plant Age on *B. tabaci* Counts on Pepper Plants

Effect of Mean Maximum Temperature

According to the data shown in Table 3 and Fig. 3, there was a highly significant negative correlation (r-value of -0.76) between the mean maximum temperature and the *B. tabaci* counts on pepper plants in 2022/2023, and a negligible positive correlation (+0.05) in 2023/2024. The population was found to reduce by 0.71 individuals per 10 leaves in the first season and to rise by 0.85 individuals per 10 leaves in the second season when the daily mean temperature was raised by 1ºC (Table 3).

Using the partial regression model, our data showed that the *B. tabaci* counts were significantly negatively impacted by the daily mean temperature (P. reg. value was -3.98) in 2022/2023 and positively (P. reg. value was +7.80) in 2023/2024 (Table 3).

Effect of the Mean Relative Humidity

According to data shown in Table 3 and Fig. 3, there was a significant negative correlation (r-value of -0.39) between relative humidity and the *B. tabaci* counts on pepper plants in 2022/2023 and a highly significant negative correlation (r-value of -0.60) in 2023/2024.

The population would grow by 3.54 and 5.21 individuals/10 leaves in both seasons, respectively, if the mean relative humidity increased by 1% in this case, according to the simple regression model (Table 3). The partial regression results revealed that relative humidity significantly negatively influences *B. tabaci* numbers in both seasons (P. reg. values: -4.92 and -4.43).

Effect of the Mean Sunshine

According to Table 3 and Fig. 3, the statistical analysis of simple correlation revealed a highly significant negative correlation (r-value was -0.57) between the mean sunshine (hours) and the *B. tabaci* counts in 2022/2023 and an insignificantly positive correlation (r-value was 0.10) in 2023/2024. According to the predicted regression approach, the population would drop by 39.06 individuals per 10 leaves in 2022/2023 and increase by 14.15 individuals per 10 leaves in 2023/2024 for every 1 h increase in mean sunshine (sunlight hours).

Table 3 explains the specific impacts of mean sunshine (hours) on *B. tabaci* counts. The first season showed an insignificantly negative relation (P. reg. value was -1.17), whereas the second season showed an insignificantly positive relation (P. reg. value was 42.03).

Effect of the Plant Age

Plant age (in days) and *B. tabaci* numbers were found to be strongly positively correlated in both seasons (r-values: 0.45 and 0.39, respectively), according to data shown in Table 3 and Fig. 3. Additionally, this analysis showed that *B. tabaci* counts would rise by 0.49 and 0.44 individuals per 10 leaves in the two seasons, respectively, for each one-day increase in plant age. The results indicated that the effect was highly significant and positive (P. reg. values: 0.77 and 1.25 throughout the two seasons, respectively).

The Combined Impact of Tested Factors on B. tabaci Counts

The combined influence of plant age and weather conditions on *B. tabaci* counts on pepper plants throughout the two seasons was extremely significant, according to the data in Table 3. The F values varied from season to season and were 30.57 and 20.98, respectively. Both growth seasons had explained variance levels of 84.17 and 78.48%, respectively.

Table 3. Simple and multiple regression analyses for describing the relationship between some weather factors and pepper plant age affecting *B. tabaci* individuals over the two seasons (2022/2023 and 2023/2024).

Season	Tested Variables	Simple correlation and regression values				Partial correlation and regression values				Analysis variance			
		r	b	S.E	t	P. cor.	P. reg.	S.E	t	F values	MR	R^2	E.V.%
2022/2023	Mean temp.	-0.76	-7.66	1.30	-5.88 **	-0.48	-3.98	1.50	-2.65*	30.57 **	0.92	0.84	84.17
	R.H. %	-0.39	-3.54	1.63	-2.18 *	-0.64	-4.92	1.22	-4.03**				
	Sunshine	-0.57	-39.06	10.94	-3.57 **	-0.03	-1.17	8.23	-0.14				
	Plant age	0.45	0.49	0.19	2.59 *	0.79	0.77	0.12	6.23**				
2023/2024	Mean temp.	0.05	0.85	3.44	0.25	0.40	7.80	3.70	2.11*	20.98 **	0.89	0.78	78.48
	R.H. %	-0.60	-5.21	1.38	-3.79 **	-0.60	-4.43	1.25	-3.55**				
	Sunshine	0.10	14.15	27.46	0.52	0.37	42.03	22.13	1.90				
	Plant age	0.39	0.44	0.20	2.15 *	0.75	1.25	0.23	5.48 **				

Principal Component Analysis (PCA)

The study found two principal components (PC1 and PC2) with eigenvalues greater than one, explaining 84.67% and 88.59% of the overall variance for the two seasons, respectively (Fig. 4). For PC1 and PC2, the independent variables were plant age, sunlight, relative humidity, and daily mean temperatures. According to Fig. 4, PC1 explained 53.54% and 57.19% of the variation in both years, whereas PC2 explained 31.13% and 31.40% of the variation, respectively.

Over 2022/2023, the average *B. tabaci* counts demonstrated a positive correlation with the plant age. On the contrary, the relationships between *B. tabaci* counts and the daily mean temperatures, relative humidity, and sunshine were negative, as shown in Fig. 4a). In this context, there were positive relationships between *B. tabaci* numbers and the independent variables, namely mean temperature, sunshine, and plant age, but only average relative humidity had a negative relationship in 2023/2024, as shown in Fig. 4b). These results provide additional support for the simple correlation analysis.

The Association between Essential Nutrients in Pepper Leaves and *B. tabaci* Counts

The chemical analysis of essential nutrients in pepper leaves across the two years (2022/2023 and 2023/2024) is shown in Table 4.

Table 5 displays the relationship between *B. tabaci* counts and essential nutrients, i.e., total carbohydrate and mineral elements (N, P, and K). Statistical analysis of the data revealed that the N, P, and total carbohydrate levels in pepper leaves had strong significant positive associations with *B. tabaci* counts ($r = +0.98$, $+0.99$, and $+0.99$) in 2022/2023 and ($r = +0.97$, $+0.96$, and $+0.99$) in 2023/2024, respectively (Table 5). Nonetheless, over the two years, there were significant negative correlations with the K content of pepper leaves assessed in the two seasons ($r = -0.97$) (Table 5).

Regarding the use of principal component analysis to assess the correlation between *B. tabaci* numbers throughout the two-season period and the observed essential nutrients, as seen in Fig. 5, the principal component analysis findings showed that *B. tabaci* counts were considerably impacted by essential nutrients (Fig. 5). For the first year (2022/2023), the first two principal components accounted for 98.78% of the variance, whereas PC1 and PC2 made up 96.66% and 2.12% of the total variance, respectively, as shown in Fig. 5a). However, during the second year (2023/2024), PC1 accounted for 98.17% of the variance and PC2 for 1.04%, meaning that the first two principal components explained 99.21% of the overall variance (Fig. 5b)).

There was a positive correlation between the first component and the total number of *B. tabaci* as well as the total amount of carbohydrate, N, and P in pepper leaves (Fig. 5). On the other hand, PC2 showed a

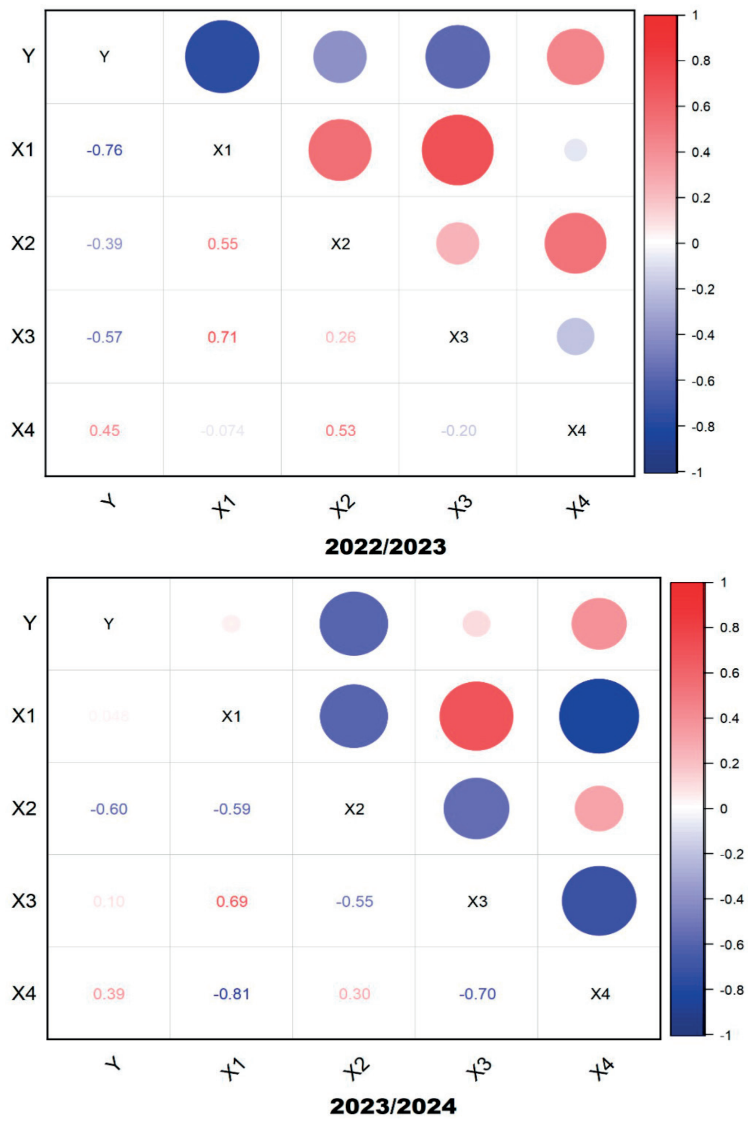

Fig. 3. The correlation between *B. tabaci* counts per 10 leaves, climatic parameters, and pepper plant age over the two seasons (2022/2023 and 2023/2024).

negative relationship with K concentration with *B. tabaci* counts (Fig. 5). Furthermore, the principal component analysis demonstrated that *B. tabaci* populations were significantly influenced by essential nutrients.

Table 4. Chemical analysis of essential nutrients in pepper leaves during the two years (2022/2023 and 2023/2024).

Essential nutrients	2022/2023	2023/2024
Total carbohydrate	52.73±4.08 a	52.27±4.51 b
N	2.13±0.08 b	2.15±0.07 a
P	0.27±0.01 a	0.26±0.01 a
K	2.49±0.10 b	2.52±0.09 a

Means followed by the same letter(s), in each row, are not significantly different at a 0.05 level of probability, by LSD test.

Discussion

The whitefly, *Bemisia tabaci* (Gennadius), is a key pest in agriculture and causes serious injury to crops both through direct feeding and as a vector for plant viruses. The deleterious effects are especially pronounced on economically important plants, resulting in lower yields and reduced plant health [39]. This work aims to study the abundance of *B. tabaci* populations in pepper plants (*Capsicum annuum*) during the 2022/2023 and 2023/2024 seasons under the conditions of the Al-Qassim Region, Saudi Arabia. We also assessed the effect of weather factors and plant age on whitefly abundance, which was analyzed using the simple correlation coefficient, multiple regression, and principal component analysis. The results showed that the number of *B. tabaci* individuals was observed on pepper plants during the interval from October 6 to April 14 in each season. Four peaks of abundance for the proportion

Table 5. Simple correlation and regression coefficients between the essential nutrients in pepper leaves and *B. tabaci* counts over the two seasons (2022/2023 and 2023/2024).

Season / Nutrients	First year (2022/2023)						Second year (2023/2024)					
	r	b	S.E.	T-test value	Y = a ± bx	E.V.%	r	b	S.E.	T-test value	Y = a ± bx	E.V.%
Total carbohydrate	+ 0.97	0.12	0.01	7.24 **	92.84 + 0.12x	94.53	+0.97	0.13	0.02	6.51**	92.66 + 0.13x	93.47
N	+0.98	6.40	0.82	7.79**	85.72 + 6.40x	95.30	+0.96	8.07	1.30	6.16**	82.28 + 8.07x	92.60
P	+ 0.99	86.21	1.02	5.64**	75.79 + 86.21x	98.23	+0.99	50.44	3.47	14.7**	86.29 + 50.44x	98.25
K	– 0.97	–4.97	0.82	6.05**	111.74 – 4.97x	92.31	–0.97	-7.02	0.99	7.02**	117.32 – 7.02x	94.34

Notes: r = Simple correlation; b = Simple regression; S.E. = Standard error; E.V% = Explained variance; ** Highly significant at P≤0.01.

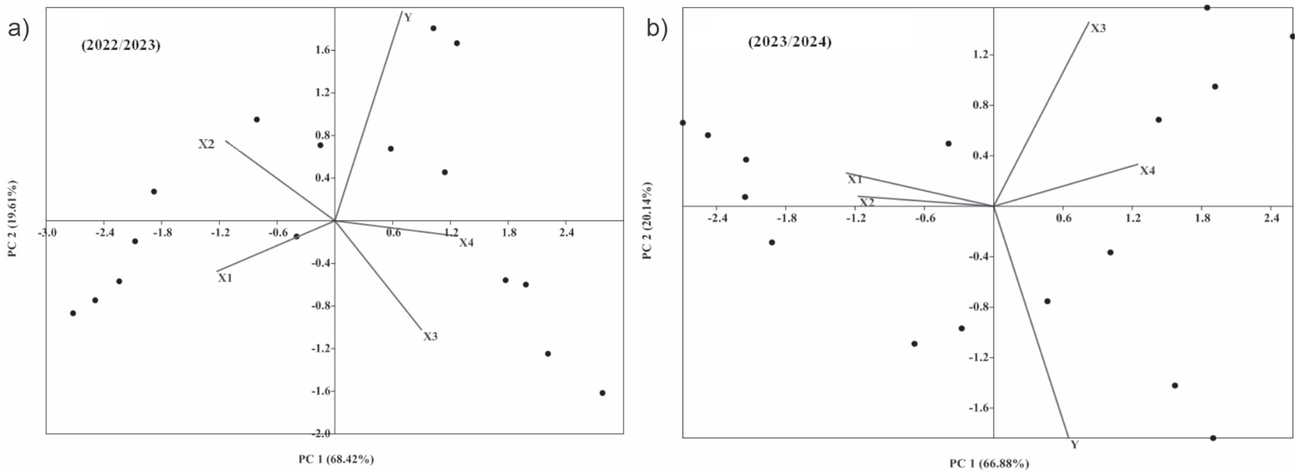

Fig. 4. A binary plot based on principal component analysis of weather parameters and plant age in relation to *B. tabaci* numbers over the two seasons (2022/2023 and 2023/2024).

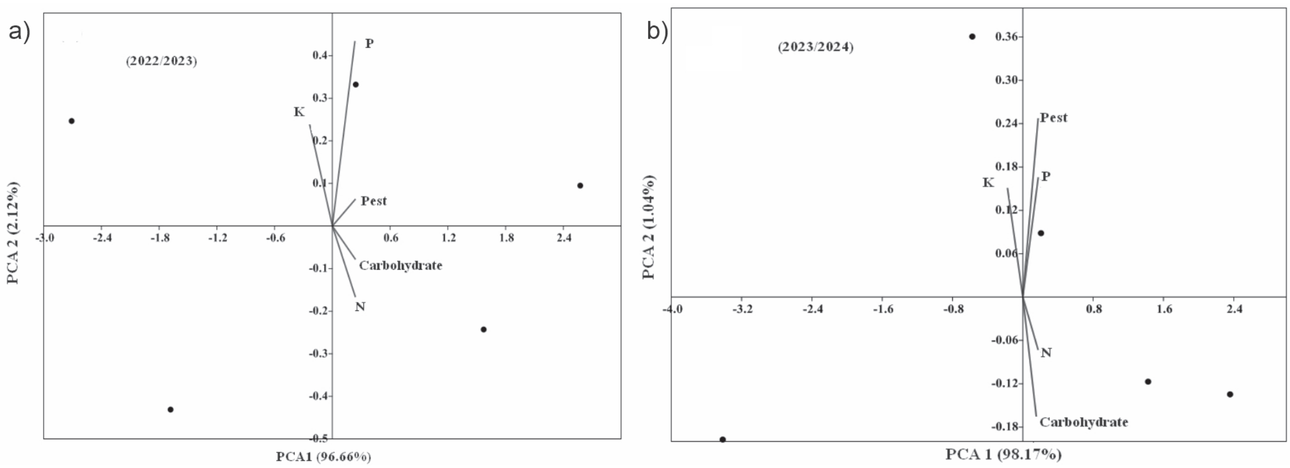

Fig. 5. A binary plot based on principal component analysis of parameters assessing the relationship between essential nutrients in pepper leaves and *B. tabaci* numbers during the two seasons. a) 2022/2023 and b) 2023/2024.

of damaged leaves by *B. tabaci* on pepper plants were also recorded. The previous season's data and statistical analysis confirm seasonal fluctuations in percentages of pepper leaves damaged by *B. tabaci*. These findings were consistent with Hegab's [40] estimates of a single peak of *B. tabaci* infesting cucumber leaves during the third week of July. On the other hand, Ahmed and Bahjat [41] found that *B. tabaci* formed three peaks every season on summer cucumber crops.

The gradual increase in *B. tabaci* numbers on tomatoes suggests early pest management, based on seedling and vegetative development phases, before the peak population is reached, as supported by El-Shazly et al. [42]. According to El-Damer et al. [43], *B. tabaci* on pepper was shown to have 1-3 peaks.

Regarding the relationship between plant age (in days) and *B. tabaci* counts, the results showed that the relationship was significantly positive. According to Shehata et al. [44], the incidence of *B. tabaci* and the age of the okra plant were significantly positively correlated.

In addition, the results showed a significant positive relationship between plant age (in days) and the percentage of damaged pepper leaves. Numerous studies have indicated that plant age can significantly influence insect activity and infestation rates, as seen with the striped mealybug, *Ferrisia virgata*, infesting *Acalypha* shrubs [45].

Regarding the effect of three weather factors and plant age on *B. tabaci* counts on pepper plants, the results indicated that the combined effect of these factors over the two seasons was very significant. The F values varied from season to season and were 30.57 and 20.98, respectively. Both growing seasons had explained variance levels of 84.17 and 78.48%, respectively. Concerning the analysis of weather variables and plant ages on *B. tabaci* abundance using principal component analysis, the results showed additional evidence supporting the simple correlation analysis.

Recent research confirms the influence of climatic conditions on damage, losses, and pest management of vegetable crops [46]. Temperature and humidity significantly influence *B. tabaci* populations on tomato plants in greenhouses [47], with the highest concentration observed in October [48].

Bakry et al. [49] discovered that weather conditions significantly influenced B. tabaci on okra plnats variation by 94.29% and 91.88% in terms of explained variance between the 2024 and 2025 seasons.

Moanaro and Choudhary [50] discovered a strong correlation between the whitefly population and the minimum and maximum temperatures of *Capsicum*, while Ghongade et al. [51] found a positive correlation between whitefly populations and temperature.

The interactions between essential nutrients in pepper leaves and *B. tabaci* populations are strong, especially with respect to nitrogen, phosphorus, potassium, and carbohydrates. Plants with higher nitrogen, phosphorus, and carbohydrate levels correspond to higher populations of *B. tabaci*, while potassium had a negative correlation. Therefore, nutrient management may affect pest dynamics in cultivated peppers. Darwish et al. [52] noted that the high nitrogen and phosphorus levels observed in pepper leaves were associated with increased numbers of *B. tabaci*, because nitrogen enhanced the nutritional value of the host plant and made it more attractive to the pest, while phosphorus benefited plant growth and development. Increased potassium levels observed in pepper leaves were associated with lower populations of *B. tabaci*, suggesting that potassium may play a role in plant defense mechanisms. Lach et al. [53] reported that yellow crazy ant abundance was found to have a positive correlation with carbohydrate resources, especially honeydew from hemipterans.

Conclusions

Data on *B. tabaci* can aid in scouting, pest monitoring, and weather assessment for effective IPM techniques, but further studies are needed for effective control. The findings can be utilized by farmers and decision-makers to develop strategies for managing and controlling *B. tabaci* while minimizing damage to pepper plants.

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Author Contributions

Badriah M.K. Asiri designed the experiment, collected the data, wrote the paper, and performed data analysis.

Conflicts of Interest

The author declares no conflict of interest.

Data Availability

All relevant data are within the paper and its supporting information files.

References

1. ROHINI N., LAKSHMANAN V. Evaluation studies of hot pepper hybrids (*Capsicum annuum* L.) for yield and quality characters. The Electronic Journal of Plant Breeding, **8** (2), 643, **2017**.
2. AMAECHI N.C., UDEOGU E., OKORONKWO C.U., IRONDI C.P. Nutritional and phytochemical profiles of common pepper (*Capsicum spp.*) foliage consumed as leafy vegetables in Southeast Nigeria. Food Research, **5** (5), 136, **2021**.
3. IBRAHIM A., ABDEL-RAZZAK H., WAHB-ALLAH M., ALENAZI M., ALSADON A., DEWIR Y.H. Improvement in growth, yield, and fruit quality of three

red sweet pepper cultivars by foliar application of humic and salicylic acids. HortTechnology, **29** (2), 170, **2019**.
4. BATIHA G.E.-S., ALQAHTANI A., OJO O.A., SHAHEEN H.M., WASEF L., ELZEINY M., ISMAIL M., SHALABY M.M., MURATA T., ZARAGOZA-BASTIDA A., RIVERO-PEREZ N., BESHBISHY A.M., KASOZI K.I., JEANDET P., HETTA H.F. Biological Properties, Bioactive Constituents, and Pharmacokinetics of Some *Capsicum* spp. and Capsaicinoids. *International Journal of Molecular Sciences*, **21** (15), 5179, **2020**.
5. GÓRA V., CSEPREGI K. Changes in antioxidant properties of pepper leaves (*Capsicum annuum* L.) upon UV radiation. International Journal of Secondary Metabolite, **11** (2), 333, **2024**.
6. RODRIGUES C.A., NICÁCIO A.E., JARDIM I.C.S.F., VISENTAINER J.V., MALDANE L. Determination of Phenolic Compounds in Red Sweet Pepper (*Capsicum annuum* L.) Using a Modified QuEChERS Method and UHPLC-MS/MS Analysis and Its Relation to Antioxidant Activity. Journal of the Brazilian Chemical Society, **30** (6), 1229, **2019**.
7. MARTÍNEZ-ISPIZUA E., MARTÍNEZ-CUENCA M.-R., MARSAL J.I., DÍEZ M.J., SOLER S., VALCÁRCEL J.V., CALATAYUD Á. Bioactive Compounds and Antioxidant Capacity of Valencian Pepper Landraces. Molecules, **26** (4), 1031, **2021.**
8. HAMEED G.A., ABDULLAH M.A., ELHADEETI, S.A.K. Population density of *Bemisia tabaci* on sweet pepper (*Capsicum annuum*) varieties in the greenhouse. Sciences IOP Conf. Series: Earth and Environmental Science, **1262,** 3, **2023.**_
9. SHEHATA E.A., MOHAMED L.H.Y., ELMASRY N.S. Effect of weather change and plant age on the whitefly *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) on tomato plants and its control in Dakhlia Region, Egypt. Journal of Plant Protection and Pathology Mansoura University, **15** (8), 213, **2024**.
10. IBRAHIM M. Population density of piercing-sucking pests and their associated natural enemies on pepper, *Capsicum annuum* L. plants under greenhouse condition at Ismailia Governorate, Egypt. Journal of Plant Protection and Pathology Mansoura University, **8** (9), 451, **2017**.
11. JEEVANANDHAM N., MARIMUTHU M., NATESAN S., GANDHI K., APPACHI S. Plant resistance in chillies *Capsicum* spp against whitefly, *Bemisia tabaci* under field and greenhouse condition. Journal of Entomology and Zoology Studies, **6** (2), 1904, **2018**.
12. BAKRY M.M.S., MOHAMED G.S., ABD-ELAZEEM Z.S., ALLAM R.O.H. Monitoring of the whitefly populations on cucumber plants in a greenhouse in Luxor region of South Egypt. SVU-International Journal of Agricultural Sciences, **5** (3), 27, **2023**.
13. AL-SAIDI S.S., AL-OBAIDY S.H. Induced Resistance of cucumber *Cucumis Sativus* L. To whitefly *Bemisia tabaci* by silicon. International Journal of Agricultural and Statistical Sciences, **18**, 2147, **2022**.
14. ZAYED M.S., TAHA E.A., HASSAN M.M., ELNABAWY, E.M. Enhance systemic resistance significantly reduces the silverleaf whitefly population and increases the yield of sweet pepper, *Capsicum annuum* L. var. *annuum*. *Sustainability*, **14** (11), 6583, **2022**.
15. BAKRY M.M.S., ARBABTAFTI R., MOHAMED L.Y. Effect of certain climatic factors and plant phenology on population density of *Schizaphis graminum* on wheat plants in Luxor Governorate, Egypt. International Journal of Agriculture Innovations and Research, **8** (5), 401, **2020**.
16. BAKRY M.M.S., ABDEL-BAKY N.F., Influence of weather conditions and plant growth on populations of the solenopsis mealybug (*Phenacoccus solenopsis* Tinsley) infesting maize plants. Brazilian Journal of Biology. **84**, e283233, **2024**.
17. GAFFAR S.A., HALA A., TAMAN A., ZAKI E.M. Detecting population fluctuation of *Tuta absoluta* on some Solanum spp. in relation to different environmental conditions and it's economic evaluation in Kafr El Sheikh governorate, Egypt. Egyptian Journal of Agricultural Research, **95** (4), 1773, **2017**.
18. ALKHARPOTLY A.A. Growth and Yield Responses of Sweet Pepper (*Capsicum annum* L.) to Organic and NPK Mineral Fertilization under Plastic Houses Conditions at Arid Regions. Journal of Plant Protection and Pathology Mansoura University, **9** (3), 299, **2018**.
19. WEKSLER S., ROZENSTEIN O., HAISH N., MOSHELION M., WALLACH R., BEN-DOR E. Pepper plants leaf spectral reflectance changes as a result of root rot damage. Remote Sensing, **13** (5), 980, **2021**.
20. TORABI E., TAVAKOLI E., OLYAIE TORSHIZ A., TAHERIAN M. Investigating the efficacy of potassium silicate and potassium sulfate against the pistachio psyllid (*Agonoscena pistaciae*) under field conditions. Chemistry Proceedings, **10** (1), 40, **2022**.
21. BALA K., SOOD A.K., PATHANIA V.S., THAKUR S. Effect of plant nutrition in insect pest management: a review. Journal of Pharmacognosy and Phytochemistry, **7** (4), 2737, **2018**.
22. SUSHMITHA S., RAVI G., BANERJEE S., PRAMANIK A. Biochemical profiling of plant defense mechanisms against *Spodoptera frugiperda* (J.E. Smith) infestation in selected host species. Scientific Reports, **15**, 34193, **2025**.
23. WAMBI W., MAKUMBI D., ASEA G., ZELEKE H., BRUCE A.Y., WAKGARI M., KWEMOI D.B., PRASANNA B.M. Use of multi-trait principal component selection index to identify fall armyworm (*Spodoptera frugiperda*) resistant maize genotypes. Frontiers in Plant Science, **16**, 1544010, **2025**.
24. XU S., CUI Y., YANG C., WEI S., DONG W., HUANG L., LIU C., REN Z., WANG W. The fuzzy comprehensive evaluation (FCE) and the principal component analysis (PCA) model simulation and its applications in water quality assessment of Nansi Lake Basin, China. Environmental Engineering Research, **26** (2), 232, **2021**.
25. BAKRY M.M.S., ABDEL-BAKY N.F. Population density of the fall armyworm, *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae) and its response to some ecological phenomena in maize crops. Brazilian Journal of Biology, **83**, e271354, **2023**.
26. BAKRY M.M.S. Abundance, generation determination and spatial distribution pattern of the sunt wax scale insect, *Waxiella mimosae* (Signoret) (Hemiptera: Coccidae) infesting sunt trees in Luxor Governorate, Egypt. Current Investigations in Agriculture and Current Research, **4** (3), 523, **2018**.
27. BAKRY M.M.S., FATHIPOUR Y. Population Ecology of the Cotton Mealybug, *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) on Okra plants in Luxor region, Egypt. Journal of Agricultural Science and Technology, **25** (6), 1387, **2023**.
28. STATSOFT I. STATISTICA (data analysis software system), version 6. Tulsa, USA, **150**, 91, **2001**.
29. WICKHAM H., CHANG W. Devtools: tools to make

developing R packages easier. R package version 1.13.4, **2018**.
30. ASIRI B.M.K., BAKRY M.M.S. Impact of weather parameters on seasonal abundance of the striped mealybug, *Ferrisia virgata* (Cockerell, 1893) (Hemiptera: Pseudococcidae) on mango trees in Egypt. Polish Journal of Entomology, **94**, 75, **2025**.
31. HAMMER O., HARPER D.A.T., RYAN P.D. PAST: paleontological statistics software package for education and data analysis. Palaeontologia Electronica, **4** (1), 1, **2001**.
32. CARDOSO M.P., REGO C.A.R.M., MUNIZ L.C., REIS V.R.R., MACENA C.V.S.P., SILVA R.B., MORAIS P.A.O. Chemical attributes and soil carbon and nitrogen stocks in pastures in the Maranhão Amazon. Revista de Agricultura Neotropical, **11** (4), e8542, **2024**.
33. BAKRY M.MS., SALIM E.H., TAHA R.M., TOLBA, E.F.M. Relationship Between the *Fiorinia phoenicis* Counts and Biochemical Traits and Nutritional Status of Certain Date Palm Cultivar leaflets. Assiut Journal of Agricultural Sciences, **56** (3), 114, **2025**.
34. SUMNER M. Soil Testing and Plant Analysis: Building a Future on Our Legacy. Communications in Soil Science and Plant Analysis, **37** (15-20), 2277, **2006**.
35. ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. Official methods of analysis. 12th ed. AOAC, Washington, DC., **2023**.
36. YASAR S., ARSLAN A.K., COLAK C., YOLOĞLU S. A Developed Interactive Web Application for Statistical Analysis: Statistical Analysis Software. Middle Black Sea Journal of Health Science, **6** (2), 239, **2020**.
37. R Core Team. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. Available on: https://www.R-project.org/ (accessed on November **2023**).
38. BAKRY M.M.S., TOLBA E.F.M. Occurrence of *Fiorinia phoenicis* (Hemiptera - Diaspididae) population on date palm trees based on climatic variables applying regression and principal component analyses. Journal of Plant Protection and Pathology, Mansoura University, **16** (3), 125, **2025**.
39. FARINA A., BARBERA A.C., LEONARDI G., MASSIMINO COCUZZA G.E., SUMA P., RAPISARDA C. *Bemisia tabaci* (Hemiptera: Aleyrodidae): What relationships with and morpho-physiological effects on the plants it develops on? Insects, **13** (4), 351, **2022**.
40. HEGAB M.A.M. Effect of different varieties of cucumber plants on the attractive of some homopterous insect pests. Journal of Plant Protection and Pathology, Mansoura University, **8** (12), 641, **2017**.
41. AHMED Q., BAHJAT F. The Presence of Whitefly *Bemisia tabaci*, and Thrips *Thrips tabaci* on Different Cucumber Plant Hybrid Varieties in the Field Conditions. IOP Conference Series Earth and Environmental Science, **1252** (1), 012009, **2023**.
42. EL-SHAZLY E.A., ABDEL-ATI K.E.A., ABD-EI-WAHAB H.A., MANSOUR M.H. Incidence of cotton whitefly *Bemisia tabaci* (GENNADIUS, 1889) (Hemiptera: Aleyrodidae) infesting cucumber (*Cucumis sativus* L.) cultivars with reference to cultivar susceptibilities. Polish Journal of Entomology, **88** (4), 379, **2019**.
43. EL-DAMER M.H.M., EL-AASSAR M.R., ABOLFADEL M.A., HASSAN G.M. Diversity of piercing-sucking pests infesting some plants of solanaceae and cucurbitaceae families. Egyptian Academic Journal of Biological Sciences, **17** (1), 67, **2024**.
44. SHEHATA E.A., MOSTAFA I.M.Y., ELMASRY N.S. Population Ecology of the Whitefly *Bemisia tabaci* (Gennadius) Infesting Pepper Plants and Its Control. Egyptian Academic Journal of Biological Sciences, **17** (2), 45, **2025**.
45. BAKRY M.M.S, SHEHATA E.A., TOLBA E.F.M. The striped mealybug *Ferrisia virgata* (Hemiptera: Pseudococcidae) monitoring and population dispersion on acalypha shrubs and its control in Luxor Region, Egypt. Assiut Journal of Agricultural Sciences, **55** (2), 180, **2024**.
46. CUZCO M.E., VERA A.M., QUIÑONEZ J.P., MERA L.F., LAO M.T. Influence of a Greenhouse Adapted to the Ecuadorian Coastal Climate on Pest Dynamics in Tomato Crops. *Horticulturae*, **11** (11), **1279**.
47. KHAN M. Effect of temperature and relative humidity on the population dynamics of brinjal and tomato infesting whitefly, *Bemisia tabaci*. Jahangirnagar University Journal of Biological Sciences, **8** (1), 83, **2019**.
48. LOBIN K.K., JAUNKY V.C., TALEB-HOSSENKHAN N. A meta-analysis of climatic conditions and whitefly *Bemisia tabaci* population: implications for tomato yellow leaf curl disease. The Journal of Basic and Applied Zoology, **83**, 57, **2022**.
49. BAKRY M.M.S., BADAWY A.M.M., ALI S.M.A., ALLAM R.O.H. Population dynamics of Bemisia tabaci on okra in Upper Egypt: quantifying the interactive effects of climate and plant age on seasonal abundance and pest pressure. SVU-International Journal of Agricultural Science, **8**, 3, **2026** (Accepted).
50. MOANARO CHOUDHARY J.S. Seasonal incidence of major sucking pests complex of *Capsicum* in relation to weather parameters in Eastern Plateau and Hill region of India. Journal of Entomology and Zoology Studies, **6**, 270, **2018**.
51. GHONGADE D.S., SANGHA K.S., DHALL R.K. Population buildup of whitefly, *Bemisia tabaci* (Gennadius) on parthenocarpic cucumber in relation to weather parameters under protected environment in Punjab. Journal of Agrometeorology, **23** (4), 457, **2021**.
52. DARWISH A.A.E., ATTIA M.M., KHOZIMY A.M.H. Effect of some integrated pest management elements on the population density of *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) on tomato plants (*Solanum Lycopersicum* L.). Assiut Journal of Agricultural Sciences, **42** (1), 164, **2021**.
53. LACH L., HOFFMANN B.D., MOIR M.L. Native and non-native sources of carbohydrate correlate with abundance of an invasive ant. NeoBiota, **63**, 155, **2020**.