Journal of Plant Protection and Pathology

Journal homepage & Available online at: www.jppp.journals.ekb.eg

Occurrence of *Fiorinia phoenicis* (Hemiptera - Diaspididae) Population on Date Palm Trees Based on Climatic Variables Applying Regression and Principal Component Analyses

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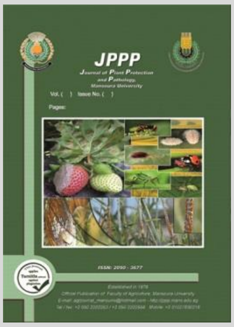

ABSTRACT

The investigation focuses on evaluating the impact of climatic conditions on the population ecology of the fiorinia date scale (FDS), *Fiorinia phoenicis* Balachowsky (Hemiptera: Diaspididae), applying regression and principal component analyses. This work was executed in a private date palm plantation in the El-Bayyarah region, Kom Omboo area, Aswan governorate, southern Egypt. According to the results, there were four yearly seasonal activity peaks for *F. phoenicis* individuals on date palm trees: mid-April, mid-June, early September/October, and mid-November. These individuals were found on date palm trees all year round. The calculated numbers of *F. phoenicis* were significantly impacted by the combined impacts of the climatic factors, which differed from year to year. The two years' explained variations in population estimates, as determined by the multiple regression approach, were 60.56% and 71.61%, respectively. The most significant variable that explained differences in the overall estimates of *F. phoenicis* in both years was solar radiation. However, the variable that had the least impact on population fluctuations over the two years was the daily mean lowest temperature.The principal components analysis produced two components (PC1 and PC2) with eigenvalues larger than 1, which explained 96.02% and 93.4% of the variation overall across the two years, respectively. The daily mean maximum and lowest temperatures, relative humidity, and solar radiation were the environmental factors for PC1 and PC2. In both years, PC1 comprised 72.81% and 72.76% of the variation, respectively, whilst PC2 comprised 23.21% and 20.64% of the variance, respectively.

*Keywords***:** Ferrisia *phoenicis, population ecology, climatic parameters, multiple regression, principal component.*

INTRODUCTION

Throughout human history, the date palm (*Phoenix dactylifera* L.; Arecaceae) has been economically significant. The date palm tree's significance stems from its capacity to tolerate and adapt to environmental stressors such as drought, high temperatures, and salt (Salem and Ali, 2020). Date palms are some of the oldest fruit plants found in dry and semi-arid regions (Krueger, 2021). Dates are a food that provides nutritional security to millions of people in arid parts of the world because of their high content of essential nutrients. Additionally, they are essential for nutrition (Chao and Krueger, 2007).

Date palms are one of the most significant horticultural crops that orchards may utilize to make additional money, regardless of whether they are cultivated for commercial purposes (Bakry, 2014). When it comes to exporting to significant international commercial centers, palm palms form the backbone of the local economy (Rathore *et al*., 2020).

Many insect pests have the potential to infest date palm trees (Alaoui and Joutei, 2024). *Fiorinia phoenicis* Balachowsky (Hemiptera: Diaspididae), the scientific name for the Fiorinia date scale (FDS), is one of the most dangerous pests of date palm trees (Ghabbour and Mohammad, 2010).The date palm's fronds are the primary target of *F. phoenicis*, which also periodically infects the dates. According to field observations, the pinnae of older date palm fronds (lower fronds) had a higher infestation of *F. phoenicis* than the newer ones (Elwan *et al*., 2011). The crawlers migrate to the date bunches and infest them throughout the fruiting period, generating thick crusts that render the dates unfit for human consumption in cases of severe infestation. Due to the serious invasion, the date palm's development was significantly impacted, particularly in the offshoots, which resulted in dry fronds and yellowish pinnae (Youssef *et al*., 2015).

This insect uses its mouthparts to suck plant sap, destroying palm tree leaves, fronds, and fruits because of its poisonous saliva (Radwan, 2012). Crop yield is lowered because of frond mortality, leaf fall, and deformities (El-Said, 2000). In addition to decreased respiration and photosynthesis, harmed palm leaves change the form, become yellow, and fall off (Bakry, 2014). The detection and accumulation of date palm scales on date palm leaf surfaces is the primary feature of date palm scale invasions, according to El-Sherif *et al*., (2001).Once planted in the orchard, farmers find it very difficult to manage (Elwan *et al*., 2011).

The weather has a significant impact on pest biology. Temperature is the primary abiotic element that affects an organism's life (Bakry *et al*., 2020). On the other hand, no climatic factor influences pest activity since the impacts of meteorological components on pests are usually muddled (Pareek *et al*., 2017). An insect species' activity is also greatly influenced by the amount of sunlight and relative

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DOI: 10.21608/JPPP.2025.360414.1316

humidity, which are the two main meteorological elements. Abiotic factors and pest activity can be correlated to create predictive models that help predict pest incidence (Chandra Kumar *et al*., 2008). It would be easier to determine the peak times of pest activity and create an efficient management plan if a comprehensive grasp of the variations in insect pest numbers in the field and their relationship to meteorological conditions was developed (Rajasekhar *et al*., 2021). Additionally, comprehending the effects of weather patterns on the Fiorinia date scale population is crucial for creating integrated pest management strategies under certain weather circumstances (Bakry *et al*., 2024).

Data dimensionality can be decreased using the multivariate analysis procedure known as principal component analysis. According to Grane and Jach (2014), this reduction helps build links between variables and makes it easier to visualize the data in fewer dimensions. With each axis representing a principal component (PC), PCA displays data along axes. According to Granato *et al.* (2018), the first principal component (PC1) explains more differences in the data than the second (PC2), which in turn explains more differences than the third (PC3). When working with data on multiple scales, PCA using correlation is usually preferable, although it may also be carried out using covariance. The primary focus of correlation-based PCA is on the associations between variables, whereas variance-based PCA highlights the variables' variation (Mishra *et al*., 2017). Eigenvalues, which show how much variance each principal component captures, are another key idea in PCA. Greater data variability can be explained by a matching principal component, according to higher eigenvalues. Additionally, eigenvalues help reduce dimensionality by aiding in the determination of the ideal number of major components (Johnson, 1998).

Many investigators focused on initial researchable problems, such as the survey of *F. phoenicis*, causes for their breakout, and management elements, because of the invasiveness, quick spread, and potential for economic damage of *F. phoenicis*. Despite the frequent presence of *F. phoenicis* in recent years, nothing is known about population dynamics in the Kom Omboo region of Aswan, Egypt. Nonetheless, the climate is changing quite quickly. Therefore, a thorough analysis of these factors is crucial to creating an insect pest control program for a particular agroecosystem. The current investigation was conducted to close this gap and learn more about the *F. phoenicis* ecology. Determining the effect of climate on the population estimates of *F. phoenicis* on date palm trees was the aim of this experiment.

MATERIALS AND METHODS

1- Population estimates:

Population ecology of the fiorinia date scale (FDS), *F. phoenicis*, on date palm trees:

An outbreak of *F. phoenicis* on date palm trees (Bartamoda cultivar) was discovered in a private plantation in the El-Bayyarah zone, Kom Omboo area, Aswan governorate, southern Egypt, during 2022/2023 and 2023/2024. The plantation is situated close to the Nile River at 24º30'55'' N, 32º57'15'' E. The plantation is approximately 8,400 square meters in size. Before and during the experiment period, the chosen orchard was treated only using natural cultivation methods; no chemical treatment methods were employed. Four date palm trees were chosen and were almost identical in terms of height, age, size, form, and vegetative development. *F. phoenicis* estimates were monitored half-monthly from early March 2022 to mid-February 2024.

In this study, there are two biological parameters: a) *F. phoenicis* abundance and b) percentage of damaged palm leaflets.

A- The first criterion is the population ecology of *F. phoenicis*:

At a rate of forty leaflets per tree, randomly selected samples were taken from five trees every fortnight from various tree levels and orientations. Continuously gathered leaflet samples were put in plastic bags and taken to the lab to be examined under a stereomicroscope. Date palm leaflets were separated into nymphs and females, and the number of living individuals on each surface was calculated and compared to each inspection period. During the two data collection years, we gathered a total of 9600 leaflets over 48 consecutive sample dates. Each year, 4800 leaflets, i.e. (40 leaflets x five trees x 24 consecutive sample dates). The pest was identified and categorized by researchers from the Plant Protection Research Institute at the Agricultural Research Center in Giza, Egypt. Population abundance was assessed using half-monthly palm tree assessments, (+) or (-) standard error, and seasonal variability in *F. phoenicis* estimates was assessed using the mean number of individuals per leaflet.

B- The second criterion is damaged leaflet percentages:

Direct visual inspection of palm leaflet samples was used to apply this criterion, which is the percentage of damaged leaflets at each examination date during the study years. This was computed by dividing the average number of damaged leaflets by pest by the total number of leaflets examined and then multiplying by one hundred. Bakry and Abdel-Baky (2023) used this technique. An Excel spreadsheet was used to categorize the data to generate statistical analysis and visualizations. An ANOVA test was performed on the data that was gathered every two weeks.

Mean crowding (Lloyd, 1967):

The mean and variance of the number of individuals in each analyzed date are represented by and S2 in this equation, respectively.

$$M* = \bar{x} + \frac{s^2}{\bar{x} + 1}$$

Invasion progression (IP):

The annual growth of FDS outbreaks became evident as an outbreak developed. According to Bakry *et al.* (2024), the data was computed using the following formula after normalizing the population occurrence distribution curve.

IP = {(2 × present numbers) + past numbers + the upcoming projections}/4.

Quotient of change (QC):

By dividing the average estimates on the current examination date by the number of individuals on the past examination date, the quotient of change was calculated to assess the degree of variance in population counts during half-monthly examinations. Bakry and Fathipour's (2023) study served as the basis for this estimate.

Relative probability of occurrence (*RPO*):

RPO = (m / M)

The number of individuals in each examined time is denoted by m, and the maximum value of individuals registered in all analyzed sample dates is M in this equation (Ghaedi *et al*., 2020).

The polynomial relationships between *F. phoenicis* estimate and mean crowding, the progression of invasion, relative probability of occurrence, and damaged palm leaflets%:

To evaluate the nonlinear relationships between *F. phoenicis* estimates (independent variable) and the mean crowding, the progression of invasion, the relative probability of occurrence, and the percentages of damaged leaflets are represented as dependent variables. Bakry and Abdel-Baky (2023 and 2024) explain these associations using this formula.

2- Influences of the climatic factors on *F. phoenicis* counts infesting date palm trees:

The environmental parameters for the Kom Omboo region, Aswan governorate, were obtained by the Central Laboratory for Agricultural Climate, Agricultural Research Center, Ministry of Agriculture, Giza, Egypt, for two years (2022/2023 and 2023/2024). These parameters comprised solar radiation, mean relative humidity percentages and the highest and lowest temperatures. To determine the daily averages of *F. phoenicis* estimations over fourteen days, average daily measurements of these parameters were calculated. MSTAT-C was used to perform various regression and correlation studies (Freed, 1991) to determine associations between the data (Fisher, 1950). The data that was gathered was calculated, illustrated, and shown using Microsoft Excel 2007. Plotting of Pearson's simple correlation values between different parameters was done using R program (R Core Team, 2019).

3. Principal component analysis:

Data dimensionality is reduced using a multivariate analytic technique known as principal component analysis (PCA). According to Grane and Jach (2014), this reduction facilitates the visualization of the data in fewer dimensions and aids in the establishment of connections between variables. Using R software and Principal Component Analysis (PCA), a scatterplot was created to illustrate the multidimensionality of meteorological factors in *F. phoenicis* estimations on date palm leaflets (R Core Team, 2019).

RESULTS AND DISCUSSION

1. Population studies of *F. phoenicis* on date palm trees:

Population ecology:

For two years (2022/2023 and 2023/2024), date palm leaves attacked with *F. phoenicis*, as shown in Fig. (1), were found every half-monthly in the El-Bayyarah region, Kom Omboo district, Aswan governorate. Furthermore, the half-monthly average values of *F. phoenicis* population estimates, damage, and climatic conditions during the course of the two-year research are shown in Tables (1 and 2) and Figs. (2 and 3). The numbers of *F. phoenicis* nymphs and females fluctuated in quite similar ways. The seasonal activity, which was calculated by averaging the number of nymphs and females per leaf during the sample dates, should thus be included.

A) *F. phoenicis* abundance:

Over 2022/2023 year:

According to the findings, the average number of *F. phoenicis* nymphs and females per leaf during 2022/2023 was 42.45 ± 1.75 and 42.45 ± 1.75 individuals, respectively (Table 1). The periods in mid-April, mid-June, early October, and mid-November were the annual abundance peaks of nymphs, with numbers of 40.84 ± 3.00, 59.35 ± 4.07, 67.11 ± 6.74, and 75.48 ± 5.96 individuals per leaf, respectively. However the number of nymphs decreased in mid-February (Table 1 and Fig. 2).

In mid-April, mid-June, early October, and mid-November, the total live numbers (nymphs + females) per leaf, which displayed four maximum values every year, were 73.85 ± 6.29, 95.85 ± 7.65, 117.90 ± 11.85, and 138.22 ± 12.23 individuals per leaf, respectively. However, as Table (1) and Fig. (2) demonstrate, the overall number of live individuals declined around the middle of March.

In the 2022–2023 year, the results showed statistically significant variations in the number of nymphs, females, and total live individuals evaluated at different assessment dates (Table 1). The percentages of the coefficient of variance were 6.94, 7.68, and 6.40%, while the L.S.D. values were 4.17, 3.52, and 6.77, respectively.

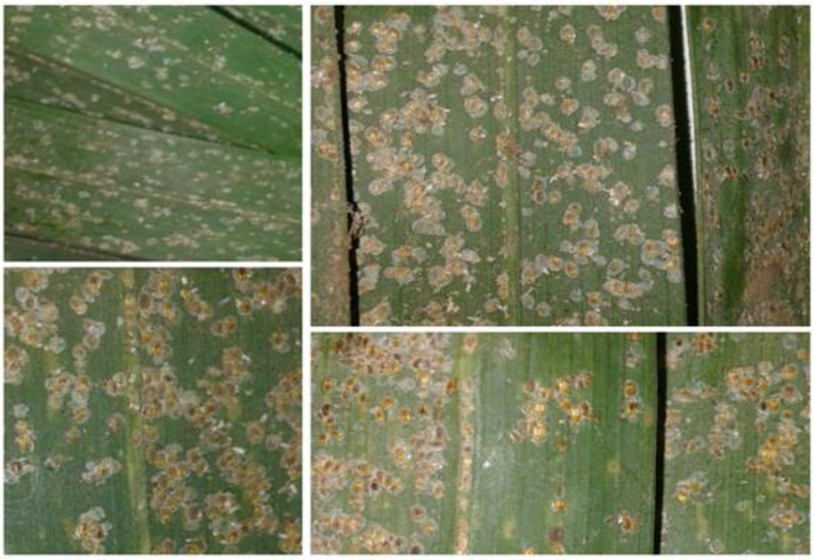

Fig. 1. Pictures showing signs of infestation by the *F. phoenicis* on date palm leaflets, photographed by Dr. Moustafa M.S. Bakry, September 2022.

Table 1. Half-monthly estimations of *F. phoenicis* counts, percentages of damaged palm leaflets, mean crowding, the progression of invasion on date palm leaflets and associated climatic variables over 2022/2023 year.

Sampling date		Nymphs	Females	No. of individuals per leaf	Mean crowding intensity	Progress of invasion	Quotient of change	RPO	% Damaged leaflets	Max. temp .°C	Min. temp. °C	% R.H.	Solar radiation
Mar., 2022	1	18.82 ± 2.04	22.03 ± 2.21	40.85 ± 4.24	41.62	33.92	------	0.30	65.00 ± 3.68	24.24	10.41	43.43	18.65
	15	26.58 ± 1.27	27.40 ± 2.74	53.98 ± 3.96	53.14	53.17	1.32	0.39	69.38 ± 6.80	29.14	12.82	31.58	21.78
Apr	1	31.25 ± 2.82	32.61 ± 3.28	63.86 ± 6.07	62.99	63.89	1.18	0.46	78.13 ± 5.44	29.54	14.73	34.03	22.60
	15	40.84 ± 3.00	33.01 ± 3.32	73.85 ± 6.29	72.91	66.53	1.16	0.53	79.38 ± 6.16	31.15	16.62	26.40	23.82
May	1	35.97 ± 4.05	18.60 ± 1.87	54.57 ± 5.92	54.32	55.98	0.74	0.39	76.88 ± 4.61	34.46	19.65	20.15	25.10
	15	24.58 ± 3.12	16.33 ± 1.64	40.91 ± 4.73	41.45	51.84	0.75	0.30	73.75 ± 5.82	37.06	21.43	18.98	26.61
Jun	1	35.66 ± 3.82	35.28 ± 3.55	70.94 ± 7.33	70.05	69.66	1.73	0.51	76.88 ± 3.13	39.45	24.64	19.21	25.27
	15	59.35 ± 4.07	36.50 ± 3.67	95.85 ± 7.65	94.93	85.50	1.35	0.69	82.50 ± 3.39	41.70	25.83	18.08	26.51
Jul	1	53.53 ± 3.97	25.85 ± 2.60	79.37 ± 6.54	78.42	79.50	0.83	0.57	79.38 ± 2.37	40.88	25.59	20.54	25.05
	15	44.47 ± 2.72	18.93 ± 1.90	63.40 ± 4.59	63.25	65.81	0.80	0.46	80.00 ± 2.04	40.45	26.51	20.78	24.75
Aug.	1	37.48 ± 2.89	19.60 ± 1.97	57.08 ± 4.85	58.66	59.49	0.90	0.41	85.63 ± 2.58	41.95	28.05	21.06	24.29
	15	31.05 ± 2.28	29.36 ± 2.95	60.42 ± 5.21	59.62	58.71	1.06	0.44	89.38 ± 4.13	42.19	27.61	21.90	24.39
Sept.	1	31.89 ± 4.47	25.03 ± 2.19	56.91 ± 6.64	56.13	65.34	0.94	0.41	95.00 ± 2.70	40.24	26.48	22.79	22.91
	15	45.77 ± 6.58	41.33 ± 4.15	87.10 ± 10.69	86.17	87.25	1.53	0.63	99.38 ± 0.63	42.14	27.55	24.83	22.47
Oct.	1	67.11 ± 6.74	50.79 ± 5.11	117.90 ± 11.85	117.44	103.24	1.35	0.85	100.00± 0.00	41.08	25.65	26.78	21.60
	15	63.32 ± 5.59	26.74 ± 2.69	90.06 ± 8.28	90.82	101.41	0.76	0.65	94.38 ± 2.58	39.36	24.48	26.93	19.61
Nov	1	52.94 ± 3.85	54.68 ± 5.50	107.62 ± 9.33	106.73	110.88	1.19	0.78	91.25 ± 1.61	36.16	21.01	28.29	18.09
	15	75.48 ± 5.96	62.75 ± 6.31	138.22 ± 12.23	137.31	123.92	1.28	1.00	98.13 ± 1.20	28.79	16.66	35.33	14.79
Dec	1	66.78 ± 4.25	44.83 ± 4.51	111.61 ± 8.72	110.67	113.93	0.81	0.81	94.38 ± 1.57	26.16	12.36	37.67	14.68
	15	52.77 ± 3.54	41.49 ± 4.17	94.26 ± 7.69	94.04	94.82	0.84	0.68	86.25 ± 3.15	26.87	11.51	40.43	14.75
Jan, 2023	1	41.45 ± 2.78	37.70 ± 3.79	79.16 ± 6.54	79.93	80.92	0.84	0.57	81.25 ± 3.15	25.29	11.37	41.81	13.89
	15	36.99 ± 3.64	34.11 ± 3.43	71.10 ± 7.05	70.27	68.66	0.90	0.51	74.38 ± 3.29	19.34	6.56	50.70	13.59
Feb	1	28.07 ± 2.76	25.21 ± 2.53	53.28 ± 5.29	52.50	52.93	0.75	0.39	63.13 ± 0.63	21.36	8.16	48.18	14.79
	15	16.54 ± 1.73	17.54 ± 1.76	34.08 ± 3.49	33.25	30.36	0.64	0.25	48.13 ± 1.88	23.33	8.20	46.58	17.22
General average		42.45 ± 1.75	32.40 ± 1.38	74.85 ± 2.94	74.44 ± 5.34	74.07 ± 5.01	1.03 ± 0.06	0.54 ± 0.04	81.74 ± 1.42	33.43	18.91	30.27	20.72
C.V.%		6.94	7.68	6.40					8.23				
F-value		117.88	97.29	120.68					14.21				
L.S.D. at 0.05 level		4.17**	3.52**	6.77**					9.51*				

Explanations: S.E. refers to standard error; C.V.= Coefficient of variance, F-value = analysis of variance; L.S.D = Least significant differences; %R.H. = The relative humidity percentage; * refers to Significant at $P \leq 0.05$; ** refers to Significant at $P \leq 0.01$.

Table 2. Half-monthly estimations of *F. phoenicis* counts, percentages of damaged palm leaflets, mean crowding, the progression of invasion on date palm leaflets and associated climatic variables over 2023/2024 year.

Sampling date		Nymphs	Females	No. of individuals per leaf	Mean crowding intensity	Progress of invasion	Quotient of change	RPO	% Damaged leaflets	Max. temp. °C	Min. temp.° C	% R.H.	Solar radiation
Mar., 2023	1	32.45 ± 3.48	24.06 ± 2.42	56.51 ± 5.89	57.96	46.37	------	0.39	66.25 ± 4.62	25.44	11.41	30.08	17.90
	15	38.69 ± 1.92	33.77 ± 3.38	72.46 ± 5.24	71.62	71.08	1.28	0.50	68.13 ± 7.39	26.72	10.80	28.42	20.91
Apr	1	40.46 ± 3.65	42.41 ± 4.26	82.87 ± 7.88	82.02	76.07	1.14	0.58	76.88 ± 6.64	28.24	14.45	30.63	21.70
	15	36.49 ± 2.68	29.59 ± 2.97	66.07 ± 5.63	65.16	66.62	0.80	0.46	80.63 ± 7.24	29.62	15.53	23.76	22.87
May	1	33.86 ± 3.82	17.58 ± 1.77	51.44 ± 5.58	51.54	57.41	0.78	0.36	75.63 ± 5.72	33.19	17.13	18.13	24.10
	15	36.40 ± 4.62	24.28 ± 2.44	60.68 ± 7.01	61.49	63.80	1.18	0.42	75.00 ± 5.63	34.89	19.37	17.08	25.55
Jun	1	38.99 ± 4.19	43.43 ± 4.36	82.42 ± 8.51	81.54	73.07	1.36	0.57	73.75 ± 4.84	40.33	23.22	19.21	26.33
	15	37.29 ± 2.57	29.46 ± 2.96	66.75 ± 5.47	65.91	67.67	0.81	0.46	80.63 ± 4.25	43.13	26.85	18.08	27.62
Jul	1	33.58 ± 2.50	21.19 ± 2.13	54.77 ± 4.62	53.86	61.01	0.82	0.38	81.25 ± 3.15	43.40	25.73	20.54	26.09
	15	40.13 ± 2.41	27.63 ± 2.78	67.75 ± 5.14	67.82	70.96	1.24	0.47	79.38 ± 2.58	44.30	26.04	20.78	25.78
Aug.	1	55.39 ± 4.14	38.17 ± 3.84	93.56 ± 7.95	95.21	91.51	1.38	0.65	85.00 ± 2.70	42.13	25.19	21.06	25.30
	15	58.37 ± 4.22	52.81 ± 5.31	111.19 ± 9.49	110.33	109.15	1.19	0.77	93.13 ± 4.00	41.27	26.18	21.90	25.40
Sept.	1	64.44 ± 8.98	56.25 ± 4.91	120.68 ± 13.86	119.82	116.42	1.09	0.84	96.25 ± 2.98	40.50	25.33	22.79	23.86
	15	59.68 ± 9.26	53.46 ± 5.80	113.14 ± 15.01	112.21	111.09	0.94	0.79	98.75 ± 0.72	39.42	25.38	24.83	23.40
Oct.	1	44.79 ± 4.50	52.59 ± 5.29	97.39 ± 9.79	97.24	97.32	0.86	0.68	99.38 ± 0.63	39.53	23.63	26.78	22.50
	15	42.41 ± 3.61	38.94 ± 3.91	81.36 ± 7.52	81.91	93.75	0.84	0.57	95.63 ± 2.31	35.05	18.66	26.93	20.42
Nov	1	75.59 ± 5.75	39.31 ± 3.95	114.90 ± 9.69	113.99	113.70	1.41	0.80	92.50 ± 2.70	39.47	22.17	28.29	18.84
	15	84.80 ± 5.92	58.86 ± 5.29	143.66 ± 11.80	142.73	126.46	1.25	1.00	99.38 ± 0.63	34.65	17.85	35.33	15.41
Dec	1	49.33 ± 2.83	54.31 ± 5.46	103.64 ± 8.23	102.69	107.51	0.72	0.72	95.63 ± 2.13	33.27	16.93	37.67	15.29
	15	41.94 ± 2.46	37.15 ± 3.73	79.09 ± 6.16	78.93	83.99	0.76	0.55	87.50 ± 2.50	26.93	11.10	40.43	15.37
Jan, 2024	1	43.13 ± 2.90	31.02 ± 3.12	74.15 ± 6.00	74.82	68.67	0.94	0.52	80.00 ± 3.54	26.50	9.39	41.81	14.47
	15	26.43 ± 2.60	20.87 ± 2.10	47.30 ± 4.69	46.54	51.71	0.64	0.33	73.13 ± 3.44	23.18	7.73	50.70	14.15
Feb	1	20.63 ± 2.03	17.48 ± 1.76	38.10 ± 3.78	37.40	39.31	0.81	0.27	61.25 ± 2.17	24.46	8.65	48.18	15.41
	15	18.50 ± 1.95	15.23 ± 1.53	33.73 ± 3.48	32.89	26.39	0.89	0.23	46.25 ± 3.31	27.90	13.20	46.58	17.93
General average		43.91 ± 1.77	35.83 ± 1.53	79.73 ± 3.15	79.40 ± 5.68	78.79±5.40	1.00 ± 0.05	0.56 ± 0.04	81.72 ±1.53	34.31	18.41	29.16	21.11
C.V.%		9.58	8.46	8.29					9.56				
F-value		56.87	81.03	71.61					11.84				
L.S.D. at 0.05 level		5.95**	4.28**	9.35**					11.05**				

Explanations: S.E. refers to standard error; C.V.= Coefficient of variance, F-value = analysis of variance; L.S.D = Least significant differences; %R.H. = The relative humidity percentage; * refers to Significant at $P \leq 0.05$; ** refers to Significant at $P \leq 0.01$.

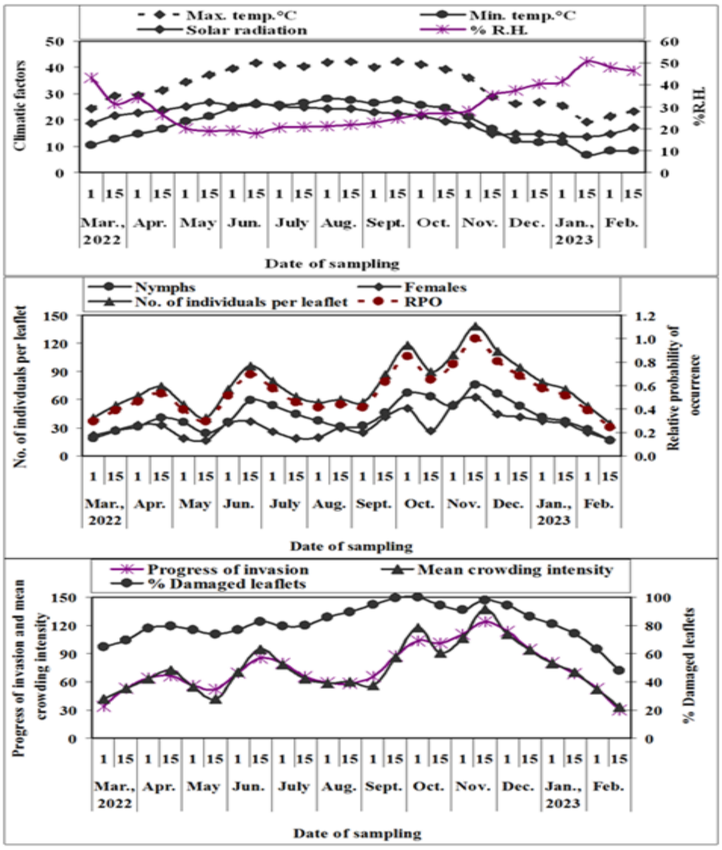

Fig. 2. Half-monthly estimations of *F. phoenicis* counts, percentages of damaged palm leaflets, mean crowding, the progression of invasion on date palm leaflets and associated climatic variables over 2022/2023 year.

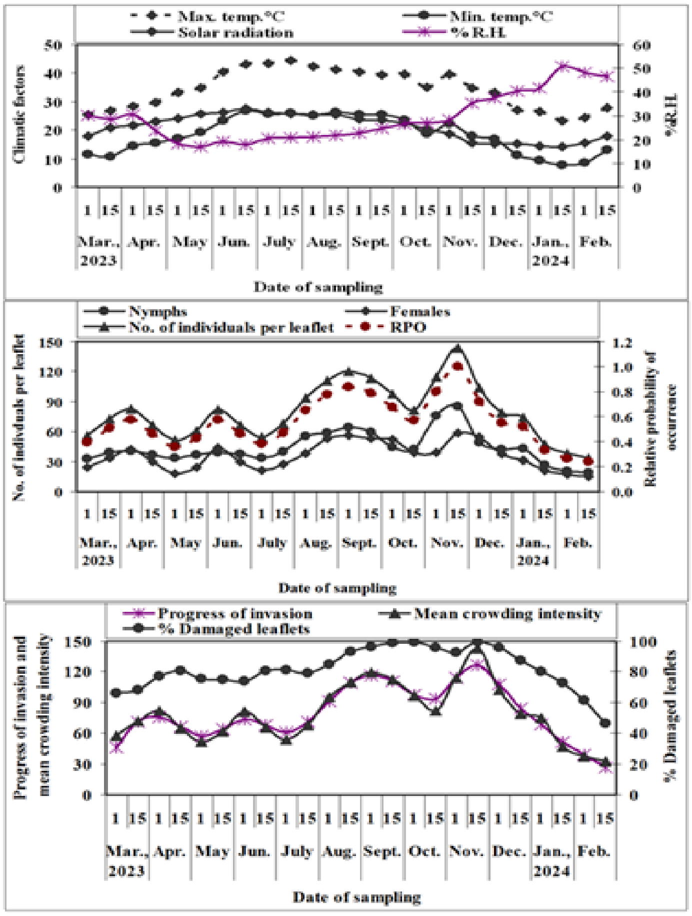

Fig. 3. Half-monthly estimations of *F. phoenicis* counts, percentages of damaged palm leaflets, mean crowding, the progression of invasion on date palm leaflets and associated climatic variables over 2023/2024 year.

Over 2023/2024 year:

The average estimates of *F. phoenicis* females and nymphs per leaf in 2023/2024 were 35.83 ± 1.53 and 43.91 ± 1.77, respectively, as shown in Table (2). The four annual occurrence peaks of nymphs were observed in early April, early June, early September, and mid-November, with 40.46 ± 3.65, 38.99 ± 4.19, 64.44 ± 8.98, and 84.80 ± 5.92 individuals per leaf, respectively. However, as seen in Tables (2) and Fig. (3), the number of nymphs declined in mid-February.

In early April, early June, early September, and mid-November, adult females exhibited four annual maximums of abundance, with an average of 42.41 ± 4.26, 43.43 ± 4.36, 56.25 ± 4.91, and 58.86 ± 5.29 individuals per leaf. However, February showed a decline in the number of females (Table 2 and Fig. 3).

In mid-April, mid-June, early October, and mid-November, the total live numbers (nymphs + females), which displayed four maximum values every year, were 82.87 ± 7.88, 82.42 ± 8.51, 120.68 ± 13.86, and 143.66 ± 11.80 individuals per leaf, respectively. However, as Table (2) and Fig. (3) demonstrate, the overall number of live individuals declined in February.

In the 2023–2024 year, the findings revealed statistically significant changes in the number of nymphs, females, and total live individuals evaluated at different examination dates (Table 1). The percentages of the coefficient of variance were 9.58, 8.46, and 8.29%, but the L.S.D. values were 5.95, 4.28, and 9.35, respectively.

The results revealed that the average total number of *F. phoenicis* individuals on date palm leaflets was lower in the first year (2022/2023) than in the second year (2023/2024).

The average number of *F. phoenicis* per leaflet throughout the two years was calculated to be 74.85 ± 2.94 and 79.73 ± 3.15 individuals, respectively. In comparison to 2022–2023, the development of *F. phoenicis* estimates increased by almost 1.07 times in 2023–2024.

In addition, statistical analysis of the data revealed a significant difference in the number of nymphs, females, and total individuals living between the two years (CV values were 8.35, 8.10, and 7.43%, and LSD values were 1.40, 0.80, and 1.66), respectively.

b) Percentage of damaged palm leaflets:

The percentages of damage to palm leaflets by pests recorded four peaks of activity, reaching 79.38 ± 6.16, 82.50 ± 3.39, 100.00 ± 0.00, and 98.13 ± 1.20% in mid-April, mid-June, early October, and mid-November, respectively. In both years, the lowest percentage of damaged leaflets was observed in mid-February.

There was a significant difference in the percentages of damaged leaflets (LSD values were 9.51 and 11.05) throughout the two years, and the C.V.% values were 8.23 and 9.56%, respectively (Tables 1 and 2).

Data in Tables (1 and 2) showed that the percentage of leaflets damaged in both years was somewhat similar, being 81.74 ± 1.42 and 81.72 ± 1.53%, respectively. Consequently, when comparing the two years, statistical analysis showed no significant differences between the percentages of damaged leaflets.

The variations in the seasonal ecology of *F. phoenicis* that have been observed by several authors at different places are interesting to observe. The numerous ecological factors influencing *F. phoenicis* populations are demonstrated by these findings. Elwan *et al.* (2011) in the Giza governorate, Egypt, mentioned that there are three yearly maxima for *F. phoenicis* on date palm. Radwan (2012), in Qalubyia Governorate, Egypt, it was reported that *F. phoenicis* estimates (nymphal and adult stages) on date palms had two times of seasonal activity annually. El-Zoghby (2015) in Qalubyia Governorate, Egypt, reported that *F. phoenicis* was observed on date palm trees throughout the year, with three peaks annually. Youssef *et al.* (2015) noted that nymphal and adult stages have three peaks of activity every year, those that emerged in early June, in August/September, and in October/November. El-Shafei and Attia (2023) in Giza, Egypt, found that *F. phoenicis* population density registered three periods of activity every year.

Mean crowding and invasion progression of *F. phoenicis*:

The mean invasion trend and crowding of *F. phoenicis* had four active times throughout the two years. As shown in Tables (1 and 2) and depicted in Figs. (2 and 3), these times were noted in early April, early June, early September, and mid-November in 2022/2023, and mid-April, mid-June, early October, and mid-November in 2023/2024.

On date palm leaflets, the average number of *F. phoenicis* individuals was larger in the second year (79.40 ± 5.68) than in the first (74.44 ± 5.34). Compared to 2022/2023, the increase in 2023/2024 was roughly 1.07 times, as shown in Tables (1 and 2).

In this context, the annual number of *F. phoenicis* invasions multiplied, from 74.07 ± 5.01 individuals in 2022/2023 to 78.79 ± 5.40 individuals in 2023/2024. Approximately 1.06 times as much invasion development occurred in the second year as in the first (Tables 1 and 2).

Quotient of change (QC):

Half-monthly monitoring intervals were used to compute the quotient of change (Q.C.) in *F. phoenicis* estimations on date palm leaflets (Tables 1 and 2).

The period that displays the variation in insect activity throughout the year is represented by this model. Q.C. > 1 indicates a time of increased activity, < 1 indicates a period of decreased activity, and equal to 1 indicates no change in activity (Bakry and Abdel-Baky 2023).

The half-monthly change in the total living population (quotient of change: Q.C.) during the study period revealed that the favorable times occurred in mid-March, early April, mid-May, early June, and mid-July and continued until early September and early and mid-November in 2022/2023, where rates of change were recorded above one. Similarly, in 2023/2024, favorable times were mid-March through mid-April, early and mid-June, mid-August, mid-September, early October, and early and mid-November, where the variance ratios were above one.

Relative probability of occurrence (*RPO*):

According to the relative probability of occurrence, the degree of probability increases with a value's proximity to one and decreases with its distance from one. Relative likelihood of occurrence had four maximum periods throughout the year, displayed in early April, early June, early September, and mid-November in 2022/2023 and in mid-April, mid-June, early October, and mid-November in 2023/2024, according to data shown in Tables (1 and 2) and Figs. (1 and 2).

The relative probabilities of occurrence values of the pest were 0.53, 0.69, 0.85, and 1.00 in the first year and 0.58, 0.57, 0.84, and 1.00 through the second year, respectively. In this context, the mean values of *F. phoenicis* relative probability of occurrence on date palm leaflets were higher in the second year, being (0.54 ± 0.04), as compared to the first year (0.56 ± 0.04). The increased by about 1.02 times in 2023-2024 compared to 2022-2023, as shown in Tables (1 and 2) and illustrated in Figs. (1 and 2).

In general, the percentages of damaged leaflets, mean crowding intensity, invasion progress, quotient of change, and relative probability of occurrence using a half-monthly investigation clearly showed that climatic parameters were more conducive to *F. phoenicis* growth and activity on date palm leaflets during periods of increased *F. phoenicis* counts, as presented in Tables (1 and 2).

The polynomial relationships between *F. phoenicis* estimates, percentages of damaged palm leaflets, mean crowding, the progression of invasion, and relative probability of occurrence:

Fig. (4) exhibits the nonlinear relationships between *F. phoenicis* estimates (as an independent variable) and the dependent variables: mean crowding, the progression of invasion, the relative probability of occurrence, and the percentages of damaged leaflets. Statistical mathematical relationships are shown in Table (3).

Table 3. The polynomial relationships between *F. phoenicis* estimates, percentages of damaged palm leaflets, mean crowding, the progression of invasion, and relative probability of occurrence:

Variables	Year	Regression equation	R^2	E.V. %
F. phoenicis estimates versus percentages of damaged leaflets	2022/2023	$Y = 8E\text{-}05X^3 - 0.024X^2 + 2.536X - 4.5691$	0.63	63.40
	2023/2024	$Y = 3E\text{-}05X^3 - 0.0115X^2 + 1.6314X + 11.694$	0.77	76.77
F. phoenicis estimates versus mean crowding	2022/2023	$Y = -2E\text{-}06X^3 + 0.0005X^2 + 0.9541X + 1.1318$	1.00	99.93
	2023/2024	$Y = 5E\text{-}06X^3 - 0.0016X^2 + 1.1508X - 4.3069$	1.00	99.93
F. phoenicis estimates versus progression of invasion	2022/2023	$Y = -3E\text{-}05X^3 + 0.0039X^2 + 0.8469X + 1.6817$	0.95	94.82
	2023/2024	$Y = -3E\text{-}05X^3 + 0.0041X^2 + 0.8566X + 0.142$	0.96	95.93
F. phoenicis estimates versus relative probability of occurrence	2022/2023	$Y = 1E\text{-}19X^3 - 2E\text{-}17X^2 + 0.0072X - 8E\text{-}14$	1.00	100.00
	2023/2024	$Y = 8E\text{-}20X^3 - 2E\text{-}17X^2 + 0.007X - 7E\text{-}14$	1.00	100.00

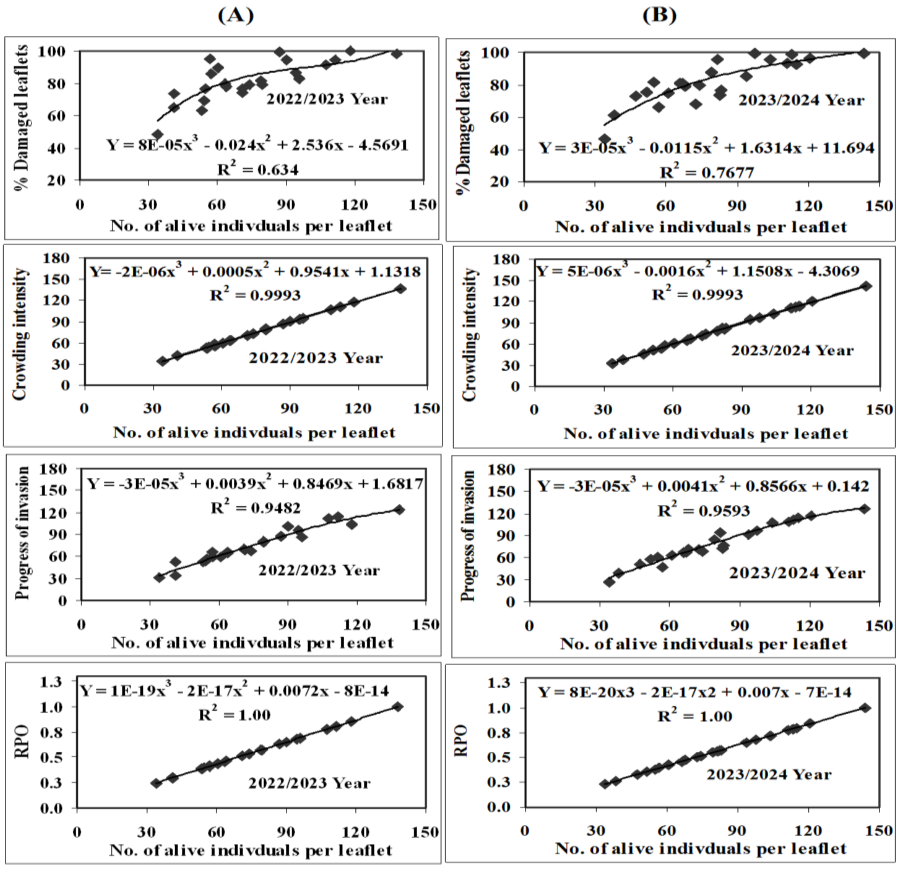

Fig. 4. Estimation of the relationships between *F. phoenicis* estimates, percentages of damaged palm leaflets, mean crowding, the progression of invasion, and relative probability of occurrence (RPO) over the two years [2022/2023 (A) and 2023/2024 (B)].

In both years, all mathematical relationships that were examined were extremely important(Table 3and shown in Fig. 4).

The percentages of explained variation (E.V.) between the percentages of damaged leaflets and the *F. phoenicis* estimations for the two years were 76.77% and 63.40%, respectively.

In this case, there was a 99.93% correlation between the mean annual crowding and *F. phoenicis* numbers. Additionally, in both years, the E.V.% between the number of *F. phoenicis* and the invasion's progress was 94.82% and 95.93%, respectively. Furthermore, the E.V.% between *F.*

phoenicis populations and relative chance of occurrence was 100% every year, as shown in Table (3) and Fig. (4).

2- Impacts of the climatic parameters on *F. phoenicis* counts infesting date palm leaflets:

Effect of daily mean maximum temperature:

This variable and the *F. phoenicis* count in 2022/2023 had a positive simple correlation and were insignificant (r-value of +0.13); however, in 2023/2024 there was a substantial positive simple correlation (r-value of +0.45), as shown in Table (4) and Figure (5). The regression coefficient indicates that an increase in population of 0.46 and 1.8 individuals per leaflet over two years, respectively, would be the result of a 1°C rise in the mean daily maximum temperature (Table 4).

Table 4. Different correlation and regression analyses to evaluate the relationship between climatic variables and total *F. Phoenicis* counts during the two years (2022/2023 and 2023/2024).

Year	Tested Variables	Simple correlation and regression values				Partial correlation and regression values				Efficiency %	Rank	Analysis variance			
		r	b	S.E	t	P. cor.	P. reg.	S.E	t			F values	MR	R^2	E.V.%
2022/2023	Max. temp	0.13	0.46	0.73	0.64	0.14	2.80	4.65	0.60	0.76	3	7.29 **	0.78	0.61	60.56
	Min. temp	0.16	0.57	0.76	0.76	-0.11	-2.07	4.48	-0.46	0.44	4				
	R.H.%	-0.04	-0.11	0.54	-0.20	-0.49	-3.41	1.38	-2.47 *	12.64	2				
	Solar radiation	-0.31	-1.82	1.20	-1.52	-0.75	-10.14	2.05	-4.96 **	51.03	1				
2023/2024	Max. temp	0.45	1.84	0.77	2.39 *	-0.40	-5.86	3.07	-1.91	5.40	4	11.98 **	0.85	0.72	71.61
	Min. temp)	0.47	2.03	0.82	2.49 *	0.59	11.25	3.53	3.19 **	15.14	2				
	R.H.%	-0.24	-0.65	0.57	-1.15	-0.57	-2.57	0.84	-3.06 **	13.95	3				
	Solar radiation	0.04	0.24	1.35	0.17	-0.78	-11.30	2.06	-5.47 **	44.72	1				

r = Simple correlation; P. cor. = Partial correlation; MR = Multiple correlation; R^2= Coefficient of determination; b = Simple regression; P. reg.= Partial regression; E.V% = Explained variance; S.E = Standard error * Significant at P ≤ 0.05; ** Highly significant at P ≤ 0.01

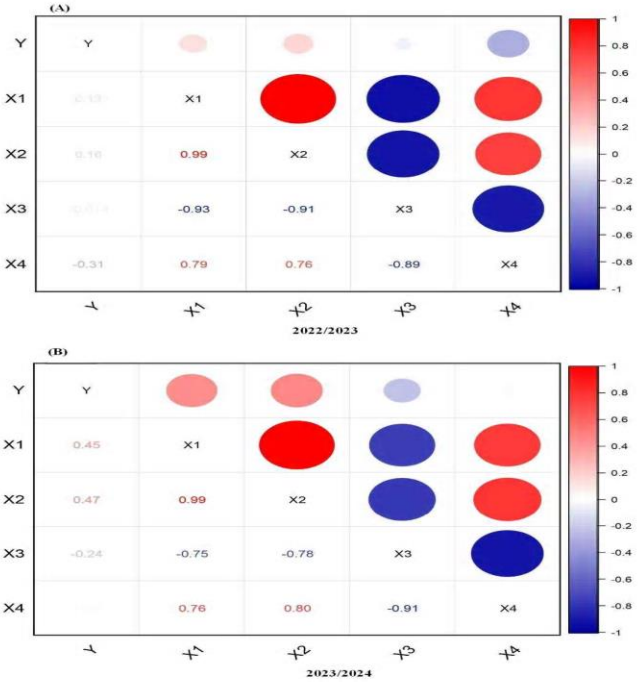

Fig. 5. Heat map depicting the correlation between *F. phoenicis* estimates per date palm leaflet and climatic parameters over the two years [2022/2023 (A) and 2023/2024 (B)].

In 2022/2023, there was an insignificant positive correlation (P. reg. value of 2.80) between the daily mean maximum temperature and the total population of *F. phoenicis*; in 2023/2024, there was an insignificant negative correlation (P. reg. value of -5.86). Concurrently, Table (4) shows that the t-test results for the two years were 0.60 and -1.91, and the partial correlation (P. cor.) values were +0.14 and -0.40, respectively.

The data collected showed that the daily mean maximum temperature in 2022/2023 is within the ideal range of *F. phoenicis* numbers; however, in 2023/2024 it is consistently within the ideal range. The maximum temperature was the least effective variable for change throughout the two years, with only 0.76% and 5.40% of the variance explained, respectively (Table 4).

Effect of daily mean minimum temperature:

Table (4) and Fig. (5) demonstrate that the simple correlation between the *F. phoenicis* estimates and the daily mean lowest temperature in 2022/2023 was insignificantly positive (r value was +0.16), but in 2023/2024 it was significant and positive (r value was +0.47). The population increased by 0.57 and 2.03 individuals per leaflet for the two subsequent years, respectively, when the daily mean lowest temperature increased by 1˚C, according to the simple regression coefficient (Table 3).

The results of our partial regression analysis showed that mean daily minimum temperature had a non-significant negative effect (P. reg. value was -2.07) during 2022/2023 and a highly significant positive effect (P. reg. value was +11.25) on *F. phoenicis* numbers in 2023/2024. In the present study, the t-test results were -0.46 and +3.19, respectively, while the partial correlation values were -0.11 and +0.59 (Table 4).

The results showed that in 2022/2023 the daily mean lowest temperature was consistently within the optimal range of *F. phoenicis* activity, and in 2023/2024 it was completely below the optimal range of *F. phoenicis* abundance. Minimum temperature was the abiotic parameter that partially explained the change in the total *F. phoenicis* population, which varied by 0.44% and 15.14% in the two years, respectively (Table 4).

Effect of the mean relative humidity:

As shown by the data in Table (4) and Fig. (5), the relationship between relative humidity and the *F. phoenicis* estimates was weakly negative (r-values were -0.04 and -0.24) in two years, respectively. The simple regression coefficient showed that for each of the two years, a 1% rise in relative humidity would result in a 0.04 and 0.24 reduction in *F. phoenicis* estimates per date palm leaflet, respectively (Table 4).

The partial regression analysis revealed a significant negative relationship (P. reg. value of -3.41) between the daily mean relative humidity and the total population of *F. phoenicis* in 2022/2023, while a very significant negative relationship (P. reg. value of -2.57) was observed in 2023/2024. The T-test findings for the two years were -2.47 and -3.06, and the partial correlation (P. cor.) values were -0.49 and -0.57, respectively, according to Table (4).

The mean relative humidity was above the ideal range *for F. phoenicis* abundance in 2022/2023 and completely above the ideal range activity in 2023/2024. In this regard, the relative humidity accounted for 12.64% and 13.95% of the variation in the overall *F. phoenicis* population for the two years, respectively (Table 4).

Effect of the mean solar radiation:

The correlation between the estimations of *F. phoenicis* and solar radiation was insignificant and negative in 2022/2023 (r-value was -0.71) and slightly positive in 2023/2024 (r-value was +0.04), as seen in Table (4) and Fig. (5). According to Table (4), the regression coefficient showed that the counts would drop by 1.82 individuals per leaflet in 2022/2023 and increase by 0.24 individuals per leaflet in 2023/2024 for every 1 MJ/m² increase in solar radiation.

The partial regression method (P. reg.) values show that solar radiation had a highly significant and negative effect in both years (P. reg. values were -10.14 and -11.30). T-test values were -4.96 and -5.47 for each of the two years, while the partial correlation estimates were -0.75 and -0.78, respectively (Table 4). Every year, the amount of solar radiation was higher than the ideal range for *F. phoenicis* activity. The range in the *F. phoenicis* counts of 51.03 and 44.72% each year, respectively, was best explained by this parameter (Table 4).

The pooled impacts of climatic parameters on *F. phoenicis* counts:

The climatic variables on *F. phoenicis* counts were evaluated using the multiple linear regression technique as follows:

Over 2022/2023:

$$Y = 333.5^{*} + 2.80\,X_1 - 2.07X_2 - 3.41X_3^{*} - 10.14X_4^{**} \quad \text{Equation (1)}$$

F value = 7.29 MR= 0.78 E.V.= 60.56%**

Over 2023/2024:

$$Y = 386.78^{**} - 5.86\,X_1 + 11.25\,X_2^{**} - 2.57\,X_3^{**} - 11.30\,X_4^{**} \quad \text{Equation (2)}$$

F value = 11.98 MR= 0.85 E.V.= 71.61%**

Where,

X_1= daily mean maximum temperature; X_2= daily mean minimum temperature; X_3= daily mean relative humidity; X_4= daily mean solar radiation; MR=multiple correlation; E.V.= explained variance.

As demonstrated in Table (4) and equations (1 and 2), the cumulative impacts of these studied factors on *F. phoenicis* estimations over the two years were very significant and differed every year. The multiple correlation values were 0.78 and 0.85 throughout the two years, while the F-values were 7.29 and 11.98, respectively. The explained differences between these examined environmental characteristics on *F. phoenicis* estimations were 60.56% and 71.61% for both years, respectively, as shown in Table (4) and Equations (1 and 2).

Most scholars investigated a lot of studies to find out how *F. phoenicis* was impacted by temperature and relative humidity. These findings are consistent with those of Elwan *et al.* (2011), who found that the daily mean temperature and percentage R.H. had a significant impact on the annual field generations of *F. phoenicis* on date palm at the Giza Governorate. The combined impact of these weather factors may be attributed to the variations in the half-month counts of the nymph and adult populations, which ranged from 66.1-69% and 48.1-49.2% for the first generation (early summer generation); 65.4-74.0% and 63.8-78.4% for the second generation (late summer generation); and 60.9-77.4% and 48.6-63.5% for the third generation (autumn generation) over the two years, respectively. According to Youssef *et al.* (2015), the meteorological elements that were investigated (daily mean temperatures and percentage RH) had a substantial impact on the duration of seasonal activity for both nymphal and adult phases. In the first and second periods of activity, the cumulative influence of the investigated meteorological conditions on population activity varied from 71.2% to 63.4% and 59.9% to 69.7%, respectively, while in the third period for the two years, it ranged from 70.2% to 58.9%. Radwan (2012) demonstrated that daily mean maximum and minimum temperatures, as well as percentage R.H., had a substantial impact on the lengths of seasonal activity for *F. phoenicis* nymphs and adults. While the combined effect of these factors on adult activity ranged from 53.9% to 76.3% in the first period and 84.9% to 87.9% in the second period for the two years, the combined effect of these factors on nymphal activity ranged from 58.2% to 74.8% in the first period of activity and 66.9% to 74.8% in the second one, respectively. According to El-Zoghby (2015), the relative humidity and the daily mean minimum and maximum temperatures had a substantial impact on *F. phoenicis* activity. The cumulative effect of these variables resulted in variations in the population's half-monthly counts, which varied between 61.6 and 72.5% for nymphs and 59.4 and 66.7% for adults (the first and second years, respectively).

2- Principal component analysis (PCA):

For this investigation, principal components analysis produced two components (PC1 and PC2) with eigenvalues larger than one, which accounted for 96.02% and 93.40% of the total variance for the two years, respectively (Fig. 6). The daily mean maximum and lowest temperatures, relative humidity, and solar radiation were the environmental variables for PC1 and PC2. In both years, PC1 accounted for 72.81% and 72.76% of the variation, respectively, whereas PC2 explained 23.21% and 20.64% of the variance, respectively, as shown in Fig. (6).

The average of *F. phoenicis* estimates demonstrated a strong positive correlation with the highest and lowest temperatures in 2022–2023, with respect to the variable PC1, which had a high explanatory power. As well, *F. phoenicis* numbers and the highest and lowest temperatures and solar radiation in 2023–2034 are all positively correlated. In this context, there was a negative relationship between *F. phoenicis* counts and the independent variables, which are average relative humidity and solar radiation during 2022/2023, but only average relative humidity in 2023/2024, as shown in Fig. (6).

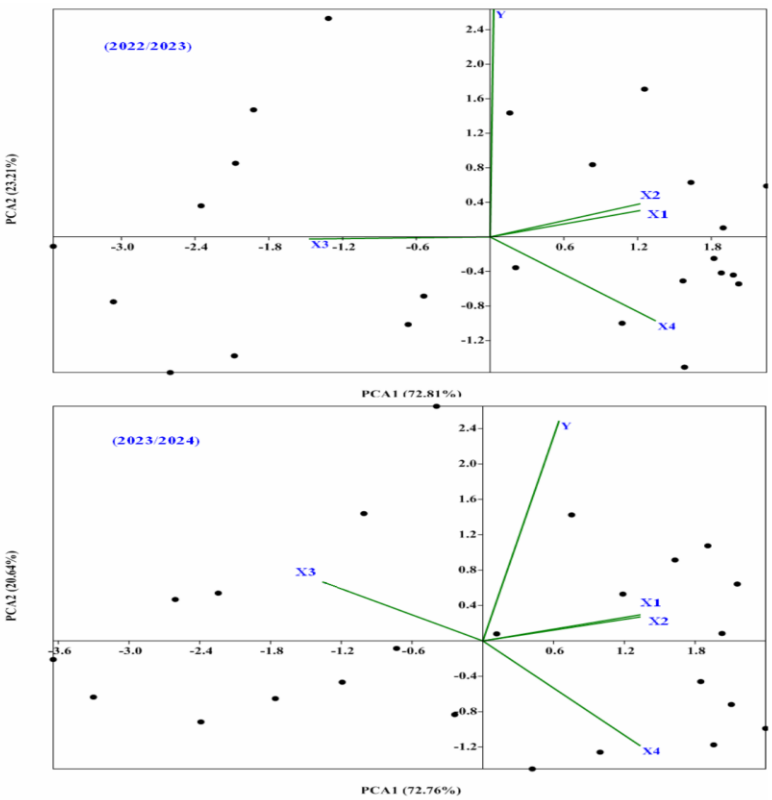

Fig. 6. Principal component analysis correlation-based biplot of climatic variables and *F. phoenicis* estimations over the two years.

RECOMMENDATIONS

The information gathered may be utilized to monitor insect populations, conduct scouting, and evaluate the impact of weather in the application of successful IPM strategies. However, to assess the activity and behavior of this pest and manage it, more research on the ecology of *F. phoenicis* on date palms in different Egyptian governorates is required. Growers and decision-makers to develop strategies for managing and controlling *F. phoenicis* and reducing damage to date palm plants can use the results mentioned above.

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تواجد مجموع حشرة فيورينيا النخيل القشرية *Fiorinia phoenicis* على أشجار نخيل البلح معتمداً على المتغيرات المناخية باستخدام تحليل الأنحدار والمكونات الرئيسية

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الملخص

يركز البحث على تقييم تأثير الظروف المناخية على تواجد تعداد حشرة فيورينيا النخيل القشرية *Fiorinia phoenicis*على أشجار نخيل البلح باستخدام تحليل الانحدار وطريقة المكونات الرئيسية. تم تنفيذ التجربة في مزرعة نخيل خاصة في منطقة البيارة، منطقة كوم أمبو، محافظة أسوان، جنوب مصر.أظهرت النتائج، أن حشرة فيورينيا النخيل القشرية تتواجد على وريقات أشجار نخيل البلح على مدار العام ولها أربع قمم لنشاط التعداد الكليّ للحشرة خلال العام والتي سُجِّلتْ فى منتصف أبريل، ومنتصف يونيو، وأوائل سبتمبر / أكتوبر، ومنتصف نوفمبر. وأوضحت نتائج الدراسة، أن تأثير العوامل المناخية وهي متوسطات (درجة الحرارة القصوى والدنيا اليومية ونسبة الرطوبة النسبية والاشعاع الشمسي) على التعداد الحشرى خلال العامين كان واضحا، وأن تأثير هذه العوامل يختلف من عام إلى أخر، وأظهر التحليل الإحصائي باستخدام طريقة الانحدار المتعدد، أن التأثير المشترك لجميع العوامل المناخية المختبرة على التعداد الكلى الحشرى بلغ (60.65، 71.61%) للعامين على التوالى. وأن الاشعاع الشمسي كان المتغير الأكثر فعالية للتغيرات فى التعداد الحشرى، بينما كانت درجة الحرارة الدنيا اليومية هى المتغير الأقل فعالية.وأيضا أظهرت النتائج، أن طريقة المكونات الرئيسية فسرت نسبة التباين للمكون الأول والثاني بنسبة 96.02 ، 93.40%، على التوالى. وأن متوسطات كلا من درجة الحرارة القصوى والدنيا اليومية ونسبة الرطوبة النسبية والاشعاع الشمسي هى العوامل البيئية للمكون الأول والثاني خلال العامين. وأوضح المكون الأول أعظم تباين (يفسر أكبر نسبة من هيكل التباينات للمتغيرات) بنسبة 72.81 ، 72.76% للعامين على التوالى.بينما نسبة التباين المفسر للمكون الثانى كانت23.21، 20.64% للعامين على التوالى.