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Temperature and Humidity Effects on Fruit Fly Abundance and Distribution: A Comparative Study

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ABSTRACT

Living organisms are affected by climate changes, which impact their reproduction or extinction. This study shows that when temperatures rise, a type of fly, Ceratitis capitata, increases, and its numbers decrease with the arrival of cold months. There is a positive relationship between temperature and the fly population, with a correlation coefficient of 0.13. On the other hand, as relative humidity increases, the relationship turns negative, with the population decreasing and a correlation coefficient of -0.01. In contrast, the species Bactrocera zonata and Bactrocera oleae increase with decreasing temperatures and decrease with increasing temperatures. The correlation type is strongly negative, at -0.67 and -0.46, respectively. Additionally, their populations increase with high humidity and decrease with low humidity, where the positive relationship is 0.27 and 0.13. By examining the climate variables, represented by temperature and relative humidity, in relation to the three fly species using the marginal probability function, it was found that Bactrocera zonata is best suited to the climate during this period.

تأثير درجة الحرارة والرطوبة على انتشار وتكاثر ذبابة الفاكهة: دراسة مقارنة

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الكلمات المفتاحية:
ذبابة الخوخ.
ذبابة الزيتون.
ذبابة البحر المتوسط.
تغير المناخ.
درجة الحرارة.
الرطوبة النسبية.

الملخص

تتأثر الكائنات الحية بالتغيرات المناخية، ويؤثر ذلك على تكاثرها أو انقراضها، وقد تبين في هذه الدراسة أنه عند ارتفاع درجات الحرارة يزداد نوع من الذباب وهو Ceratitis Capitata وهناك علاقة طردية بينهما ويقل مع دخول الأشهر الباردة بمعامل ارتباط 0.13، ومع زيادة الرطوبة النسبية تكون العلاقة سلبية مع هذا النوع يتناقص بمعامل ارتباط -0.01، بينما يحدث العكس مع كل نوع، ومن الأنواع Bactrocera Zonata وBactrocera Oleae التي تزداد بانخفاض درجات الحرارة وتقل بارتفاع درجات الحرارة، وكان نوع الارتباط سلبي قوي حوالي -0.67. -0.46 على التوالي، بينما تزداد كمياتها مع ارتفاع الرطوبة وتنخفض مع انخفاض الرطوبة، حيث تكون العلاقة الموجبة حوالي 0.27 و0.13، ومن خلال توضيح المتغيرات المناخية المتمثلة بدرجة الحرارة والرطوبة النسبية مع أنواع الذباب الثلاثة باستخدام دالة الاحتمالية الهامشية، تبين أن النوع Bactrocera Zonata هو المناسب للمناخ لهذه الفترة من السنة.

1. Introduction

Numerous factors, categorized according to the scale at which they have the greatest effects, influence the distribution of insects over time and space [1]. The Tephritidae family of fruit flies contains about 4,300 identified species spread over approximately 500 genera worldwide [2]. These species are common agricultural pests that infest a wide variety of fruits and vegetables, leading to significant financial losses [3]. According to [4], *Ceratitis capitata* is currently found in North Africa, the Mediterranean region, Europe, South and Central America, Australia, and Hawaii. Fruit fly species pose a threat to the

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biodiversity of various ecological and agricultural systems in the Mediterranean region. Notably, three species of fruit fly—*Bactrocera oleae* Rossi, *Bactrocera zonata* Saunders, and *Ceratitis capitata* Wiedemann (Diptera: Tephritidae)—are considered highly economically significant [5, 6, 7].

Any species in the Tephritidae family is a fruit fly, and they are among the most devastating pests in the world. Their larvae primarily consume fruit, particularly apple, guava, pear, grape, cherry, orange, avocado, and citrus fruits [8, 9, 10, 11]. The most substantial damage to fruit production and marketing is believed to be caused by *C. capitata* infestations. The olive fruit fly, *B. oleae*, is the most dangerous pest to olives globally, causing significant damage to olive production [7, 12, 13]. The peach fly, *B. zonata*, is considered one of the most dangerous insect pests, attacking various fruit trees, while the Mediterranean fruit fly, *C. capitata*, is one of the most economically significant pests, affecting all types of citrus fruits as well as the fruits of deciduous and stone trees [14]. Fruits and vegetables are just a few of its many hosts [15].

The population and attack rates of fruit fly species are influenced by meteorological elements such as temperature, humidity, and rainfall, which can vary depending on ecological conditions. These species can occur throughout the year and be found in a wide range of climate conditions [16]. Temperature and humidity are the two main variables that affect insect biology; the length of time that fruit flies develop is also a key factor [17]. Alongside the known changes in the global climate over the past few decades, there has been an increase in average worldwide temperatures [18].

Global climate change poses significant challenges to ecosystems and the environment, and even small changes to the main climate variables can significantly impact the population dynamics and spatial distribution of many harmful organisms, including fruit flies. These pests have a significant economic impact in areas where they reproduce year-round [19]. The effects of climate change on species distribution and the need for creative solutions to address increased invasion threats should also be considered [16].

2. Objectives

1. To examine the effect of climate factors on the diversity of fly species.
2. To review previous studies on the effect of climate and its impact on the biological diversity of fruit flies.

3. Study Area and Data

The study was conducted at the agricultural research station at the University of Tripoli, Libya, at latitude 32.846 and longitude 13.223. Traps were set for three types of flies (*Ceratitis capitata*, *Bactrocera zonata*, and *Bactrocera oleae*) from 1/6/2022 to 31/12/2022. Climate data for temperature (°C) and relative humidity (%) at the same location were obtained from the NASA website [20] for the same time period.

Figure.1: Study area

3.1. Distribution of flies types with temperature and humidity

The month of June is considered the beginning of the summer season and is characterized by a gradual rise in temperatures and a gradual decrease until the end of the year. By collecting samples of the types of flies from the beginning of month 6 to the end of month 12, Figure 2 shows that the species *Ceratitis capitata* increases in prevalence with an increase in temperature, and while the type The second type, *Bactrocera Zonata*, has a higher prevalence when temperatures decrease, while the third type, *Bactrocera Oleae*, which increases in prevalence with a decrease in temperatures, as shown in Figure (2, a). It is known that humidity begins to rise at the end of the summer and the beginning of the fall, and it has been shown Figure (2, b) shows the relative humidity with the spread of fly species. It is shown that with *Ceratitis Capitata* it decreases with an increase in relative humidity, and in contrast with *Bactrocera Zonata* its spread increases when the humidity is high, and similarly with the *Bactrocera Oleae* species it increases with high humidity.

Figure (3, a) shows the total average of the samples he collected for the flies and the total average of temperatures and relative humidity. It was shown that the largest reproductive number is *Bactrocera Zonata*, as the climate is suitable for it during this period, unlike *Ceratitis Capitata* and *Bactrocera Oleae*. Variation analysis was conducted for these three species. Which was shown to have a statistically significant relationship at the level of significance p<0.001, as in Figure (3, b).

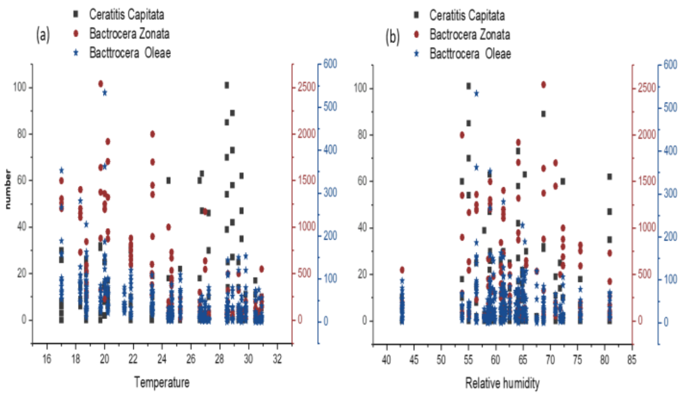

Figure 2: Distribution of types of flies with: (a) Temperature C^0 , (b) Relative humidity %, during the period from 6-12 months of 2022.

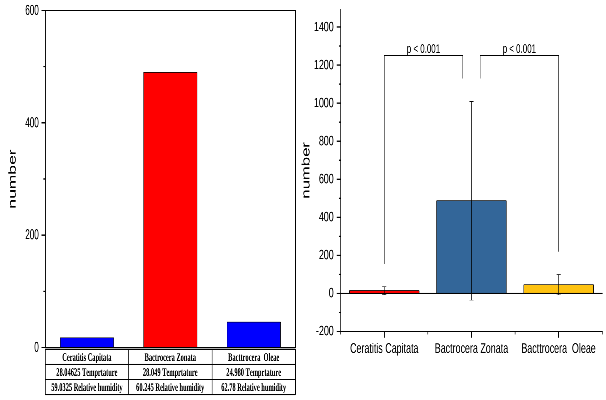

Figure 3: (a) Total average of fly species, Temperature, and Relative humidity, (b) Analysis of variance for the three fly species, during the period from 6-12 months of 2022.

4. Materials and Methods

Using the Pearson correlation between Relative humidity,Temprtature and the three types of flies) Ceratitis *Capitata*, *Bactrocera Zonata*, *Bacttrocera Oleae*).was taken coefficient of the following formula:

$$r=\frac{\sum(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{(x_i-\bar{x})^2(y_i-\bar{y})^2}}\text{--------------}(1)$$

The terms in that formula are:

n= the number of data points.

values of the x-variable in the data set (Relative humidity (%),Temprtature (C^0)), and values of the y-variable in the data set (three types of flies(*Ceratitis Capitata*, *Bactrocera Zonata*, *Bacttrocera Oleae*) (number)).

And the marginal distribution was used to determine the marginal probability density function for both the Relative humidity (%),Temprtature (C^0) (*X*) , and three types of flies) Ceratitis *Capitata*, *Bactrocera Zonata*, *Bacttrocera Oleae* (number) (*Y*), through the following formulas:

The marginal probability density function:

$$f(x,y), \{a \le x \le b, c \le y \le d\}\ ,\ \int_a^b \int_c^d f(x,y)\, dydx \text{ ------(2)}$$

Where $\{a \le x \le b\}\ ,\ \int_a^b f_X\,(x)dx$-------------------------------(3)

$$\{c \le y \le d\}\ ,\ \int_c^d f_Y\,(y)d \text{ ----------------------------(4)}$$

The probability density function of *X*, denoted by fX(*x*), is called the marginal probability density function of *X, and* the probability density function of *Y*, denoted by fY(*y*), is called the marginal probability density function of *Y)* Ramez.K ,2018) [21].

We have the following:

$$f_X\,(x) = \sum_y f_{X,Y}\,(x,y) \text{-----------------------------(5)}$$

$$f_Y\,(y) = \sum_x f_{X,Y}\,(x,y) \text{-----------------------------(6)}$$

For an ongoing condition:

$$f_X(x) = \int_{-\infty}^{\infty} f_{X,Y}(x,y)dy \text{-------------------------(7)}$$

$$f_Y(y) = \int_{-\infty}^{\infty} f_{X,Y}\,(x,y)d \text{--------------------------(8)}$$

5. Results and Discussion

Climate is an important indicator of the biological diversity of living organisms on the surface of the Earth, and this is what we see through the effect of temperature and relative humidity on different types of flies. It was found that the effect of temperature on the *Ceratitis Capitata* species increases and the correlation is positive about 0.13, while the *Bactrocera Zonata* species decreases with an increase in Temperatures have a strong negative correlation coefficient of about -0.67, and the species *Bactrocera Oleae* also decreases with temperatures and reaches a negative correlation coefficient of about -0.46, and this is reflected by an increase in temperature and a decrease in humidity, as the species *Ceratitis capitata is* affected by relative humidity with a negative correlation coefficient of about - 0.01, while the species *Bactrocera Zonata* and *Bactrocera Oleae* have a positive correlation coefficient with relative humidity of about 0.27 and 0.13, respectively. See Table 1.

Table 1: Pearson correlation coefficient for the three types of flies with Temperature and Relative humidity from the period 6-12 months of 2022

Correlation	Relative humidity	Temprtature
Ceratitis Capitata	-0.01	0.13
Bactrocera Zonata	0.27	-0.67
Bacttrocera Oleae	0.13	-0.46

Applying the marginal distribution was used to determine the marginal probability density function, for each of the relative humidity (%), temperature (C0), and three types of flies: *Ceratitis Capitata*, *Bactrocera Zonata*, and *Bactrocera Oleae* (number), as shown in Figure 4. The marginal probability density function shows the degree of Temperature with the three types of flies. It has been observed that the number of *Ceratitis Capita*a increases with increasing temperature and decreases with decreasing temperature. This is explained by the marginal probability density, where the distribution of number between 0-50 is higher than the number of 50-100, while *Bactrocera Zonata* increases with decreasing temperatures and decreases with increasing temperatures. The number from 0-500 is denser than the numbers from 550-2500, and the third type, *Bacttrocera Oleae*, also decreases with increasing temperatures, as Figure 4 shows that the density of numbers from 0-200 is higher than 200-600, and in Figure 5, which shows the probability density function. The marginal probability of relative humidity with the three species, where with *Ceratitis Capitata* the number decreases with high relative humidity while the number increases with low humidity, and in two species *Bactrocera Zonata* and *Bactrocera Oleae* it increases with an increase in relative humidity as shown in Figure 5 showing the marginal probability density distribution.

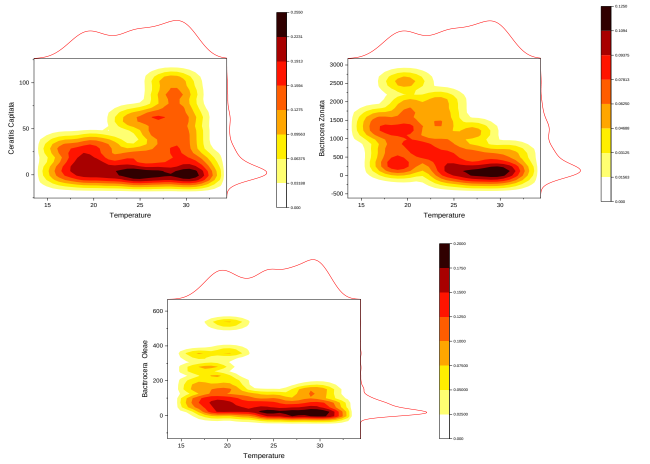

Figure 4: Marginal distributions between Temperature (C^0) and three types of flies during the period of 6-12 months of 2022.

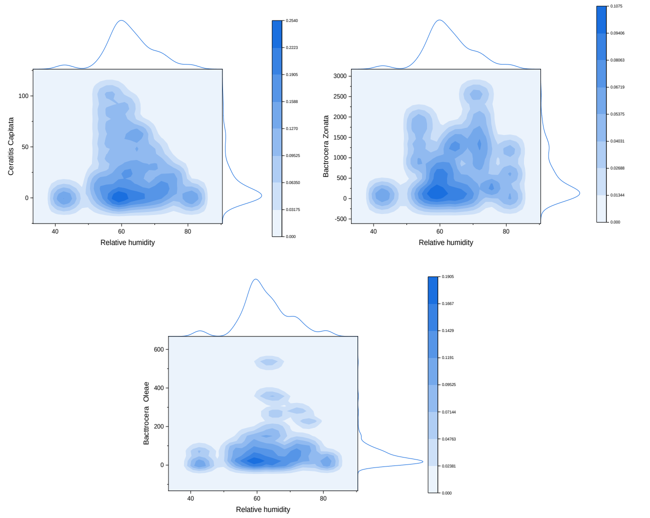

Figure 5: Marginal distributions between Relative humidity (%) and three types of flies during the period of 6-12 months of 2022.

6. Conclusion

Climate plays an important role in the biological diversity of insects. This study demonstrated that when temperatures rise, *Ceratitis capitata* (Mediterranean fruit fly) increases, as the relationship between temperature and the fly population is positive. However, *Ceratitis capitata* decreases with an increase in humidity, showing a negative relationship. In contrast, both *Bactrocera zonata* (peach fly) and *Bactrocera oleae* (olive fruit fly) increase with lower temperatures and decrease with higher temperatures, exhibiting a strong negative correlation. Their populations increase with higher humidity and decrease with lower humidity, where the positive relationship is confirmed using the marginal probability distribution function, illustrating the spread of fly species in relation to temperature and humidity.

It was noted that the period from June to December 2022 was relatively low in terms of fly population, which can be explained by the low numbers of *Ceratitis capitata* as the cold months approached, causing its numbers to decrease. Conversely, the populations of both *Bactrocera zonata* and *Bactrocera oleae* proliferated with lower temperatures and increased relative humidity.

7. Recommendations

1. Support the field of research on fruit flies at universities and research centres from both an environmental and economic perspective.
2. Raise awareness among farmers about the importance of olive trees and fruit trees, encourage timely application of prevention and treatment measures, and promote proper methods of preserving production throughout all stages until it reaches the final consumer.

8. Author Contributions

The conceptualization and design of the study were assisted by all authors. In terms of material preparation, data collection, and analysis, all authors contributed, with the initial draft written by Haifa. Once the published version of the work was reviewed, all authors approved it.

9. Funding

There was no outside support for this study.

10. Informed Consent Statement

Not applicable.

11. Data Availability Statement

Publicly available climate data were used for this study. This information can be accessed at https://power.larc.nasa.gov/data

Conflicts of Interest

The authors declare no conflicts of interest.

12. Acknowledgments:

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