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Impacts of the olive fruit fly on the 'Cyprus Local' and 'Gemlik' olive cultivars

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The objective of this study was to investigate damage rate and impact of *Bactrocera oleae* on olive oil quality on the 'Cyprus Local' and 'Gemlik' cultivars in Northern Cyprus. This study included 11 olive groves which were located in two different districts. A total of 11 olive groves from two separate cities (Güzelyurt and Girne) were selected during the maturity time where cvs, 'Cyprus Local' and 'Gemlik' are grown intensively. Two hundred and fifty fruits (25 fruits/10 trees) were randomly selected from each orchard and the damaged fruits were counted. These data were compared with the environmental conditions to determine relationships among the damage rates and environmental conditions.
The results showed that the damage rate of olive fruit fly had a moderate correlation with the temperature, while the temperatures above 20°C were found to provoke the highest damage rate on both cultivars. Moreover, the results showed that cv. 'Cyprus Local' is more sensitive to olive fruit fly damage, especially at higher temperatures. An important result of the current work is that an increase in the damage rate raises the acidity ratio of the fruits and reduces the fruit quality.

Keywords: *Bactrocera oleae*, climatic conditions, olive oil quality, damage rate

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Воздействие оливковой плодовой мухи на сорта оливы ‘Cyprus local’ и ‘Gemlik’

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Целью этого исследования было изучение степени повреждения и влияния *Bactrocera oleae* на качество оливкового масла сортов ‘Cyprus Local’ и ‘Gemlik’ на Северном Кипре. В исследование входили 11 оливковых рощ, которые расположены в двух разных регионах. В общей сложности 11 оливковых рощ в двух разных городах (Гюцелюрт и Гирне), где сорта ‘Cyprus Local’ и ‘Gemlik’ интенсивно выращиваются, были выбраны в сезон созревания плодов. Двести пятьдесят плодов (25 плодов/10 деревьев) произвольно выбрали из каждого сада и подсчитали поврежденные плоды. Эти данные сопоставили с условиями окружающей среды, чтобы определить взаимосвязь между степенью повреждения и экологическими условиями.

Результаты показали, что степень повреждения оливковой плодовой мухой имеет умеренную корреляцию с температурой, а температура выше +20°C приводит к наибольшей степени повреждения обоих сортов. Более того, результаты показали, что сорт ‘Cyprus Local’ более чувствителен к повреждению оливковой плодовой мухой, особенно при более высоких температурах. Важным результатом текущей работы является то, что увеличение степени повреждения увеличивает коэффициент кислотности плодов и снижает качество плодов.

Ключевые слова: *Bactrocera oleae*, климатические условия, качество оливкового масла, степень повреждения

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Introduction

The origin of olive (*Olea europaea* L.) is Upper Mesopotamia and Southern Asia Minor, which includes the Southeast Anatolia region (Heywood, 1978). The distribution of this fruit in the world was realized in 3 ways. The first was Morocco and Tunisia via Egypt, the second was the Aegean Islands, Italy, Spain and Greece through Anatolia, and the third was China and Pakistan via Iran. Firstly, it was cultivated and improved by the Semites (Özkaya et al., 2008). Olive oils contain important bioactive compounds and are rich in oleic acid which has beneficial health effects, including positive effects on gut microbiota, and reduction of cardiovascular diseases, hypertension and cancer (Gavahian et al., 2019). The quality and bioactive composition of olive oil are known to be significantly affected by the planting system (Usanmaz et al., 2019), genetics and environment (Hajdarov, 2016; Navas-López et al., 2020), irrigation practices (Siakou et al., 2021), plant nutrition (Nargesi et al., 2022), and pest damages (Mraicha et al., 2010; Martínez-Pertíñez, Vélez, 2020).

Olive is a Mediterranean plant grown on a limited area in 30 countries in the northern hemisphere and 8 countries in the southern hemisphere, between the latitudes of 30–45 degrees in the world. Ninety-eight percent of the olive tree in the world is dominant in this region, which is also called the Mediterranean basin (Öztürk et al., 2009). Cyprus and Crete are the islands where olives were first cultivated, and they were the first distribution points of the olive tree to the Mediterranean countries where its cultivation is widespread today; therefore, they were recognized as the second homeland of olives. It is accepted that the olive spread to the Greek and Aegean regions via Crete and to the North African coasts via Cyprus. It is reported that olive fruits have been used as food since the Neolithic age (6000–3000 BC) and olive cultivation has been carried out since the late Bronze Age in Cyprus (Orphanides, 2017). Today, there are many olive trees more than 1000 years old: these are monumental trees in Northern Cyprus. The most beautiful examples of them are found collectively in a valley in Güzelyurt District (Kalkanlı). These olives were taken under protection as monumental trees in 2007. In this research, the 'Cyprus Local' and 'Gemlik' olive cultivars were selected for investigation. The country of genetic origin for cv. 'Gemlik' is Turkey (Belaj et al., 2002), and Eastern Mediterranean for cv. 'Cyprus Local' (Anestiadou et al., 2017).

Being important production areas in history, the slopes of the Girne Mountains and the Lefke–Yedidalga area still maintain their importance today in Northern Cyprus. However, the excessive and distorted construction that has arisen due to tourism and second house construction in the last few years causes great destruction in the olive groves in Girne District (Tozlu, 2007). There are insect pests such as olive fruit fly (*Bactrocera oleae* Gml.), black scale (*Saissetia oleae* Oliver), olive moth (*Prays oleae*), olive weevils and olive thrips (*Liothrips oleae* Costa) which affect the quantity and quality of olives and olive oil. Among these, *Bactrocera oleae* is the most significant insect in terms of the damage to olives before harvest (Dıraman, 2007). Olive fruit fly is the major and destructive insect among these pests. Olive fruit fly lays its eggs inside the developing fruit, the larvae feed and grow in the mesocarp of the fruit, and the fruits fall down before they mature. In this case, it is not appropriate to use the fruits as table consumption products or for olive oil: if it is done, the quality of olive oil is very low (Skouras et al., 2007). In a study on this subject, the damage rate of olive fruit fly was determined for cv. 'Memecik' which is grown in Aydın Province, Turkey, and the highest damage rate was determined as 8.9% and 3.7% in Dalama and Çakmar Districts, Aydın Province, respectively (Apak, Başpınar, 2021). Under no-control conditions, yield losses due to this pest reached up to 20–30% in normal years and up to 70% in epidemic years (Bozbuğa, Ulusoy, 2008). In this research, the aim was to detect the damage rate and impact of *B. oleae* on olive oil acidity for the 'Cyprus Local' and 'Gemlik' olive cultivars that are grown in Güzelyurt and Girne Districts of Northern Cyprus. It was also aimed to determine the relationships between the environmental conditions and the damage rate.

Material and methods

This research was conducted to determine the damage rate of *Bactrocera oleae* and its effect on olive oil quality in 11 olive orchards with the 'Cyprus Local' and 'Gemlik' olive cultivars in Güzelyurt (6 orchards) and Girne (5 orchards) Districts, where olive cultivation is intense, in the TRNC between 2015 and 2016. Climatic data in Güzelyurt and Girne Districts where the study was carried out were obtained as follows: for 2015, the data were taken from the Statistics Yearbook published by the State Planning Organization of the TRNC in January 2017, and the data for 2016 were taken from the Meteorology Department of the Ministry of Tourism and Environment, and used in this study. In order to determine the damage rate, the chemical control method was applied in the orchards where fruit samples were taken and an insecticide was applied in different growing periods for both olive cultivars (Table 1).

In the period when the fruits started to be oiled, in 11 olive groves selected in Girne and Güzelyurt Districts, where 'Cyprus Local' and 'Gemlik' are grown intensively, 250 fruits (25 fruits/10 trees) were randomly selected from each orchard and the count of damaged fruits was made. The harvesting time for cv. 'Cyprus Local' is December, and September for cv. 'Gemlik' in each district. It is known that *B. oleae* causes both direct product losses and a significant increase in oil acidity due to the damage on table and oil cultivars.

For this reason, 0.5 L of oil was taken in the olive oil squeezing process of the producer after harvest in order to determine the effect of the insect on olive oil quality. Olive oil was extracted from a bulk of olive samples per orchard for each treatment using an industrial olive mill.

The malaxation temperature was +28°C for 30 min. The oil was then separated with a vertical centrifuge; and thus left to decant. Afterwards, oil samples were filtered and kept in 100 mL dark bottles at 4°C until the analysis (Usanmaz et al., 2019). The analyses of these olive oil samples were made in the laboratory under the Ministry of Agriculture and Natural Resources. The relationships between the olive fruit fly population density and damage rate were statistically demonstrated. The effects of the temperature, cultivar, area and altitude on the olive fly damage rate were compared with SPSS 20.0 using ANOVA and T-test, and average values were determined by Duncan's multiple test. The effect of the damage rate on olive oil quality was compared with SPSS 20.0 using ANOVA and T-test, and average values were determined by Duncan's multiple test.

Results

This study was carried out to determine the damage rate of fruits surveyed from selected 11 orchards, Güzelyurt (6) and Girne Districts (5). As a result of the counts, the damage rate of olive fruit fly in each orchard was determined (Table 2, 3). The evaluation of the first year data showed that the highest damage rate (75.6%) was obtained from the 1st or-

Table 1. Chemical applications in orchards where the olive fruit fly damage rate was determined (2015 and 2016)
Таблица 1. Применение химикатов в садах, где определялась степень поражения оливковой плодовой мухой (2015 и 2016 г.)

Name	Cultivar	Location	Insecticide	Application date	Application period
1st year data (2015) Güzelyurt district					
Erten Kurnaz	Cyprus Local	Kalkanlı 1	Dimethoate	July	Fruit
Arife Kandulu	Gemlik	Kalkanlı 2	Dimethoate	July–August	Bud and fruit
Ümit Zeki	Gemlik	Zümrütköy	Dimethoate	July–August	Bud and fruit
Erkin Bilgin	Gemlik	Yeşilyurt	Dimethoate	August	Fruit
Hasan Ergel	Gemlik	Doğancı	Dimethoate	July–August	Bud and fruit
Hüseyin Mahmutoğlu	Cyprus Local	Çamlıköy	Dimethoate	July	Fruit
1st year data (2015) Girne district					
Talip Sancar	Gemlik	Geçitköy	Dimethoate	May	Before and after flowering
Ufuk Hacıelmas	Cyprus Local	Lapta 1	Dimethoate	March	Flowering
Andaç Kireççi	Cyprus Local	Lapta 2	Dimethoate	March–June	Bud and fruit
İrfan Candemir	Cyprus Local	Zeytinlik	–	–	–
Tanser Nizam	Cyprus Local	Karakum	Dimethoate	July	Fruit
2nd year data (2016) Güzelyurt district					
Erten Kurnaz	Cyprus Local	Kalkanlı 1	Dimethoate	July–August	Fruit
Arife Kandulu	Gemlik	Kalkanlı 2	Dimethoate	June–July	Bud and fruit
Ümit Zeki	Gemlik	Zümrütköy	Dimethoate and Delthamethrin	April–June–July–August	Flowering and fruit
Hasan Ergel	Gemlik	Doğancı	–	–	–
Erkin Bilgin	Gemlik	Yeşilyurt	–	–	–
Hüseyin Mahmutoğlu	Cyprus Local	Çamlıköy	Dimethoate	August	Fruit
2nd year data (2016) Girne district					
Talip Sancar	Gemlik	Geçitköy	Dimethoate	July	Fruit
Ufuk Hacıelmas	Cyprus Local	Lapta	–	–	–
Andaç Kireççi	Cyprus Local	Lapta	Dimethoate	May–September	Flowering and fruit
İrfan Candemir	Cyprus Local	Zeytinlik	–	–	–
Tanser Nizam	Cyprus Local	Karakum	Dimethoate	July	Fruit

Table 2. **Damage and acid ratios obtained from fruit samples taken from orchards in 2015**

Таблица 2. **Показатели повреждения и кислотности, полученные у образцов плодов, взятых из садов в 2015 г.**

District	Location	Cultivar	Usage	Damage rate (%)	Acidity ratio (%)
Güzelyurt	Kalkanlı	Cyprus Local	Oil and table	6.4	3.1
	Kalkanlı	Gemlik	Oil and table	2.0	0.8
	Zümrütköy	Gemlik	Oil and table	2.0	1.4
	Doğancı	Gemlik	Oil and table	4.4	3.8
	Yeşilyurt	Gemlik	Oil and table	8.0	3.7
	Çamlıköy	Cyprus Local	Oil and table	8.4	3.7
Girne	Geçitköy	Gemlik	Oil and table	17.2	2.3
	Lapta 1	Cyprus Local	Oil and table	75.6	5.2
	Lapta 2	Cyprus Local	Oil and table	12.0	2.2
	Zeytinlik	Cyprus Local	Oil and table	28.0	5.6
	Karakum	Cyprus Local	Oil and table	60.4	4.8

Table 3. **Damage and acid ratios obtained from fruit samples taken from orchards in 2016**

Таблица 3. **Показатели повреждения и кислотности, полученные у образцов плодов, взятых из садов в 2016 г.**

District	Location	Cultivar	Usage	Damage rate (%)
Güzelyurt	Kalkanlı 1	Cyprus Local	Oil and table	11.2
	Kalkanlı 2	Gemlik	Oil and table	14.4
	Zümrütköy	Gemlik	Oil and table	5.2
	Doğancı	Gemlik	Oil and table	29.2
	Yeşilyurt	Gemlik	Oil and table	20.8
	Çamlıköy	Cyprus Local	Oil and table	49.6
Girne	Geçitköy	Gemlik	Oil and table	4.4
	Lapta 1	Cyprus Local	Oil and table	83.2
	Lapta 2	Cyprus Local	Oil and table	11.6
	Zeytinlik	Cyprus Local	Oil and table	44.4
	Karakum	Cyprus Local	Oil and table	50.4

chard in Lapta, followed by the second highest damage rate (60.4%) in Karakum, Girne District. The most important factor in the high damage rate was the inadequate and wrong practices in the management against this insect pest. One of the best examples to be given to this interpretation is the application of insecticides in March (flowering period) in the 1st orchard in Lapta (see Table 1). Even if there were adult flies in the environment, the insecticide thrown during this period was wasted because there was no fruit. As a result of the study conducted in 11 orchards on the damage rate of olive fruit fly, the lowest damage rate was found in the 2nd orchard in Kalkanlı (2%) and Zümrütköy (2%) in Güzelyurt District.

Considering the relationship between the cultivar, temperature and damage rate, the maximum damage rate on cv. 'Gemlik' (18.4%) was observed when the temperature reached above 20°C and was noted to decrease when the tem-

perature reduced. Similar results were observed for cv. 'Cyprus Local': the highest damage rate (47.4%) was detected at the temperature > 20°C and a decrease was observed in the damage rate when the temperature reduced below 15°C (Table 4).

A moderately significant positive correlation was found between the mean temperature and damaged fruit (Pearson's correlation: +0.523; P = 0.01). This means that when the temperature rises there is a moderate increase in the damage rate. The results indicated that the adult female population and the damage rate correlated, but the mean air temperature also affected the damage rate. In this way, the correlation between the adult female population and the damage rate was moderate, due to a decrease in olive fruit fly motility and egg laying at higher temperatures (see Table 4 and Table 5).

As expected, a moderate positive to high correlation was found between the damage rate and acidity ratio (Pearson's correlation: +0.735; P = 0.01). The lowest acidity rate was measured in the 2nd olive orchard (0.8%) in Kalkanlı where the damage rate was determined as 2%, and the highest acidity rate was measured in the 1st olive orchard in Lapta where the damage rate was 75.6% (5.6%). Adults of this insect are active between 20°C and 30°C, but above this temperature the behavior of the adults deteriorates and they move quickly to

Table 4. Interaction between cultivar/temperature and olive fruit fly damage/population

Таблица 4. Взаимодействие сорта/температуры и повреждения/популяции оливковой плодовой мухи

Cultivar	Temperature	Damage rate (%)	Male population	Female population
Gemlik	< 15°C	4.1 b	16.8 b	20.5 a
	15–20°C	17.3 a	18.1 a	13.3 c
	> 20°C	18.4 a	18.8 a	18.3 b
Cyprus Local	< 15°C	7.4 b	17.9 b	32.4 c
	15–20°C	39.3 b	100.9 a	103.9 b
	> 20°C	47.4 a	99.6 a	116.5 a

Note: according to Duncan's multiple test (5%), no significant difference was detected between the data shown with the same letter or letters in the same column separately for each cultivar

Примечание: по множественному критерию Дункана (5%) не выявлено достоверного различия между данными, обозначенными одной буквой или буквами в одном столбце отдельно для каждого сорта

Table 5. Olive fruit fly damage rates and total number of female and male individuals identified in 2015 and 2016 in olive orchards in Güzelyurt and Girne Districts

Таблица 5. Показатели повреждения оливковой плодовой мухой и общее количество особей женского и мужского пола, определенные в 2015 и 2016 г. в оливковых садах в районах Гюцелюрт и Гирне

District	Orchard	Damage rate (%)			Adult population (male) (#/trap)			Adult population (female) (#/trap)		
		2015	2016	Mean	2015	2016	Mean	2015	2016	Mean
Güzelyurt	Kalkanlı 1	6.4 f-g	11.6 g	9.0 g-h	9.33 i	15.16 i	12.25 e	17.83 h	18.83 h	18.33 de
	Kalkanlı 2	2.0 g	14.0 g	8.0 g-h	27.83 g	15.0 i	21.41 e	45.83 ef	22.83 g	34.33 cd
	Zümrütköy	2.0 g	5.2 h	3.6 i	2.5 j	11.33 j	6.9 e	2.3 k	9.6 jk	6.0 e
	Yeşilyurt	8.0 e-f	20.8 f	14.4 e-f	11.0 i	41.16 f	26.08 e	8.8 j	13.33 i	11.08 de
	Doğancı	4.4 f-g	29.2 e	16.8 e	25.66 g	4.6 k	15.16 e	25.16 g	3.6 l	14.41 de
	Çamlıköy	8.4 e-f	48.4 c	28.4 d	26.5 g	5.0 k	15.75 e	47.0 e	8.33 k	27.66 de
Girne	Karakum	60.4 b	50.4 c	55.4 b	256.33 a	109.16 c	182.75 a	246.83 a	68.5 d	157.66 a
	Lapta 1	75.6 a	83.2 a	79.4 a	50.16 e	75.33 e	62.75 d	54.83 d	131.66 b	93.25 b
	Lapta 2	12.0 e	11.6 g	11.8 f-h	110.33 c	124.0 b	117.16 c	127.83 c	145.5 a	136.66 a
	Zeytinlik	28.0 c	44.4 d	36.2 c	168.16 b	89.83 d	129.0 bc	166.83 b	120.3 c	143.58 a
	Geçitköy	17.2 d	4.4 h	10.8 f-h	18.33 h	18.83 h	18.58 e	17.0 hi	18.33 h	17.66 de

Note: according to Duncan's multiple test (5%), no significant difference was detected between the data shown with the same letter or letters in the same column separately for each cultivar

Примечание: по множественному критерию Дункана (5%) не выявлено достоверного различия между данными, обозначенными одной буквой или буквами в одном столбце отдельно для каждого сорта

the right and left, thus preventing the adult females from laying eggs in the fruit. Besides, olive fruit fly's activity stops at temperatures above 35°C (Wang et al, 2009). In order to detect the effect of this insect on the acidity of olive oil, samples were obtained only in 2015 from orchards where fruit samples were taken and could not be repeated in 2016 due to the periodicity.

After the olive oil squeezing by the producers, 0.5 L was taken from the producer and the acidity analyses were performed. A conclusion was made that the olive oil samples taken from the 2nd olive orchard in Lapta and Geçitköy, Girne District, had the best acidity ratio, and the samples taken from the 2nd olive orchard in Kalkanlı and Zümrütköy, Güzelyurt District, had the best acidity ratio (see Table 4). As expected, a moderate positive to high correlation was found between the damage rate and the acidity ratio. The lowest acidity ratio was obtained in the 2nd olive orchard (0.8%) in Kalkanlı, where the damage rate was 2%, and the highest acidity rate was measured in the 1st olive orchard in Lapta, where the damage rate was determined as 75.6% (5.6%). It was ascertained that the obtained oil analysis results were inconsistent with the damage rate in olives due to the fact that the producers cleaned damaged fruits before the squeezing operation.

Discussion

Bactrocera oleae is the most destructive insect in olive cultivation due to both yield losses and increased acidity of olive oil (Bjelis, 2009). The results showed that the adult female population and damage rate increased at temperatures of 20°C and above. The adult population and damage rate developed in parallel with each other. T. Perović and S. Hrnčić (2013) determined that high air temperatures (20–26°C) caused water loss and wrinkling in olive fruits, and the olive fly had no suitable environment for egg laying. According to the results of this study, a decrease in the damage rate was observed in a high humidity environment. In order to determine the damage rate of olive fruit fly in 2015 and 2016, 250 fruits were randomly collected from each orchard and the highest damage rate was observed in the 1st olive orchard in Lapta (75.6%), while the 2nd highest damage rate was in the orchard in Karakum Village (60.4%), Girne District. In 2016, the maximum damage rate was detected in the 1st olive orchard in Lapta (83.2%), as in 2015, and 2nd highest damage rate was registered in Karakum (50.4%), Girne District. The lowest damage rate was found in the 2nd orchard in Kalkanlı (2%) and Zümrütköy (2%), Güzelyurt District. In both orchards, cv. 'Gemlik' is cultivated and the harvesting is done in September. In this period, the high temperatures in Güzelyurt District cause deformation in olive fruits, and this situation is not suitable for oviposition. Therefore, the lowest damage rate was observed in both orchards. In addition, the reason for the high sensitivity of cv. 'Cyprus Local' to olive fruit fly is that olive fruit fly larvae feed on fruit flesh and the fruit of this cultivar is morphologically (fruit flesh thickness) suitable for olive fruit fly to lay eggs and for feeding of larvae, which may cause a high damage rate in the orchards where this cultivar is grown.

In this study, the effect of this insect on olive oil acidity was analyzed. Olive oil samples (0.5 L) were obtained from the orchards where traps were hung after the harvest in 2015. It was determined that the olive oil samples obtained from the 2nd orchard in Kalkanlı, Güzelyurt District, had the best acidity ratio. In 2016, olive oil samples could not be taken because there was not enough olive fruit in the orchards due to periodicity.

Conclusion

This is the first study in Northern Cyprus explaining the relationships between the air temperature and olive fruit fly damage. The results demonstrated that the temperatures above 20°C favor both male and female populations of the fly and increase the damage rate on the fruits. Moreover, an increase in the damage rate significantly increases the acidity ratio of olive oil.

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