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Susceptibility of Two Olive Varieties Aldeibli and Alkhudairi to Olive Fruit Fly *Bactrocera oleae* (Gemlin) (Diptera: Tephritidae)

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Abstract: This study was carried out in the western region of the Homs province (34°40' N, 36°45' E) in 2010 to determine the susceptibilities of two varieties Aldeibli and Alkhudairi to olive fruit fly *Bactrocera oleae*. The results showed two major periods of fly activity, the first period extended from June to mid-August, while the second fly period started the last week of September and ended during harvest period in middle October. The first infection signs appeared on the Aldeibli variety in the third week of June. The average fruit length, diameter, weight and oil content were: 1.59 ± 0.97 cm, 1.2 ± 0.06 cm, 1.7 ± 0.29 g and 1.76 ± 0.11% respectively. Percent infection starts to rise during the third week of August and this rise was accompanied by an increase in the length, diameter, weight and oil content of the olive fruit. Correlation coefficients concerning the fly activity in relation to fruit injury and epicarp hardness of the variety Aldeibli was negative (epicarp hardness was 57.08 ± 4.83 g with the start of infection and 54.51 ± 6.08 g with the end of the first period). In contrast, observable infection symptoms in the Alkhudairi variety did not appear during the first period of fly activity. Significant differences observed between the two varieties concerning the average fruit length, diameter, weight and oil content. Epicarp hardness of Alkhudairi variety 65.33 ± 0.06 g was higher than the Aldeibli variety 56.73 ± 0.19 g. Infection symptoms on Alkhudairi variety started to rise with the beginning of the second fly period. In contrast in the Aldeibli variety no new symptoms were observed. Average of fruit length, diameter and weight of Aldeibli was higher than that of Alkhudairi variety and no significant difference were observed concerning oil contents between the two varieties. Significant differences between the two varieties were observed concerning epicarp hardness, color of fruits Index Jaen of pigmentation.

Key words: *Bactrocera oleae*, olive varieties, olive fruit fly, olive fruit weight, hardness of epicarp.

1. Introduction

The olive fruit fly *Bactrocera oleae* is the most important pest of olive [1]. The species is monophagous feeding on olives fruits of the genus *Olea* spp., and is found in the Mediterranean, Africa, Asia, and North and Central America [2]. Infection and fruit damage of this pest can be up to 100% [3] and especially in those areas that have not applied any control programs [4]. The damage caused by the fly is the result of the main reasons:

(1) Fruits drop early as a result of tunnels drilled by the larvae inside the fruit during summer;

(2) Lack of fruit weight (50-270 mg/fruit) and reduced amount of oil (2%-20%);

(3) Decrease in olive quality because of high acidity oil content due to late fruit injury [5].

There are several reports on the role of visual cues such as the shape and size of host tree in Tephritidae foraging behavior [6, 7]. Besides visual stimuli, chemical cues emanating from the host tree might be important in attracting flies to the trees [8]. Volatile

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components of ripening olives might be an important long-range factor for guiding olive flies to host plants [3].

Several, field studies indicate that *B. oleae* populations exhibit strong ovipositional preferences in their endemic range [9-14].

Neuenschwander [15] for instance, examined the ovipositional preference in 40 olive varieties and has found preferences to be positively correlated with weight, but unrelated to color or hardness of the epicarp. Gümusay [12] examined the susceptibility of the variety Cilli in olive attack by means of hardness of epicarp, color, shape, weight, and oil and water content of the fruit. In addition it was observed that the variety Cilli, which has a heavier and spherical olive shape with high water content and soft epicarp, stayed green throughout the season and was the most heavily infested compared to others.

The fruit fly is considered as the major key pests affecting olives crops in Syria. In Homs Province the percentage of infection by the olive fly on the Aldeibli variety was 92% during the first months of the season of 2007 and 95% on the Alkhudairi variety as observed during the end of the season [16].

In the context of ongoing research on the olive fruit fly concerning the factors that affect their population dynamics and control, this research has been made to demonstrate the impact of specific and measurable fruits characteristics (length, diameter, weight, hardness of epicarp, color of the fruit, and proportion of oil) in fly attack. Such kind of information are essential to determine which qualitative olive factors are affecting olive susceptibility to fruit attack in order process on a genetic varieties improvement which is essential to olive fly resistant varieties classification in Syria.

2. Materials and Methods

2.1 Experimental Orchard

The study was carried out during 2010 near the Nara village, which is located about 50 km west of Homs city. In this Region the most important varieties that are planted are the Aldeibli and Alkhudairi varieties. The average age of trees was about 30 years, pruning or irrigation program had not been applied to any tree for about five years. Climatic data was obtained from the monitoring station which was located in the experimental field (Fig. 1).

2.2 Determining the Percentage of Infection

To calculate the percentage of infection, samples of olive fruits were taken as follows: First 20 trees were identified and the 10 fruits were taken from each tree at random. In total, fruit injury was observed in 100

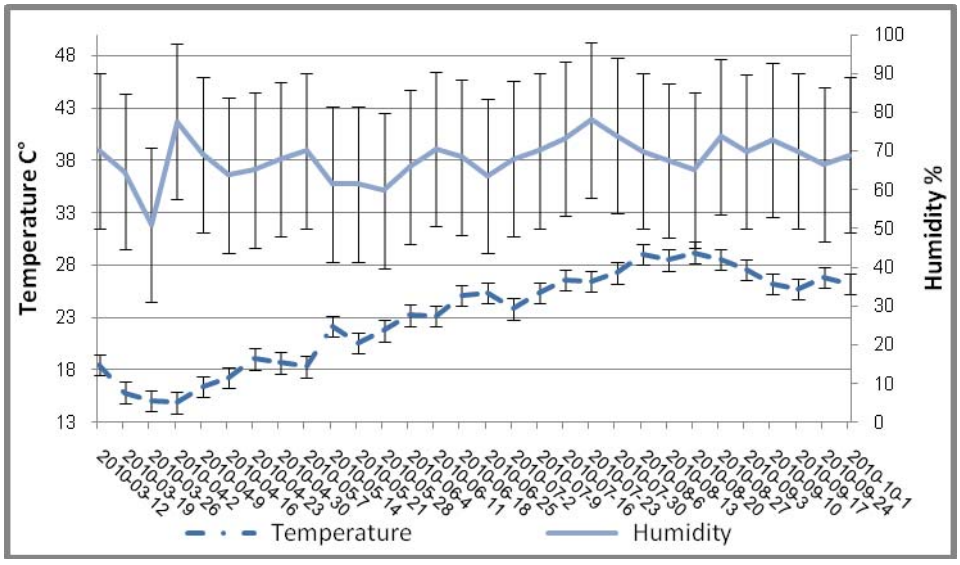

Fig. 1 Average of temperature and humidity.

fruit. Observations were made from the beginning of infection to the stage of fruits drop or harvest. Fruits originated from each variety and during the observation times were signed and then transferred to the laboratory of Agriculture College, where they were examined under stereoscope. Data concerning the number of eggs, larvaes, pupe as well as and the holes were recorded and then the percentage of total infection% was calculated.

2.3 Study Indicators

The following fruit quality indicators were measured.

2.3.1 Length, Diameter, Hardness of Epicarp, and Weight of Fruit

A random sample of 40 non-infected by fruit fly fruits was taken, from each cultivar, starting from the date of the injury and until the stage of fruits drop or harvest. Every two weeks indicators were examined as follows:

(1) The length and diameter of fruits were measured by using an ordinary measurement tool;

(2) The hardness of epicarp was measured using a Texture Analyser machine (Use the probe like a machine of female for egg-laying, the symbol of this probe is p/2n) the hardness of epicarp was expressed as Gram;

(3) Fruit weight was measured by a sensitive balance and expressed as Gram.

2.3.2 Fruit Pigmentation

Random samples of 40 intact fruit were taken and 3 replicates were made for each cultivar. The fruit pigmentation was determined by using Jaen pigmentation index and calculated with the following formula [17]:

Pigmentation index = $\sum_{i=0}^{7}(i * ni) / N$

Where: Ni = the number of olives in relation to the color group; N = the total number of olives in the sample.

The pigmentation climax is as follows:

0 = green fruit epicarp;

1 = yellow fruit epicarp;

2 = olive with superficial pigmentation on less than 50% of the epicarp;

3 = olive with superficial pigmentation on more than 50% of the epicarp;

4 = olive with superficial pigmentation on 100% of the epicarp;

5 = olive with superficial pigmentation on 100% of the epicarp and pigmentation on less than 50% of the pulp thickness;

6 = olive with superficial pigmentation on 100% of the epicarp and pigmentation on more than 50% of the pulp thickness;

7 = olive with superficial pigmentation on 100% of the epicarp and pigmentation on 100% of the pulp thickness.

2.3.3 Oil Content

Random samples of 40 non-infected olive fruits were taken from each cultivar, extending from the date of the injury and until the stage of fruits drop or harvest. Oil content was measured every two weeks by using a Sohlet apparatus [18].

2.4 Monitoring of Olive Fruit Fly

Four pheromone traps were placed in March 2010. Each trap was placed at a height of 170 cm in the south-eastern side of the tree. The distance between the traps was about 40 meters. Males caught on traps were counted at 7 days intervals. Pheromone was a mixture of [1, 7-dioxaspiro (5, 5) undecane] produced in the United Kingdom (Qlure-Dao® manufactured by Russell IPM Ltd, Uk).

2.5 Statistical Analysis

The correlation coefficient was calculated between the percentage of total infection % and the average fruit weight, length, diameter, hardness and oil content by using the correlation coefficient (r) of Person.

The means of each indicator were compared between varieties and observation dates and separated by using the LSD test at $P = 0.05$ hypothesis testing

and according to a complete randomized design. Statistical analysis was performed by GenStat V11 and plots were performed by using Excel 2007.

3. Results and Discussion

3.1 Determining the Percentage of Total Infection

The results of fruits autopsy have displayed that infection by the olive fruit fly started on Aldeibli variety during the third week of June and the percentage was 9%, Table 1 with an interval of four weeks from the start of attracting of males to traps Fig. 2. Infection was not observed on the fruits of Alkhudairi variety until the first week of October and the total infection did not exceed 10% till harvest date. Table 1 and Fig. 2 display the existence of two major periods of the activity of the fly. The first period start from the beginning of the growth season to mid-August whereas the second period continues from late September to the date of harvest on 15 October.

3.2 Qualitative Fruit Indicator Measures During the First Infection Period

The correlation between the percentage of total infection and the length of the fruit was positive (r = 0.96, y = 54.32x - 67.02) (Fig. 3).

Statistical analysis identifies that the value of the correlation coefficient between the percentage of total infection and fruit diameter was (r = 0.92, y = 42.81x - 40.05) (Fig. 4).

The Relationship between the Hardness of Epicarp and the Percentage of total Infection is given in Fig. 5. Through statistical analysis the value of the correlation coefficient was weak and negative (r = -0.41, y = -1.617x + 110.3).

The Relationship between Oil Contents and the percentage of Infection was positive (r = 0.83, y = 1.380x + 11.09) (Fig. 6).

The correlation coefficient between the percentage of total infection and the fruit weight is high and

Table 1 Percentage of infection.

Percentage of infection %					
Alkhudairi cultivar	Aldeibli cultivar	Date	Alkhudairi cultivar	Aldeibli cultivar	Date
0	No new infection	2010/08/27	0	9	2010/06/25
0	No new infection	2010/09/3	0	14	2010/07/2
0	No new infection	2010/09/10	0	17	2010/07/9
0	No new infection	2010/09/17	0	18	2010/07/16
0	No new infection	2010/09/24	0	20	2010/07/23
3	No new infection	2010/10/1	0	23	2010/07/30
7	No new infection	2010/10/8	0	23	2010/08/6
10	No new infection	2010/10/15	0	25	2010/08/13
Harvest	Harvest of fruit	2010/10/22	0	24	2010/08/20

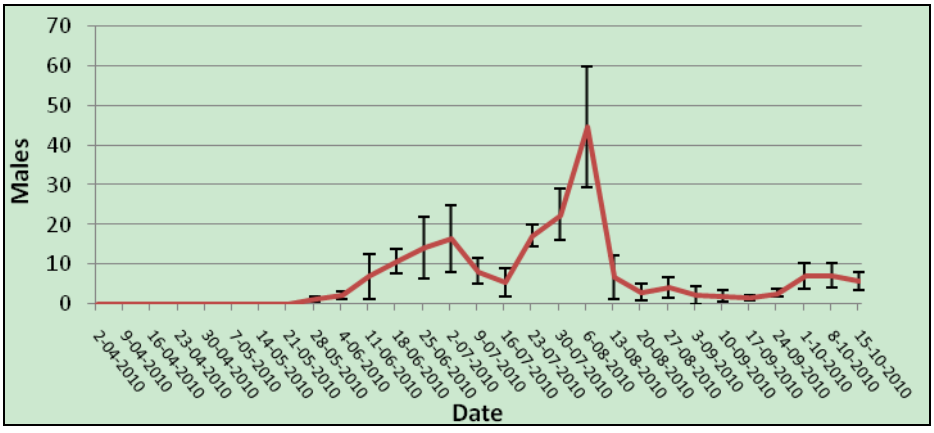

Fig. 2 Average number of males in Nara village.

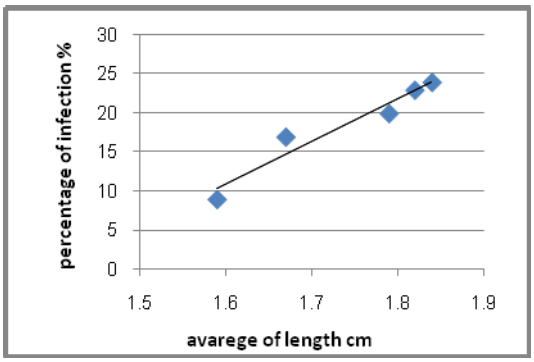

Fig. 3 Relationship between length and percentage of infection.

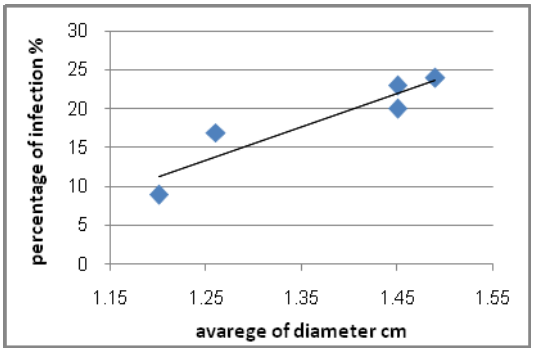

Fig. 4 Relationship between diameter and percentage of infection.

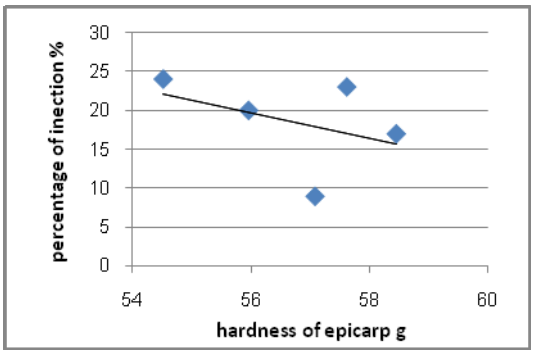

Fig. 5 Relationship between hardness of epicarp and percentage of infection.

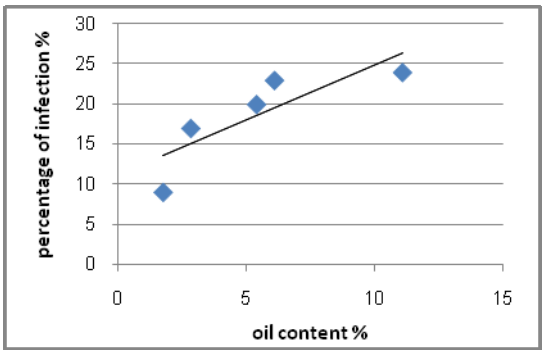

Fig. 6 Relationship between hardness of epicarp and percentage of infection.

positive (r = 0.94, y = 13.83x - 13.16) (Fig. 7).

The color of green fruit did not change during the first period of infection, and the index value for the discoloration of Jaen remained 0 during this period.

3.3 Fruit Variety Quality Indicators and Relation to Fruit Attacks

3.3.1 The Length and Diameter of Fruit

The results of statistical analysis and the significant difference between the average length and diameter of the fruit between the two varieties and dates show that fruits of Aldeibli variety had more length and diameter during the dates studied to the end of the first period (Table 2).

This coincided with an indication on Aldeibli variety, while it did not show any signs of infection on Alkhudairi variety. When the fruit length and diameter, in both varieties had the highest value during the first period in 20 August, the percentage of infection of the Aldeibli variety was 24%, and no infection was detected on the Alkhudairi variety. In general the average length and diameter of the fruit in Aldeibli variety exceeded that on Alkhudairi variety (Table 3).

3.3.2 Hardness of Epicarp

The significant difference between the hardness of epicarp in the two varieties and the dates show that the fruits of Alkhudairi variety were more during most observation dates except on 20 August, when fly was attracted to the Aldeibli variety but not to the Alkhudairi variety (Table 4). In addition, the average

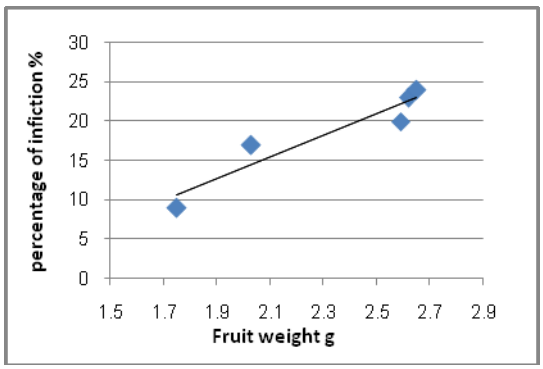

Fig. 7 Relationship between fruit weight and percentage of infection.

Table 2 Fruit's length and diameter comparison for two olive tree varieties in different dates.

Variety	Date	Length (cm)	Diameter (cm)	Percentage of infection (%)
Aldeibli	6/25/2010	1.59±0.97d	1.2±0.06d	9
	7/07/2010	1.67±0.06c	1.26±0.05c	17
	23/7/21010	1.79±0.102b	1.45±0.12b	20
	6/08/2010	1.82±0.102ab	1.45±0.08b	23
	20/08/2010	1.84±0.101a	1.49±0.77a	24
Alkhudairi	6/25/2010	1.39±0.09g	0.96±0.64h	0
	7/07/2010	1.44±0.07f	0.99±0.03g	0
	23/7/21010	1.53±0.11e	1.03±0.04f	0
	6/08/2010	1.56±0.11de	1.04±0.04ef	0
	20/08/2010	1.57±0.13d	1.06±0.04e	0
LCD		0.04	0.03	
CV%		4.9	4.9	

There is significant difference between the averages followed by different letters in one column ($P = 0.05$).

Table 3 Fruit's length and diameter comparison for two olive tree varieties in different dates during the first period.

Variety	Diameter (cm)	Length (cm)
Aldeibli	1.57 ± 0.14a	1.14 ± 0.13a
Alkhudairi	1.21 ± 0.06b	1.90 ± 0.12b
CV%	4.9	4.9
LSD	0.01	0.02

There is significant difference between the averages followed by different letters in one column ($P = 0.05$).

Table 4 Fruit's hardness of epicarp comparison for two olive tree varieties in different dates.

Variety	Date	Percentage of infection (%)	Hardness of epicarp g
Aldeibli	6/25/2010	9	57.08±4.83cd
	7/07/2010	17	58.46±9.39c
	23/7/21010	20	55.96±3.62cd
	6/08/2010	23	57.62±6.124c
	20/08/2010	24	54.51±6.08d
Alkhudairi	6/25/2010	0	70.66±5.64a
	7/07/2010	0	68.9±7.92a
	23/7/21010	0	63.15±4.66b
	6/08/2010	0	62.38±7.33
	20/08/2010	0	61.54±5.94 b
LSD			3.04
CV%			11.1

There is significant difference between the averages followed by different letters in one column ($P = 0.05$).

of epicarp hardness for the fruits from Alkhudairi variety was higher than those from Aldeibli variety during the entire first period (Table 5).

3.3.3 Oil Content

Table 6 shows that oil content in the variety Aldeibli was higher than Alkhudairi variety on all dates. The percentage of oil was the highest on 20 August for both varieties, while no new infection was registered on Alkhudairi variety during this period.

3.3.4 Fruit Weight

The average fruit weight in the Aldeibli variety was higher than that of the Alkhudairi variety during the first period of the season and on all the observation dates (Table 7).

3.4 Relationship between the Qualitative Fruit Indicators and Infection during the Second Observation Period

Determination of correlation coefficient and related to regression equation was no possible due to the short

Table 5 Fruit's hardness of epicarp comparison for two olive tree varieties in different dates during the first period.

Variety	Hardness of epicarp (g)
Aldeibli	56.73 ± 0.19b
Alkhudairi	65.33 ± 0.06a
LSD	1.36
% CV	11.1

There is significant difference between the averages followed by different letters in one column ($P = 0.05$).

Table 6 Fruit's oil content comparison for two olive tree varieties in different dates.

Variety	Date	Percentage of infection (%)	Oil content (%)
Aldeibli	6/25/2010	9	1.76±0.11g
	7/07/2010	17	2.83±0.15f
	23/7/21010	20	5.43±0.15e
	6/08/2010	23	8.2±0.1c
	20/08/2010	24	12.16±0.11a
Alkhudairi	6/25/2010	0	0.8±0.1i
	7/07/2010	0	1.3±0.1h
	23/7/21010	0	2.7±0.2f
	6/08/2010	0	6.16±0.05d
	20/08/2010	0	11.1±0.1b
LSD			0.21
CV%			2.4

There is significant difference between the averages followed by different letters in one column ($P = 0.05$).

Table 7 Fruit's weight comparison for two olive tree varieties in different dates.

Variety	Date	Percentage of infection (%)	Fruit weight (g)
Aldeibli	6/25/2010	9	1.70±0.29c
	7/07/2010	17	2.30±0.24b
	23/7/21010	20	2.59±0.45a
	2010/08/6	23	2.63±0.22a
	2010/08/20	24	2.65±0.44a
Alkhudairi	6/25/2010	0	0.82±0.26g
	7/07/2010	0	1.06±0.281f
	23/7/21010	0	1.31±0.33e
	2010/08/6	0	1.44±0.34d
	2010/08/20	0	1.55±0.38d
LSD	0.15		
CV%	18.8		

There is significant difference between the averages followed by different letters in one column (P = 0.05).

observation period and the start of harvest. However, the trends and the relationships concerning the observables are discussed virtually (non-statistical) throughout the subsequent paragraphs.

3.5 Correlation between Fruit Quality and Susceptibility to Olive Fly During the Second Period

3.5.1 Length and Diameter of Fruit

Table 8 shows that the length and diameter of Aldeibli remained higher than the Alkhudairi fruit during this period. However there were no new symptoms of infection on Aldeibli variety during this period while symptoms of infection began to appear on Alkhudairi fruit in the last week of September.

3.5.2 Hardness of Epicarp

Hardness of epicarp of Aldeibli variety remained less than Alkhudairi variety in this period for the dates studied, while the flies are attracted to the Alkhudairi variety unlike the first period (Table 9).

3.5.3 Oil Content

There were no significant differences between the oil content for two varieties during this period, in despite the injury appeared on Alkhudairi variety (Table 10).

3.5.4 Fruit Weight

The average of fruit weight from Aldeibli Variety remained higher than the one from Alkhudairi variety during the second period of the season, while the flies attracted to the Alkhudairi variety unlike the first period (Table 11).

3.5.5 Color of Fruit

There were significant differences between the average of index value of Jaen discoloration during this period where the proportion of discoloration for Aldeibli fruits was higher than Alkhudairi variety (Table 12).

Table 8 Comparison of fruit's length and diameter between two olive varieties and during different observation dates.

Variety	Date	Percentage of infection (%)	Diameter (cm)	Length (cm)
Aldeibli	1/10/2010	No new infection	1.78±0.14b	2.15±0.28b
	15/10/2010	No new infection	1.88±0.15a	2.32±0.28a
Alkhudairi	1/10/2010	3	1.46±0.16d	1.97±0.11c
	15/10/2010	10	1.66±0.05c	2.06±0.13bc
LSD			0.04	0.09
CV%			6.2	10.7

There is significant difference between the averages followed by different letters in one column (P = 0.05).

Table 9 Comparison of fruit's hardness of epicarp between two olive varietys and during different observation dates

Variety	Date	Percentage of infection (%)	Hardness of epicarp (g)
Aldeibli	1/10/2010	No new infection	53.06±5.11bc
	15/10/2010	No new infection	51.56±4.99c
Alkhudairi	1/10/2010	3	57.12a5.69±
	15/10/2010	10	55.42±7.51ab
LSD			2.65
CV%			11

There is significant difference between the averages followed by different letters in one column (P = 0.05).

Table 10 Comparison of fruit's oil content between two olive varieties and during different observation dates.

Variety	Date	Percentage of infection (%)	Oil content (%)
Aldeibli	1/10/2010	No new infection	18.5a
	15/10/2010	No new infection	22.1a
Alkhudairi	1/10/2010	3	17.8a
	15/10/2010	10	23.8a
LSD			8.6
CV%			17.1

There is significant difference between the averages followed by different letters in one column (P = 0.05).

Table 11 Comparison of fruit's weight between two olive varieties and during different observation dates.

Cultivator	Date	Percentage of infection (%)	Fruit weight g
Aldeibli	1/10/2010	No new infection	3.00±0.72b
	15/10/2010	No new infection	3.75±0.73a
Alkhudairi	1/10/2010	3	1.9±0.42d
	15/10/2010	10	2.5±0.44c
LSD			0.26
CV%			21.6

There is significant difference between the averages followed by different letters in one column (P = 0.05).

Table 12 Comparison of fruit's color between two olive varieties and during different observation dates.

Cultivator	Date	Percentage of infection (%)	Color
Aldeibli	1/10/2010	No new infection	1.25b
	15/10/2010	No new infection	1.6a
Alkhudairi	1/10/2010	3	0.86d
	15/10/2010	10	1.13c
LSD			0.06
CV%			6.1

There is significant difference between the averages followed by different letters in one column (P = 0.05).

4. Conclusion

The results of this study indicate that the activity of olive fly began in early June during the 2010 season, and two major periods passed through this season. The first period of fly activity started from the emergence of the fly and continued to mid-August while the second period started from the last week of September and continued to the date of harvest in mid-October. During the period between the third week of August and the beginning of the fourth week of September a lack of activity of the olive fly was observed, and the number of males attracted to the traps decreased. This is probably due to the high temperature in this period (temperature exceed 35 °C).

Female flies began to lay eggs on the fruits of Aldeibli variety during the third week of June, where the percentage of infection was 9% on 25 June, and the average of length and fruit diameter was 1.2 ± 0.06, 1.59 ± 0.97 cm respectively. The percentage of infection continued to rise gradually to reach 24% in 20 August. This rise was accompanied by an increase in the length and diameter of the fruits. The correlation coefficient was positive. This result confirms the findings of Antonelli & Chesi [19] in which the rate of infection also increases with the increase of weight and diameter, length of the fruit. In addition Mesbah & Magda [20] stressed the positive relationship between the size of olives and the percentage of infection of olive fruit fly.

The average fruit weight of Aldeibli variety was 1.70 ± 0.29 g on 25 June when the symptoms of infection appeared, and this result was close to the findings exposed by Edriss [16] who pointed out that the olive fruit fly did not begin to lay eggs in the fruits of Aldeibli variety except when the average fruit weight was more than 0.8 g (0.8 g average weight of the fruit in the first week of June). This fact is one conducted to the result from researchers that conducted trials on other areas and this is probably due to the changes in the cultivated varieties and the difference in climatic conditions and farming methods as well as many other factors.

The relationship between the proportion of oil in the Aldeibli variety and the percentage of infection was positive and the correlation coefficient was high during the first period of fly activity. The relationship between the hardness of the epicarp and the percentage of infection was negative and weak and the average of hardness of epicarp of Aldeibli variety was 57.08 ± 4.83 g with the onset of infection and 54.51 ± 6.087 g when the percentage of infection was 24% on 20 August.

There was no correlation between the percentage of infection and fruit color as it remained green on Aldeibli variety throughout the first period.

Signs of infection did not appear on the fruits of Alkhudairi variety throughout the first period, despite the presence of flies in the field. From the previous results we note that the fruits of Aldeibli variety exceed in terms of length and diameter, and these indicators may have played a role in the preference of the fly to Aldeibli variety. The results of laboratory

studies have indicated that olive fruit fly preferred balls for oviposition with a diameter of 7.5 cm in comparison to smaller balls [6].

The high proportion of oil during the first period in the fruits of Aldeibli variety, in comparison to Alkhudairi variety, may have contributed to the higher attraction of fly to the fruits of Aldeibli for providing a ready source of amino acids, vitamins and growth factors that are required from the female for the maturity of the ovaries [21].

The hardness of epicarp of Aldeibli variety was low in relation to the fruits of Alkhudairi cultivar. It is possible that olive fly prefers the fruits with low hardness epicarp at Aldeibli variety in order to facilitate fruit penetration and eggs lying. Sharaf [22] has demonstrated that the small size and high hardness of epicarp in the fruit reduces the rate of infection. Gumusay [12] has indicated that the fruits of the olive-skinned soft were more susceptible to the fruits of the olive fly.

Unlike the first period at the beginning of the second period of the season, it was observed that olive flies preferred the fruits of Alkhudairi variety and were indifferent to the fruits of Aldeibli variety although the length, diameter and weight of Aldeibli fruit remained higher than the Alkhudairi variety. However there was no significant difference in the proportion of oil between the two varieties as the difference in hardness epicarp diminished substantially between the varieties from the beginning of the season. A new factor appeared in this period which is the fruit color. The value of the color index of Jaen in the Aldeibli variety was higher than that in Alkhudairi variety. Gumusay [12] has pointed out the importance of color in the preference of different types of fruit, the green color was a favorite to fly.

By taking a comprehensive look at the results of the two periods, the change has been noticed in some of the indicators studied in relation to the two varieties. It is possible that a change in the behavior of the fly has happened during the season. As a result, so the olive files choose the appropriate varieties or even the fruits of one cultivar [11], especially that the varieties of this study were some of the oldest varieties in this region. It is also possible that the fly has adapted to the qualities of these fruits. Observation of the field shows that endemic varieties are more likely to olive fly [9, 13, 15].

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