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Ecological studies on *Aonidiella aurantii* and *Saissetia oleae* infesting olive trees at Northeastern of Delta, Egypt

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Abstract
The California red scale, *Aonidiella aurantii* (Maskell) (Hemiptera: Diaspididae) and the olive black scale, *Saissetia oleae* (Olivier) (Hemiptera: Coccidae) are of the most important hemiptrous insects. The present investigation aimed to study some ecological aspects of these pests in olive orchards in to governorates of Dakahlia (Aga district) and Damietta (Kafr El Battikh district) during a whole year (from the 1st of June 2021 till the 31st of May 2022). The obtained data showed that both of *A. aurantii* and *S. oleae* exhibited four peaks of seasonal activity during the studied year in Aga and Kafr El Battikh districts. The highest activity of *A. aurantii* was recorded during autumn season; while, the highest activity of *S, oleae* was recorded during summer season. The most populations of *A. aurantii* and *S. oleae* were distributed on the twigs at the height of 1 meter from the ground (contributed approximately 50% of the collected populations) in comparison with the heights of 2 and 3 meters. Daily temperature degrees and relative humidity had insignificantly positive effects on *A. aurantii* and negative effects on *S. oleae* populations. On another hand, relative humidity was more effective on the populations of the two scale insects than temperature degrees.

Keywords: *Aonidiella aurantii* (Maskell), hemiptrous insects, olive black scale

Introduction

The California red scale, *Aonidiella aurantii* (Maskell) (Hemiptera: Diaspididae) infested many host plant species belonging to at least 80 plant families (El-Minshawy *et al.*, 1974 [11] and Moursi, 1991) [23]. *A. aurantii* inserts its mouthparts deep into plant tissues and sucks the sap from parenchymal cells. Saliva which injected as the sales feed is very toxic to the plants. Characteristic yellow spots on leaves developed under and around female scales and prolonged infestation may cause leaf drop and dieback of twigs. Mature fruits can become completely encrusted with scales and the developing scales form prominent pits on fruit which still evident; then these fruits dry out and fall off (Bedford, 1998) [7]. The population fluctuations of *A. aurantii* showed considerable differences on many host plants in different parts of the world (Selim, 1993, Yarpuzlu *et al*., 2008 [37], Morsi, 1999 [22] and Kaiju, 2013) [17].

Ibrahim and his team (Ibrahim *et al.*, 2023) [15] studied the effect of *Lepidosaphes ulmi* against olive trees under many changed ecological conditions.

Lepidsaphes beckii and *Aonidiella aurantia* were reported an invasive pest infesting some species of citrus plants, as well as their host preference and distribution were well investigated (Youssef *et al.*, 2022) [38].

The olive black scale, *Saissetia oleae* (Olivier) (Hemiptera: Coccidae), is a polyphagous species that can occur on several host plants which is considered one of the most important pests infesting leaves and twigs of olive trees in the Mediterranean region (Morillo, 1977 [21]; Ben-Dov and Hedgson, 1997 [9]; Habar & Mifsud, 2007 [13]; Moghaddam & Tavaloli, 2010 [19] and Sema & Selma, 2010) [32]. After hatching, the crawlers of *S oleae* searching for a suitable place to settle (Tena *et al*., 2007) [36] and the damages are produced when large populations are present; where, their feeding can cause physiological damage to its host plant through a depletion of nutrients and increase in the transpiration rate. According to Smith *et al*. (1997) [33]and Passos de Carvalho *et al*. (2003) [27], *S oleae* is known by its high reproductive capacity. The density of *S. oleae* populations varied from year to year and from region to region (Ilias & Hammadi, 2017) [16].

To get a good control for any pest, ecological studies should be done to determine the suitable time or method for controlling. Therefore, the present investigation was carried out to study some ecological aspects of *A. aurantii* and *S. oleae* in olive orchards.

Materials and methods

The present study had been conducted in two districts; the first district (Aga) located in Dakahlia governorate; while, the second district (Kafr El Battikh) located in Damietta governorate for a whole year (from the 1st of June 2021 till the 31st of May 2022). An area of about one feddan (= 4200 m^2) cultivated with olive trees was selected in each district for the present study. In each area, five trees homogenous in age and size (as replicates) were selected randomly. Every two weeks, ten branches of about 20 cm length were cut from each tree at the height of 1 meter from the ground, put in paper bags and well tied. To estimate the effect of height on the pests' populations, the same action was done at the heights of 2 and 3 meters from the ground. All bags were transported to laboratory for investigation. Where, on each branch, numbers of nymphs and adults of *A. aurantii* and *S. oleae* on the leaves or twig were counted and recorded.

Among the available meteorological data of Dakahlia and Damietta governorates, daily averaged temperature degrees and relative humidity were obtained from the Central Laboratory for Agricultural Climate, Agricultural Research Center, during the period from the 1st of June 2021 till the 31st of May 2022. The daily records of each weather factor were grouped into bi-weekly means according to the sampling dates. The mean bi-weekly numbers of *A. aurantii* and *S. oleae* were correlated with each weather facto and the simple, multi regressions and explained variance were analyzed by using the computer program of CoHort Software (2004) [10]. Also, data were analyzed by using one-way ANOVA followed by least significant difference (LSD) at probability level of 0.05 by using the same computer program.

Results

1. Population fluctuations of *A. aurantii* and *S. oleae*

1.1 A. aurantii

Data illustrated in Fig. (1) showed that *A. aurantii* exhibited four peaks of seasonal activity in Aga and Kafr El Battikh districts. These peaks were recorded at Aga district as 100.1, 95.0, 85.0 and 89.9 individuals/10 twigs (as total population) on the 27th of July, 21st of September, 14th of December and 8th of March, respectively. At Kafr El Battikh district, the four peaks were recorded as 111.4, 93.2, 81.7 and 85.8 individuals/10 twigs (as total population) on the 15th of June, 5th of October, 30th of November and 22nd of March, respectively.

As shown in Fig. (1), population of *A. aurantii* nymphs was higher than adults all over the year in the two districts.

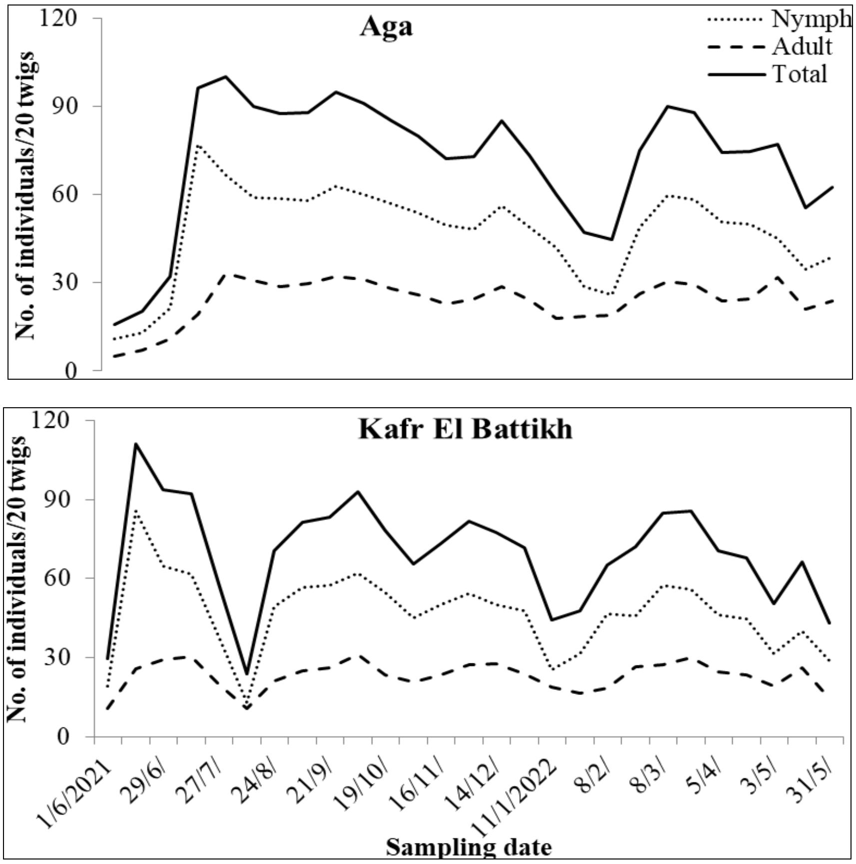

Fig 1: Population fluctuations of *A. auranatii* nymphs and adults as well as the total numbers of them in olive orchards at Aga and Kafr El Battikh districts during 2021/2022.

From the obtained data, it can be noticed that the acxtivity of *A. aurantii* population was higher during autumn season in the two studied districts with significant variation at Kafr El Battikh district. The mean population of *A. aurantii* which recorded during summer, winter and spring seasons did not differe significantly in the two districts (Fig., 2).

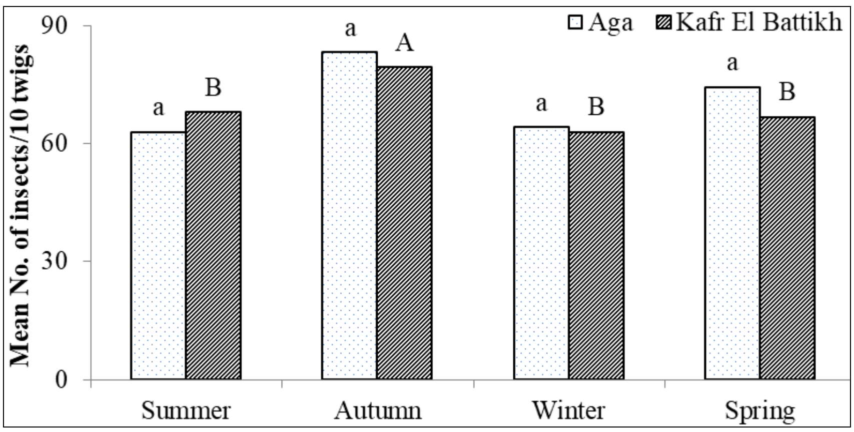

Fig 2: Mean numbers of *A. aurantii* infesting olive orchards at Aga and Kafr El Battikh districts during the four seasons of 2021/2022 year. (Notice: In each district, colomns had the same letter did not differe at significant of 5%)

1.2 *S. oleae*

With respect to *S. oleae*, its population showed four peaks of seasonal activity at the two districts and the population of nymphs was generally higher than adults (Fig., 3). At Aga district, the peaks of the total population were recorded on the 29th of June (24.6 individuals/10 twigs), 5th of October (8.3 individuals/10 twigs), 22nd of February (11.9 individuals/10 twigs) and 5th of April (13.8 individuals/10 twigs). The four peaks of the total population at Kafr El Battikh district were recorded on the 15th of June (21.6 individuals/10 twigs), 21st of September (6.9 individuals/10 twigs), 22nd of February (13.3 individuals/10 twigs) and 3rd of May (9.9 individuals/10 twigs).

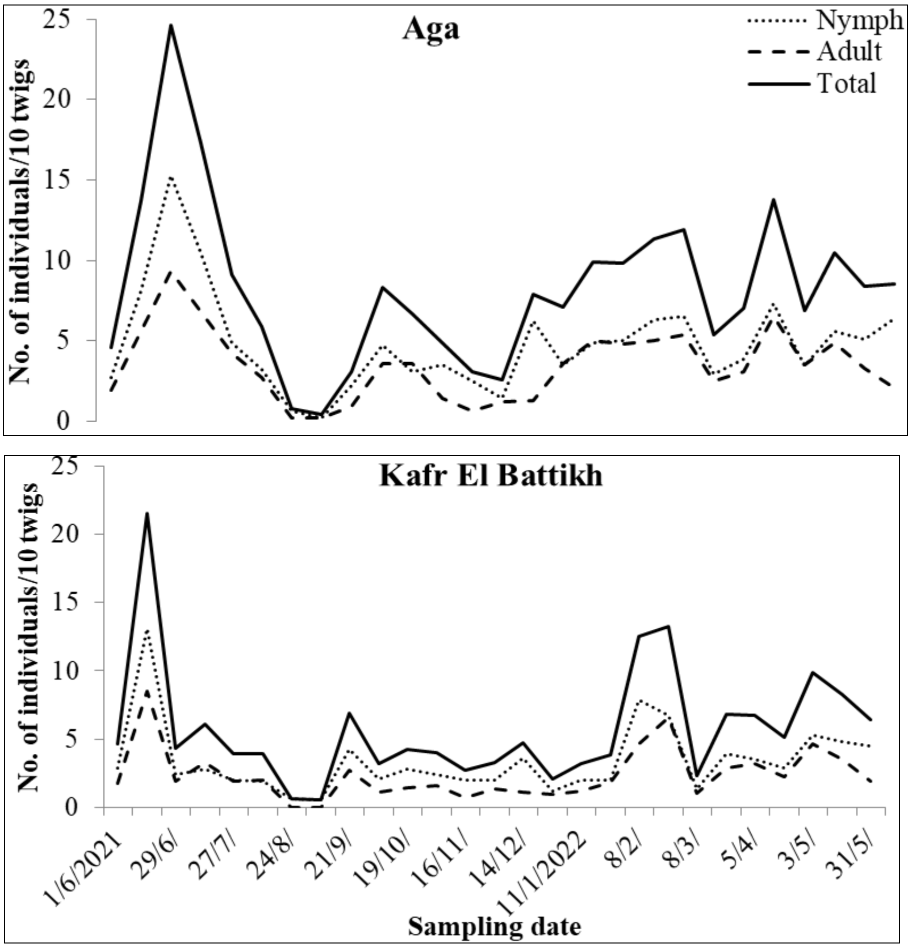

Fig 3: Population fluctuations of *S. oleae* nymphs and adults as well as the total numbers of them in olive orchards at Aga and Kafr El Battikh districts during 2021/2022.

The black scale, *S. oleae* showed its signficantly higher acxtivity durig summer season followed by spring and winter seasons (with no signficant differences between them). Fig. (4) showed also that the significantly lowest activify of *S. oleae* was recorded during autumn season at Aga and Kafr El Battikh districts.

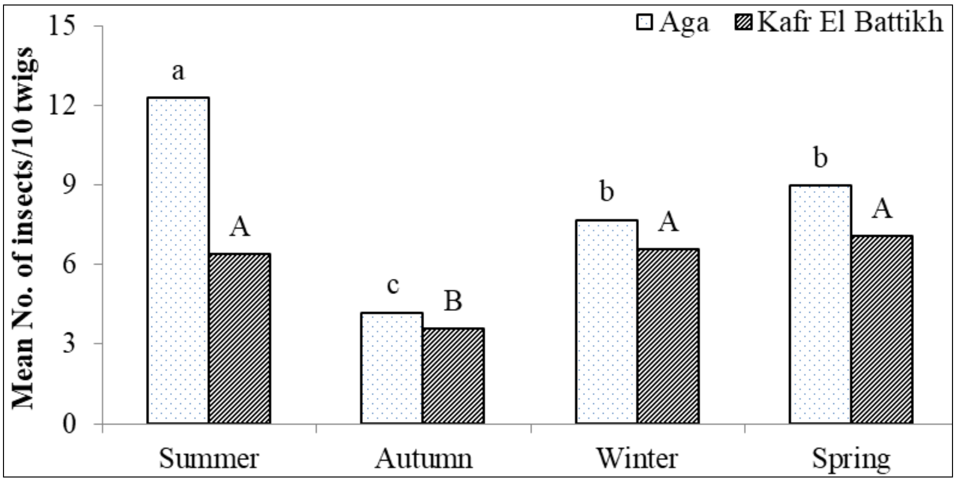

Fig 4: Mean numbers of *S. oleae* infesting olive orchards at Aga and Kafr El Battikh districts during the four seasons of 2021/2022 year. (Notice: In each district, colomns had the same letter did not differe at significant of 5%)

2. Distribution of *A. aurantii* and *S. oleae* in different heights of olive trees

1. *A. aurantii*

The populations of *A. aurantii* nymphs and adults as well as the total numbers of them were distributed with high values on the twigs which were obtained from 1 meter height from the ground followed by the twigs from the heights of 2 and 3 meters, respectively with signfucant differences between the three heights (Fig., 5). At Aga and Kafr El Battikh districts, the height of 1 meter contributed with 54.4 and 54.3% of the total population of *A. aurantii*, respectively; while, the height of 2 meters contributed with 29.9 and 29.5% and the height of 3 meters contributed with 15.7 and 16.2% of *A. aurantii* population.

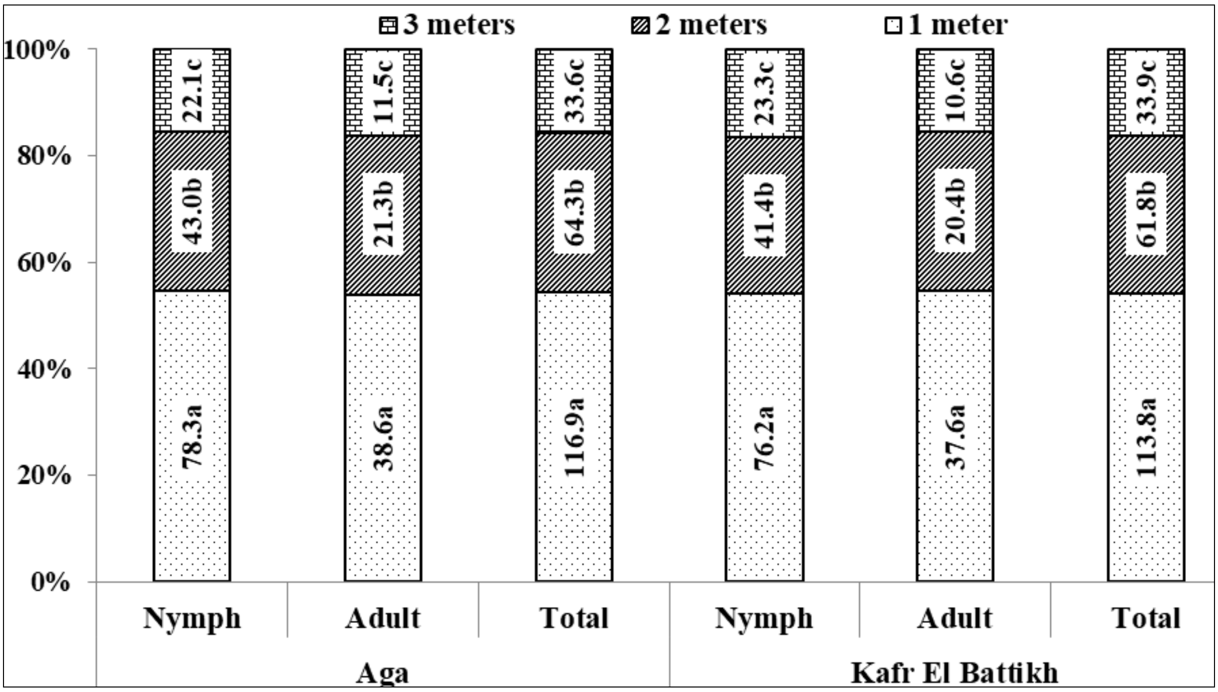

Fig 5: Distribution of *A. aurantii* population (nymphs, adults and total) in different heights (1, 2 and 3 meters) of olive trees at Aga and Kafr El Battikh districts during 2021/2022. (Notice: Heights had the same letter in the same colomn did not differe at significant of 5%)

2.2 *S. oleae*

As recorded on *A. aurantti*, the populations of *S. oleae* (nymphs, adults and total) were distributed with high values in the height of 1 meter from the ground followed by the the heights of 2 and 3 meters, respectively with signfucant differences between the three heights. At Aga district, the height of 1, 2 and 3 meters contributed with 49.8, 31.6 and 18.6% of the total population of *S. oleae*, respectively.; while, at Kafr El Battikh district these heights contributed with 47.4, 34.9 and 17.7% of *S. oleae* population (Fig., 6).

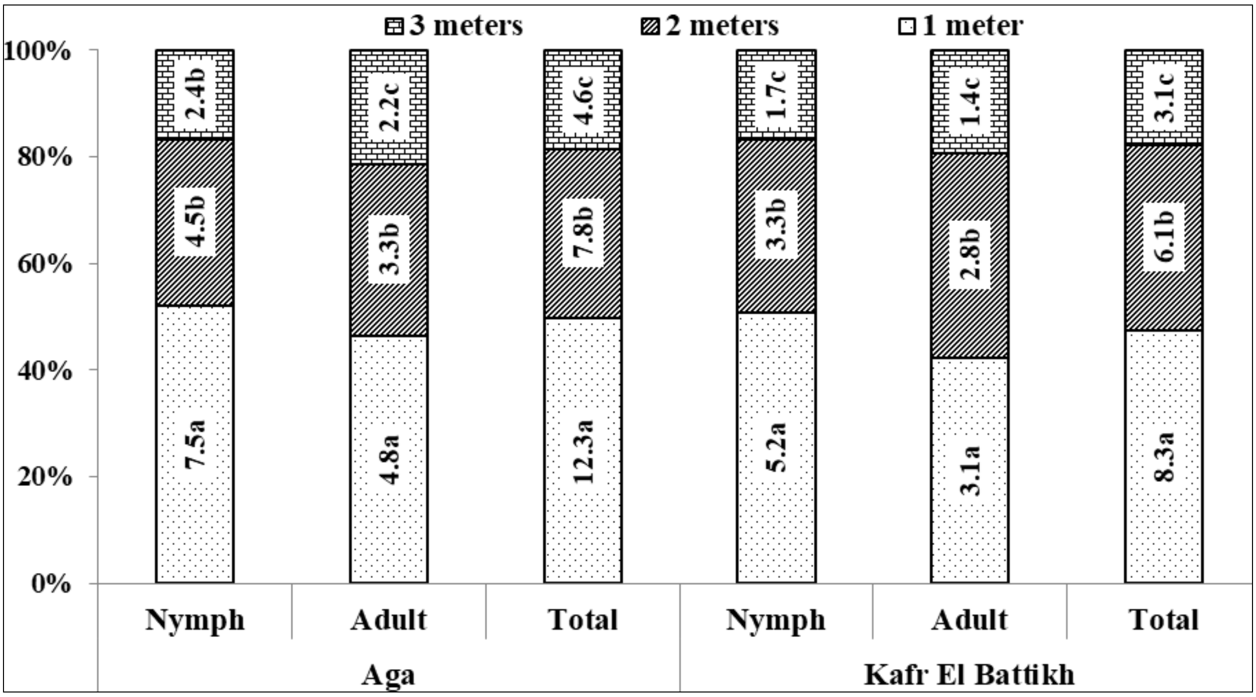

Fig 6: Distribution of *S. oleae* population (nymphs, adults and total) in different heights (1, 2 and 3 meters) of olive trees at Aga and Kafr El Battikh districts during 2021/2022. (Notice: Heights had the same letter in the same colomn did not differe at significant of 5%)

3. Effect of mean temperature and relative humidity

3.1 On the changes of *A. aurantii* population

Temperature degrees and relative humidity had positive effects on the changes of *A. aurantii* populations; where, the correlation coefficient values for the effect of temperature were 0.13^{ns} and 0.07^{ns} at Aga and Kafr El Battikh districts. The calculated r-values beween *A. aurantii* population and relative humidity reached 0.22^{ns} and 0.26^{ns} at Aga and Kafr El Battikh districts (Table, 1). The effect of relative humidity on *A. aurantii* was higher (R^2 = 5.1 and 7.1% at Aga and Kafr El Battikh districts) than temperature degrees (R^2 = 1.7 and 0.6%).

Table 1: Effect of temperature degrees and relative humidity on the changes of *A. aurantii* population in olive orchards at Aga and Kafr El Battikh districts during 2021/2022.

District	Weather factor	r	b	P	R^2
Aga	Temerature degrees	0.13	0.03	0.51	1.7%
	Relative humidity	0.22	0.06	0.25	5.1%
Kafr El Battikh	Temerature degrees	0.07	0.02	0.70	0.6%
	Relative humidity	0.26	0.09	0.17	7.1%

The combined effect of temperature degrees and relative humidity on *A. aurantii* represented by 8.9 and 9.4% of the total factors affecting pest population at Aga and Kafr El Battikh districts. The relationship between the changes of two weather factor and *A. aurantii* population could be represented by the following equations:

At Aga district:

No. of *A. aurantii* = 2.50 + 0.82 Tem. + 0.95 RH% (R^2 = 8.9%)

At Kafr El Battikh district:

No. of *A. aurantii* = 9.40 + 0.54 Tem. + 0.90 RH% (R^2 = 9.4%)

3.2 On the changes of *S. oleae* population

Unlike the case of *A. aurantii*, temperature degrees and relative humidity had negative effects on the changes of *S. oleae* populations; where, the correlation coefficient values for the effect of temperature were -0.10^{ns} and -0.17^{ns} at Aga and Kafr El Battikh districts. The calculated r-values beween *S. oleae* population and relative humidity recorded as -0.32^{ns} and -0.25^{ns} at Aga and Kafr El Battikh districts (Table, 2). On another hand, The effect of relative humidity on *S. oleae* was higher (R^2 = 10.5 and 6.7% at Aga and Kafr El Battikh districts) than temperature degrees (R^2 = 1.7 and 6.7%).

Table 2: Effect of temperature degrees and relative humidity on the changes of *S. oleae* population in olive orchards at Aga and Kafr El Battikh districts during 2021/2022.

District	Weather factor	r	b	P	R^2
Aga	Temerature degrees	-0.10	-0.14	0.51	1.7%
	Relative humidity	-0.32	-0.43	0.09	10.5%
Kafr El Battikh	Temerature degrees	-0.17	-0.22	0.37	3.1%
	Relative humidity	-0.25	-0.40	0.19	6.7%

The combined effect of temperature degrees and relative humidity on *S. oleae* represented by 15.4 and 12.8% of the total factors affecting *S. oleae* population at Aga and Kafr El Battikh districts. The relationship between the changes of two weather factor and the pest population could be represented by the following equations:

At Aga district:

No. of *S. oleae* = 28.00 + 0.20 Tem. + 0.28 RH% (R2 = 15.4%)

At Kafr El Battikh district:

No. of *S. oleae* = 21.20 + 0.19 Tem. + 0.21 RH% (R2 = 12.8%)

Discussion

The present results showed that both of the California red scale insect, *A. aurantii* and the olive black scale, *S. oleae* exhibited considerable abundance fluctuations throughout the year of study at the two studied districts (Aga, Dakahlia governorate and Kafr El Battikh, Damietta governorate). These results are in agreement with the results of Rizk et al. (1978) [29] and (Farghaly *et al.* 2016) [12] (on *A. aurantii*) and (Ilias and Hammadi 2017) [16] (on *S. oleae*).

On another hand, the present results showed that *A. aurantii* exhibited four peaks of seasonal abundance with relative high population during autumn season and low occurance during winter season. These findings are near to the findings of Swailem *et al.* (1980) [35]; they found that the populations of *A. aurantii* increased during late summer and autumn and were smallest during winter. Also, the present results are partially agreed with those obtained by Farghaly *et al.* (2016) [12]; they reported that *A. aurantii* infesting citrus trees recorded three peaks of activity with highest numbers during autumn and spring months and the low activity was recorded during winter months. Also, Selim (1993) [31], Morsi (1999) [22], Yarpuzlu et al. (2008) [37] in Turkey, Kaiju (2013) [17] who found that *A. aurantii* had 3-4 generations per year on citrus. Abd-Elghaffar *et al.* (2018) [1] reported that the highest dominance percentages of *A. aurantii* infesting citrus trees were recorded in winter and the lowest one was represented in summer. Abul- Nasr and Swailem (1975) [2] reported that the highest level of population density of *A. aurantii* on citrus tree was recorded during spring and autumn months; while, the population reached its minimum levels during winter. Mona (2012) [20] mentioned that *A. aurantii* reached its maximum population during spring season on citrus trees.

The olive black scale, *S. oleae* exhibited four peaks of seasonal abundance with relative high activity during summer season and the low activity was recorded during autumn season. These findings are near to the findings of Ilias and Hammadi (2017) [16]; they reported that *S. oleae* infesting olive trees showed four peaks of abundance for immature and mature stages with highest activity during autumn and summer months; while, the low activty was recorded during winter months. Also, Souza *et al.* (2015) [34] reported that the greater abundance of *S. oleae* was in spring and summer months, but hey recorded three generation yearly on olive trees. Noguera *et al.* (2003) [24], Pereira (2004) [28], Tena *et al.* (2007) [36] and Ouguas & Chemseddine (2011) [25] reported that the most crawler emergenceof *S. oleae* was recorded in summuer months. Barreda (2007) [6] and Mesbah *et al*. (2020) [18] reported that there was one important peak of *S. oleae* population on olive trees in summer. Badary (2002) [3] reported that *S. oleae* has two annual generations per year. Moreover, Badary (2010) [4] reported that the population of this reached the maximum during mid of August and mid of September.

The present results showed that the heights (from the ground) of the taken samples from olive trees showed significant effects on the populations of *A. aurantii* and *S. oleae*; where, samples which taken from 1 meter height of olive trees contributed more than 50% of the collected *A. aurantii* individuals and contributed near to the same percentage in the case of *S. oleae*. The samples taken from 2 meters height ranked the second; while, samples collected from 3 meters from the was the lowest height contributed with obviously less than 20% of the toltal collected individuals of *A. aurantii* and *S. oleae*. Ilias and Hammadi (2017) [16] mentioned that crawlers preferred the young leaves and branches. While, Ouguas & Chemseddine (2011) [25] suggested that young tissues are rich in sap and tender, young crawlers can easily suck the sap. Also, these crawlers remain on the same organ and do not move far away from it (Paparatti & Lecanidae, 1986) [26]. These findings may explain the present results; however, crawler stage chooses a place of a young leave or twig and settles there for the relatively long duration of its life then the young leaves or twigs became old. Also, the present findings may be attributed to the preference of scale insects to keep itselves away from the direct sunlight by being in shady places. This explanation can be supported by the findings of Ilias and Hammadi (2017) [16] and Belguendouz *et al.* (2011) [8]; they, found that some of scale insects preferred to the Center direction of the olive trees. The same authors added that, larvas, nymphs and adult females prefered the Center and North directions due to highly humidity with low mild temperature and light.

The present results revealed that daily temprature degrees and relative humidity had insignficantly positive effects on *A. aurantii* and negative effects on *S. oleae* populations. On another hand, relative humidity was more effective on the populations of the two scale insects than temperature degrees. These results agreed with Selim (1993) [31], Balboul & Helmy (2019) [5] and Salman *et al.* (2022) [30]; they found that there was positive correlation between abiotic factors (temperasture degrees and relative humidity) and the total of nymphal and female stages of *A. aurantia*. Haris (2015) [14] mentioned that the maximum temperature was the effective factor on *A. aurantii* population. Also, the present findings on *S. oleae* can be supported by Barreda (2007) [6]; who found that population of *S. oleae* population showed insignficant negative reactions to the increase of temperature degrees and relative humidity (%). Tena *et al.* (2007) [36] demonstrates that low temperatures synchronized the developmental stages of *S. oleae*, and consequently, populations were strongly synchronous after the winter. Also, Ilias & Hammadi (2017) [16] suggested that the climate change with the high temperature in summer change or influence the development of *S. oleae*. While, Mesbah *et al.* (2020) [18] showed a significant positive correlation between daily mean temperature and estimated population density of *S. oleae*.

The variations between the present results and any of the others may be attributed to the variations of climatic factors, host plant species and/or the cultivated crops which cultivated in the areas surround the experimental farms.

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