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Ecological aspects on California red scale *Aonidiella aurantii* (Hemiptera: Diaspididae) on mandarin trees in Sohag Governorate, Egypt

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Abstract:

Citrus is one of the most important fruit crops in Egypt. Its trees are attacked by many pests, especially scale insects. *Aonidiella aurantii* (Maskell) (Hemiptera: Diaspididae) is one of the dangerous pests that infest citrus trees in Egypt, especially in Upper Egypt. It was noted that mandarin trees were severely infested with this pest in the Shandawil Horticulture Research Station, Sohag Governorate during two successive consecutive seasons (2019-2020). Studying the population density of this pest revealed that, it had four activity periods simultaneously with the abundance of nymphal stage and recorded in nymphal stage, which had four peaks of activity per a year of study during as following, the period recorded on 8th March (End winter) with (114 nymphs/30 leaves), the second peak was recorded on 8th Jun (Spring peak) with (186 nymphs/30 leaves), the third peak, which recorded on 8th Sep. with (213 nymphs/ 30 leaves), finally the fourth peak that recorded on 8th Dec. (Early winter) with (179 nymphs/30 leaves) during 2019. Also recorded on 8th Mar., 8th Jun. ,23rd Sep. and 8th Dec. with a population of (148, 242, 264 and 223 nymph/30 leaves) during 2020. As a result of these activity periods three overlapping generations/year. There was a positive significant relationship between abiotic factors and the nymphal stage and the total population of *A. aurantia*, while relative humidity relations were negative and insignificant in both years of study.

Introduction

Citrus is one of the first fruit crops with a high export value. Also, come second only to grapes in planting, production of fruit trees worldwide (Spiegel-Roy and Goldschmidt, 1996). The different varieties of orange are infested by different species of insects, among them the armored scale insects (Jacas- Miret and Garcia-Mari, 2001; Garcia- Mari, 2006 and Jendoubi *et al.*, 2008). The California red scale *Aonidiella aurantii* (Maskell) (Hemiptera: Diaspididae) is considered a key pest of citrus that has spread during the last decades up to cover a vast extension of agricultural landscapes· (Balboul and Helmy, 2019). It is one of the most important pests infesting citrus trees in different parts of the world (Abd-Rabou, 2009). The California red scale *A. aurantii* is considered one of the serious pests among them (Selim, 2014). This pest inserts its mouthparts deep into plant tissue and sucks sap from parenchyma cells, where the prolonged infestation may cause leaf drop and defilation and dieback of twigs and eventually large branches, also maturing fruit can become completely encrusted with scales; developing scales form prominent pits on young fruit which are still evident when the fruit matures. Such fruit tends to dry out and fall off. Even the trunk can become heavily infested (Bedford, 1998).

The seasonal abundance of the California red scale on Balady orange gave four peaks of abundance recorded, in February, June, September, and November (Selim, 2014). *A. aurantii* has three generations in spring, summer and autumn per year on lemon orchards in Adana, and Mersin provinces during 2004-2005 (Yarpuzlu *et al.,* 2008). *A. aurantii* had three overlapping generations under the field conditions during the two years on citrus trees and the effect of the maximum and minimum temperature on the total population during two years of study were positive significant correlation during the two years of study the same side the combined effect of climatic factors on California red scale *A. aurantii* during the two years of study was significant and the explained variance (E.V.) presented (68% and 57.7%) during the two years of study (Balboul and Helmy, 2019). The simple correlation between (Maximum and minimum temperature) and the *A. aurantii* total population were positive significant during the two years of study and the explained variance of all variables recorded (74 and 73 %) in Qena Governorate (Haris, 2015).

The present work is to study the population dynamics of the California red scale, *A. aurantii* infesting mandarin trees in Sohag Governorate for two successive consecutive seasons (2019-2020).

Materials and methods

1. Seasonal abundance of *Aonidiella aurantii*:

Recording abundance of *A. aurantii* on mandarin trees was carried out in the Shandawil Horticulture Research Station, Sohag area, Sohag Governorate during two successive consecutive seasons (2019-2020). The selected orchard does not receive any chemical control during both studied seasons and two years prior to the experiment. All trees received the same horticultural practices during the studied period. Samples of infested mandarin trees leaves were taken biweekly throughout the studying period (2019-2020). Samples of 30 leaves for each direction of mandarin orchard and 30 leaves were taken from the center, (150 leaves in total). Samples were kept in polyethylene bags with minute holes and transferred directly to the laboratory for examination. Samples were examined visually or with the aid of stereoscopic binoculars. All alive found on each surface were assorted and recorded as preadult (Nymphs), adult females, and adult gravid females. Scale insect was identified by the specialists of the Department of Scale insects and Mealybugs, Plant Protection Research Institute, Giza, Egypt.

2. Age structure calculation:

To calculate the age structure per sample, the mean number of each stage was divided by the total and multiplied by 100. This method gave a percent proportion of the total per sample regardless of the total number of presenting insects (i.e., Population density). The number and duration of generation were determined using the obtained data throughout the two successive years using the age-structure technique per sample over the year.

Generation was defined, as the time required for an insect to complete its life cycle (i.e., egg to egg). In the case of Diaspididae, eggs were ovipositing under the female until they hatch and crawl out. Gravid females were defined as females with eggs. The presence of gravid females was considered in this study as the presence of the egg stage. This phenomenon was used to determine the end of each generation and the beginning of the next one (El-Amir, 2009).

3. Meteorological factors:

Weather factors data assumed to affect studied insects (i.e., maximum and minimum daily temperatures and mean percentage of daily relative humidity) were obtained for the Sohag area from the Egypt-Weather Underground https://www.wunderground.com/global/EG.html. Obtained data was summarized for each fourteen days previous to the sampling date. Considered weather factors means over each determined generation was calculated and presented.

Results and discussion

1. Seasonal fluctuations of *Aonidiella aurantii* on mandarin trees during 2019-2020 at Sohag Governorate:

The red scale insect *A. aurantii* is one of the most damaging armored scales that infest citrus crops in Sohag Governorate. This study was carried out at the Shandaweel horticulture research station in Sohag Governorate, for two successive years starting from 8/1/2019 to 23/12/ 2020.

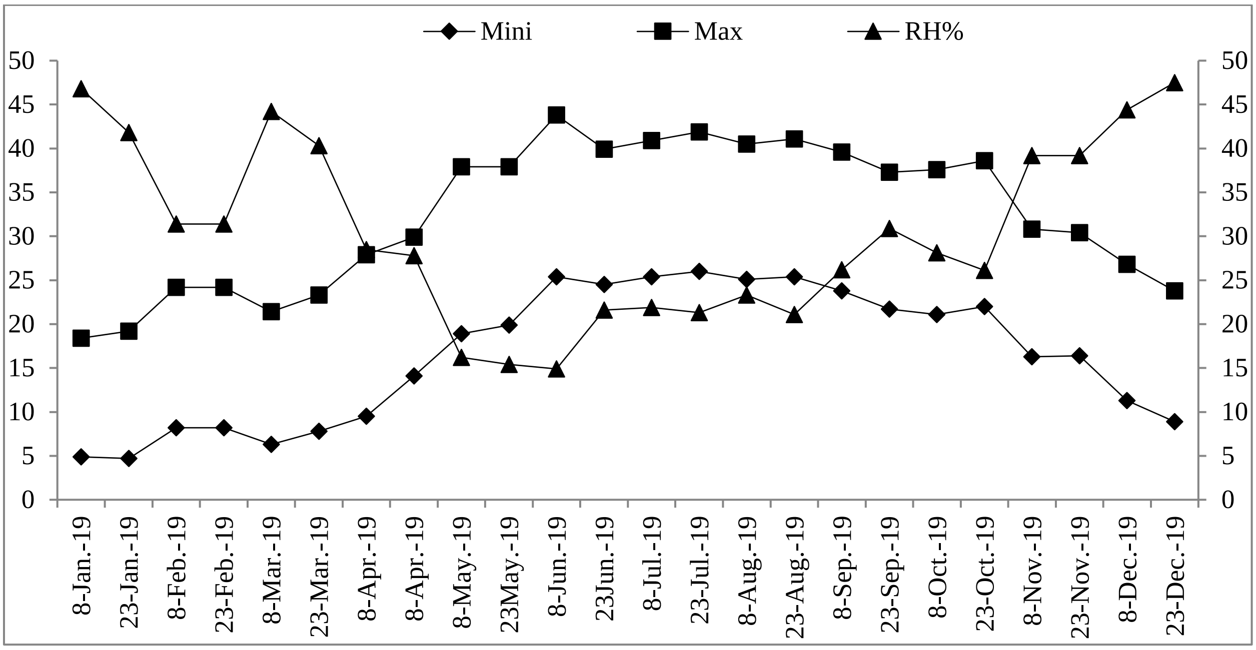
Data illustrated in Figures (1 and 2) illustrated the seasonal fluctuations of *A. aurantii* on mandarin leaves expressed as a live number of (Nymphs, adult female, and gravid female) and total population. Also, the abiotic or weather factors (Max. temp., min. temp. and relative humidity) were present in the same figures during the two years of study (2019-2020).

1.1. Nymphal stage:

Data illustrated in Figures (1 and 2) showed that the nymphal stage population had four peaks of activity per a year of study during the first year the first peak was the lowest peak due to slightly low temperature (End winter) and recorded on 8^{th} March with (114 nymphs/30 leaves), the second peak was recorded on 8^{th} Jun (Spring peak) with (186 nymphs/30 leaves) where the population increased as a result to temperature increase, the third peak which recorded on 8^{th} September was the highest one due to the more favorable abiotic factors (Temperature and relative humidity) its population recorded (213 nymphs/ 30 leaves), finally the fourth peak that recorded on 8^{th} December (Early winter) with (179 nymphs/30 leaves) its population somewhat decreased as a result of temperature decreasing.

Also, during the second year of study the nymphal stage population had four peaks of activity the first one recorded on 8^{th} March which was a low peak activity with a population of (148 nymph/30 leaves), the second peak of activity recorded on 8^{th} Jun and increased with the rising temperatures with (242 nymph/30 leaves), the third peak recorded on 23^{th} Sep. and was the highest peak of activity due to the more favorable conditions where its population reached (264 nymph/30 leaves), finally the last peak of activity recorded on 8^{th} Dec. and started to decreased again due to the noticeable drop in temperatures with a population of (223 nymph/30 leaves).

On the other hand, it is worth noting that nymphal stage number of the studying pest was present throughout the two years of study, but it decreased to some extent in winter season as a result of bad weather conditions



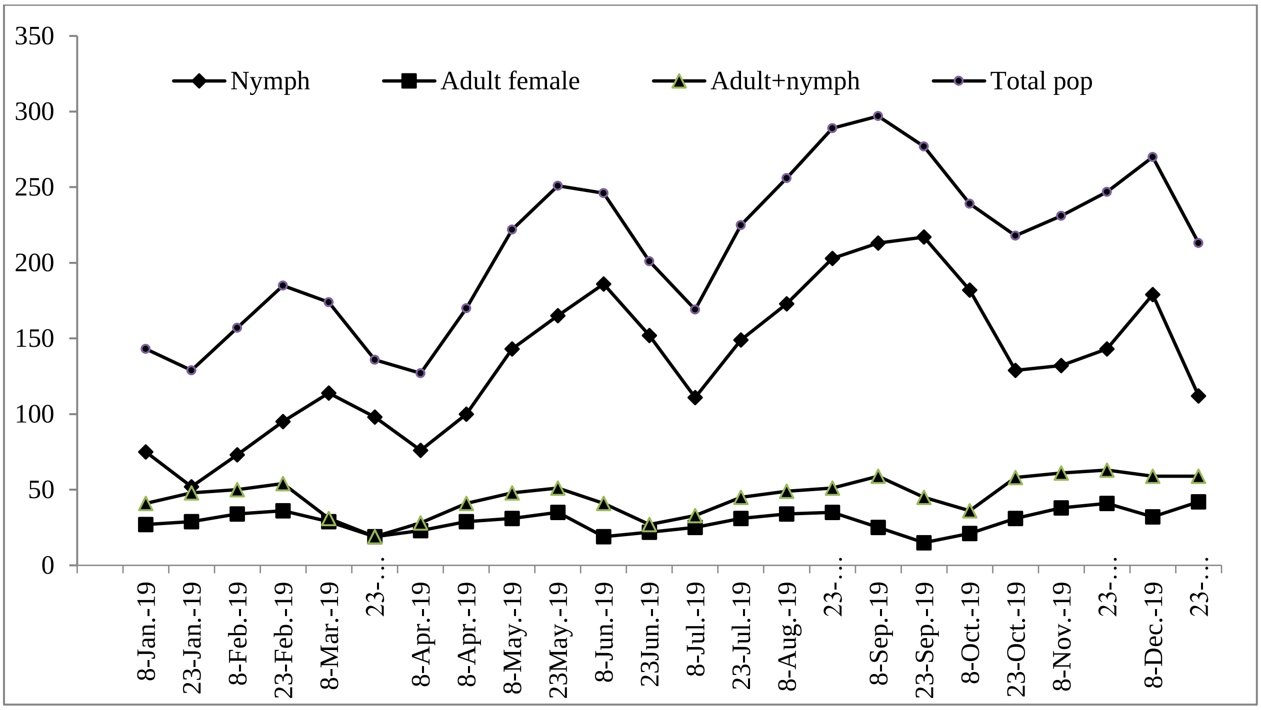
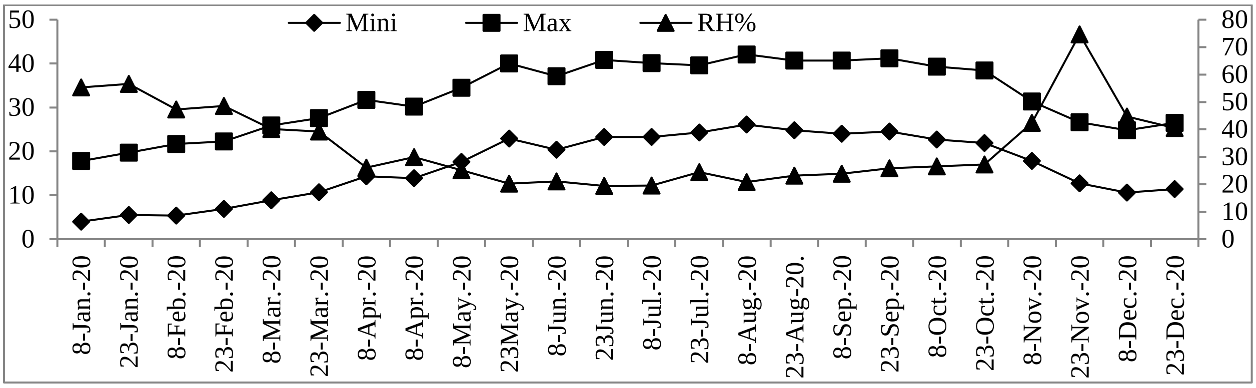


Figure (1): Seasonal fluctuation of *Aonidilla aurantii* different stages and total population during 2019.



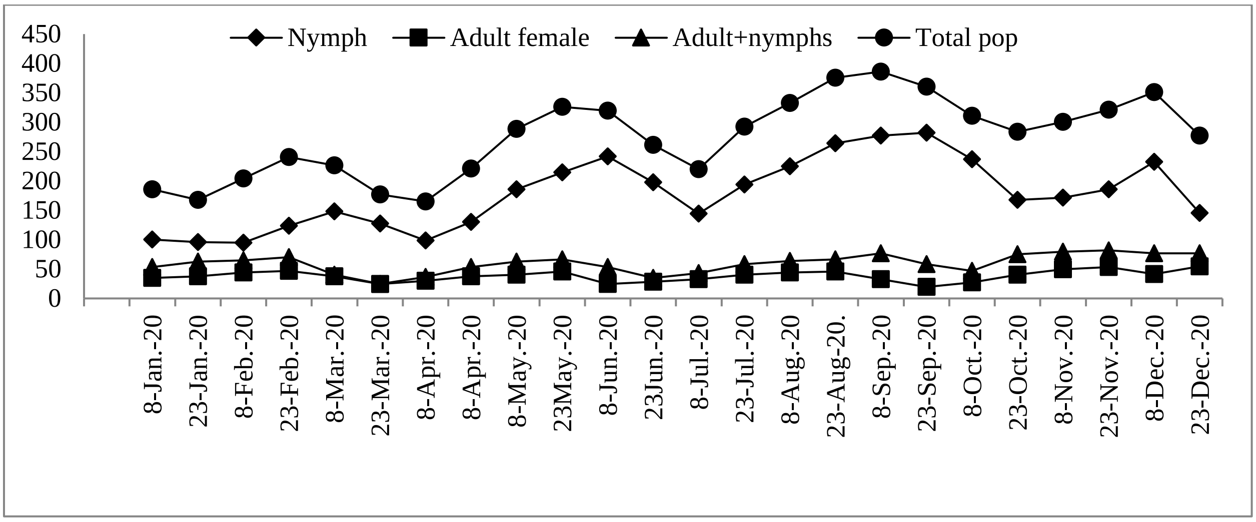


Figure (2): Seasonal fluctuation of *Aonidiella aurantii* different stages and total population during 2020.

1.2. Adult female stage:

Data recorded in the same figures showed that adult female population curve had four peaks per a year of study. During the first year the recorded on 8th Feb., 23th May, 23rd Aug. and 23rd Nov. with (34, 35, 35, and 41 adult females/30 leaves). Also, the adult female curve of the second year had four peaks recorded nearly in the same time of the first year as follows 23th Feb., 23th May, 23rd Aug. and 23rd Nov. where its population was higher than the first year as follows (47, 46, 46, and 53 adult females/30 leaves), respectively. On the other side the adult female curve recorded their lowest bottom in summer season where it reached (15 adult females/30 leaves) during the tow studying years.

1.3. Adult female with nymph stage:

Data present in the same figures showed that (Adult females+ nymphs) stage population curve had four peaks per a year of study recorded on 23rd Feb., 23rd May, 23rd and 23rd Nov. with (54, 51, 51 and 63 adult females+ nymphs), respectively for the first year of study. The same trend was recorded for the second year of study, four peaks recorded on 23rd Jan., 23rd May, 8th Sep. and 23rd Nov. with a population higher than the first year as follows (70, 66, 77, and 82 adult females+ nymphs), respectively. On the otherwise the low population of (Adult females+ nymphs) stage recorded through the first year of study in early spring and in late summer season for the second year of study.

1.4. Total population:

Total population curve of *A. aurantii* had four peaks during the first year of study recorded in 23rd Feb., 23rd May, 8th Sep. and 8th Dec. with 185, 251, 297 and 270 individual/30 leaves, respectively. On the same side during the second year of study the total population curve had four peaks exhibited at 23rd Feb., 23rd May, 8th Sep. and 8th Dec. with 241, 326, 386, and 351 individuals/30 leaves, respectively. The insect pest was present in abundant numbers throughout the two years of study, but the population decreased somewhat in the winter specifically in January.

These results were agreement with that obtained by Moustafa (2012) reported that the population of red scale *A. aurantii* has two peaks in April and October. Haris (2015) in Qena, Egypt, who reported that the population had four peaks per a year of study recorded on spring, summer, autumn and winter seasons, respectively. The highest peaks were obtained in early Aug. (Summer) and mid Oct. (Autumn) with 3102 and 3327 individuals/30 leaves, respectively.

2. Duration and number of annual generations:

The result of applying the age structure technique to the seasonal abundance data of *A. aurantii* obtained from Sohag Governorate over the two years on mandarin trees are graphically illustrated on Figures (3) and (4). Obtained trend over two studied years indicated the occurrence of four generations per year for *A. aurantii* on mandarin at Sohag location (Table 1) .

2.1. First year annual generation:

Over the first year the over wintering generation continued (Mainly as adult females and adult females + nymphs) up to the end of January. The first generation (Winter/spring generation) started on 23rd Jan. until 8th Apr. (2.5 months), 2019 (Marked by maximum population of adult females and adult females + nymphs in much synchronized fashion). The date 8th Apr., 2019 was considered as the terminal for the first generation.

The second generation (Spring generation) started thereafter and continued until re-emergence of the gravid females on 23rd Jul., therefore its duration was 3.5 months (8th Apr. till 23rd Jul.). The third generation (Summer/autumn) which started from 23rd Jul. till 23rd Oct. with duration of 3 months and characterized by the high density of nymphs as a result of high temperature which accelerate appearance of crawlers. The fourth generation (Autumn/winter generation) which started on 23rd Oct. and it was terminated in the beginning of the second year (Next Jan.) and characterized by the high density of adult females and gravid females which overwintered as it was.

2.2. Second year annual generation:

Over the second year of study similar results were obtained with little delay . The relevant dates were 23rd Jan., 8th Apr., 8th Jul. and 8th Oct. 2020 where their durations were 2.5, 3 and 3 months, respectively. The fourth generation continued to the next year.

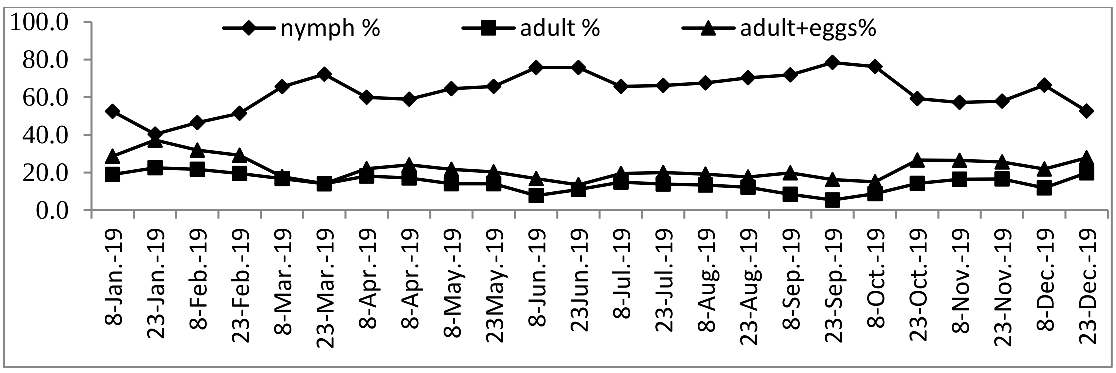


Figure (3): Age structure of *Aonidiella aurantii* different stages during 2019.

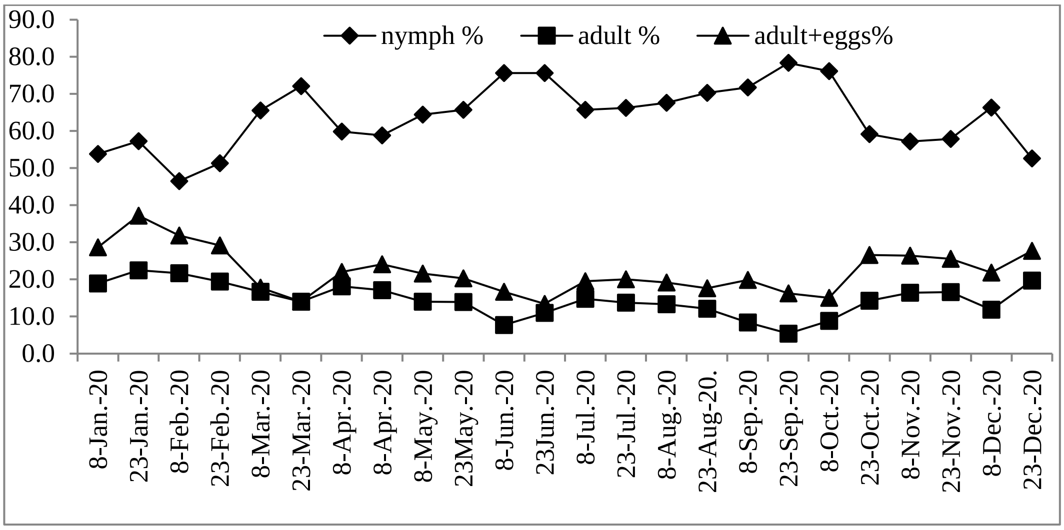


Figure (4): Age structure of *Aonidiella aurantii* different stages during 2020.

Table (1): Number and durations of the annual generations of *Aonidiella aurantii* on mandarin trees at Sohag Governorate (2019-2020).

Generations	Data from---- to	Duration in months
First year		
1st Generation	23/1 to 8/4	2.5
2nd Generation	8/4 to 23/7	3.5
3rd Generation	23/7 to 23/10	3
4th Generation	23/10 to the beginning of the following year	4
Second year		
1st Generation	23/1 to 8/4	2.5
2nd Generation	8/4 to 8/7	3
3rd Generation	8/7 to 8/10	3
4th Generation	8/10 to the beginning of the following year	4.5

El-Saadany *et al.* (1994) recorded that *A. aurantii* had four generation per a year of study on citrus. The 1st generation was observed at beginning of April till mid-July. The 2nd generation at mid of July till mid-October, while 3rd generation at the end of October till the early December. However, the 4th generation was shown at the mid February till mid-May. The red scale insect *A. aurantii* develops three generations per year on two host plants: (1st) in summer (2nd) in spring and the (3rd) in autumn. This behavior can be explained by farther study on the influence of trophic factors (Belguendouz *et al.* ,2013). Haris (2015) in Qena revealed that *A. aurantii* exhibited four generation on mandarin. The 1st generation was from early-March to end June, lasted 3 months. The 2nd generation was from early-June to mid-September and lasted 3 months. The 3rd generation was from mid-September to early-November and lasted 2 months. The 4th or last generation started from early-November to early-January and lasted 2 months.

3. Statistical analysis of the effect of abiotic factors on *Aonidiella aurantii* population on mandarin tree at Sohag 2019-2020:

Data in Tables (2 and 3) clearly showed the simple correlation and partial regression between *A. aurantii* (Different stages and total population) and abiotic factors were studied during two studied years (2019 and 2020) at Sohag Governorate.

3.1. Effect of daily maximum temperature:

During the two years of study as shown in Tables (2 and 3) max. temperature gave positive significant simple correlation with nymphal stage and total population (0.7558 and 0.6790), respectively throughout 2019 and (0.75718 and 0.64986), respectively during 2020. Simple regression. Also, simple regression was positive significant for nymph stage and total population during the two years of study as following, (4.63857 and 4.59183) and (6.09928 and 5.80658), respectively. Whereas, the simple correlation was negative insignificant with adult female stage and positive insignificant with gravid female stage (-0.18572 and 0.08056), respectively throughout 2019 and (-0.23845 and 0.00888), respectively during 2020. Simple regression was the same in case of the two stages adult female and gravid female whereas recording (-0.17279 and 0.12605), respectively throughout the first year and (-0.29845 and 0.018190), respectively during the second year.

Table (2): Statistical analysis of the effect of abiotic factors on *Aonidiella aurantii* population **on mandarin tree at Sohag 2019.**

Tested factors		**Simple correlation and partial regression**	**Nymph**	**Adult female**	**Adult+Nymph female**	**Total pop.**
Abiotic factors	Max	R	0.7558	-0.18572	0.08056	0.67900
		P	<.0001	0.3849	0.7083	0.0003
		B	4.63857	-0.17279	0.12605	4.59183
	Mini	R	0.74166	-0.21713	0.04646	0.65395
		P	<.0001	0.3081	0.8293	0.0005
		B	4.25684	-0.18893	0.06799	4.13590
	RH	R	-0.44381	0.22808	0.11364	-0.34509
		P	0.0298	0.2838	0.5970	0.0986
		B	-2.03081	0.15821	0.13258	-1.74002
Analysis of variance	Abiotic factors		F*=10.26		E.V.%= 60.61	

Table (3): Statistical analysis of the effect of abiotic factors *Aonidiella aurantii* population on mandarin tree at Sohag 2020.

Tested factors		Simple correlation & partial regression	Nymph	Adult female	Adult+Nymph female	Total pop.
Abiotic factors	Max.	R	0.75718	-0.23845	0.00888	0.64986
		P	<.0001	0.2618	0.9671	0.0006
		B	6.09928	-0.29845	0.01890	5.80658
	Mini.	R	0.72671	-0.30375	-0.08151	0.59177
		P	<.0001	0.1490	0.7050	0.0023
		B	5.40103	-0.35077	-0.16007	4.87854
	RH.	R	0.0171	0.0360	0.1222	-0.29593
		P	-0.48186	0.42997	0.32424	0.1603
		b	-1.94790	0.27007	0.34634	-1.32700
Analysis of variance	Abiotic factors		F= 9.33		E.V.%= 58.32	

3.2. Effect of daily minimum temperature:

Also, the data in the same tables showed that, simple correlation was positive and significant with nymphal stage and total population (0.74166 and 0.65395), respectively throughout 2019 and (0.72671 and 0.59177), respectively during 2020. Whereas, the simple correlation was negative insignificant with adult female stage and positive insignificant with gravid female stage.

Simple regression was positive significant in case of nymphal stage and total population of *A. aurantii* (4.25684 and 4.13590), respectively throughout 2019 and (5.40103 and 4.87854), respectively during 2020. In case of adult female simple regression was negative insignificant and positive insignificant in case of gravid female recording (-0.18893 and 0.06799) during 2019 and it was negative insignificant in case of the two stages recording (-0.35077 and -0.16007) during 2020, respectively

3.3. The effect of relative humidity percentage:

Data in Two tables mentioned that, simple correlation was negative and significant with nymphal stage (-0.44381) and negative insignificant with total population (-0.34509), respectively throughout 2019 and likewise during 2020 recording (-0.48186 and -0.29593), respectively, in case of adult and gravid females stages the simple correlation were positive and insignificant throughout the two years of study (0.22808 and 0.11364) and (0.42997 and 0.32424), respectively.

Simple regression was positive significant in case of nymphal stage and total population of *A. aurantii* (4.25684 and 4.13590), respectively throughout 2019 and (5.40103 and 4.87854), respectively during 2020.

3.4. The combined effect of abiotic and biotic factors (Partial regression):

The combined effect of climatic (abiotic) factors on the *A. aurantii* different stages and total population were significant (F = 10.26 and 9.33) and the explained variance (E.V.) presented (60.61 and 58.32 %), respectively during the two years of study.

Temperature gave positive significant relation in the 1st season and very significant in the 2nd season, while relative humidity relations was negative in 1st season and positive in the 2nd season but insignificant in both. The effect of all measures was very significant in the 1st season and insignificant in the 2nd season as the total effect was 89.71% and 61.51% during the 1st and 2nd seasons, respectively (Selim, 2014).

Statistical analysis of the relation between *A. aurantii* (Different stages and total population) and abiotic factors revealed that the Max. temp. was effective factors and the combined effect of all factors were significant and the E.V. more than 70% (Haris, 2015).

There was positive significant relationship between metrological factors and the total population of *A. aurantii* and a simultaneous occurrence of the total population of *A. aurantii*, while relative humidity relations was negative in first season and positive in the second season but insignificant in both. (Balboul and Helmy, 2019).

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