

Original research

Ecological studies on the red-scale insect, *Aonidiella aurantii* (Maskell) (Homoptera: Diaspididae) infesting Lemon trees at Aswan Governorate

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Abstract:

The study was conducted on the special farm in Kom Ombo – Aswan Governorate, from the 1st of March 2019 until the 15th of February 2021, to study the population dynamic of red scale insect infesting the lemon trees. The study aimed to study the population density and infestation of the red scale on the Lemon's trees Under the Aswan Governorate conditions. The results showed that the maximum population density was recorded in autumn (116.19 and 111.84) while the minimum numbers were recorded in winter (45.82 and 61. 58) in the first and second years, respectively. The highest Rate of Monthly variation population (R.M.V.P.) value was achieved during August of both seasons. Also, data shows there were 4 insect generations in the year; the maximum number of insects was recorded in the third generation in the two successive years. Data of the both seasons revealed that the most effective weather variables were maximum temperature and dew point.

Keywords: Population density, red scale insect, Weather factor, Rate of Monthly Variation, Field generation.

1- Introduction

Lemon trees have an important medical role, especially after COVID-19, their content is Vitamin C, which raises the immunity of humans and flavonoids as antioxidants, (**Abdelmoaty et al., 2021**). Citrus trees are affected by many of species of insect pests, mites and ailment pathogens that infest leaves, flowers, bark, fruits and the branches and induced a losses in yield. (**Kamel, 2010**). The red-scale insect, *Aonidiella aurantii* (Maskell) (Hemiptera: Diaspididae) is one of the most damaging citrus pests in different parts of Egypt (**Badary and Abd-Rabou, 2010**). This pest is a polyphagous insect pest. (**Elhassan, et al., 2020**). *A. aurantii* attacks smooth shoots, twigs, leaves, branches and fruits. Adults and nymphs of these insects feed on go-away sap with their long, sucking a large amount of nitrogen and macro- and micro-elements. Insect secretion of the toxic saliva leads to distorted leaves and poor shoot growth (**Osman, 2005 ; Bakry, 2009**). A characteristic symptom of infestation with this insect appearance is accumulation of scales of insects on attacked citrus tree parts, high level of infestation with this species and remarkable damage occurring, resulting in early leave drop and yield losses. (**Salah, 2005**).

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This work aimed to study the ecological parameters of the red scale *A. aurantii* infesting lemon trees including (population density, the percentages of infestation intensity and its incidence on lemon trees, its associated natural enemies. The rate of monthly variation in population of different stages of *A. aurantii* and estimate the annual field generations) under Aswan Governorate conditions, (Kom Ombo).

2-Materials and methods:

The study was conducted in the special farm in Kom Ombo – Aswan Governorate for two successive years began on 1st March 2019 to 15th February 2021, to study the red-scale insect infesting lemon trees.

2.1. Population density of red scale insect, *A. aurantii* infesting citrus trees and their associated natural enemies at Kom Ombo district, Aswan Governorate:

2.1.1. Sampling.

The sampling was collected from 7680 leaves by dividing the trees into 4 directions (4 trees x 4 directions x 2 stratum x 5 leaves x 48 dates) during the two successive seasons. Leaves were kept in a polyethylene bags for examination at the laboratory of the Plant Protection Department – Faculty of Agriculture and National Resources -Aswan University. Red-scale insect on both surfaces of the lemon leaves were counted by Abinocular.

The total live insects of *A. aurantii* were precisely individually divided into immature stages (pre-adults) and mature stages (adult females and gravid females), and then counted.

2.2. Seasonal fluctuations in population.

The half-monthly means of all stages were counted. Annual population data were graphically plotted in figures, (insect /leaf).

2.2.1. Age structure calculation

The mean number of each stage was divided by the total and multiplied by 100. This way gave each stage a percent proportion of the total/sample regardless of the population density (Audemard and Millare, 1975).

2.2.2. The percentages of infestation incidence and its intensity.

The percentages of infestation incidence were calculated according to the formulation of Facylate (1971).

$$A = (n / N) \times 100.$$

As,

A = Percentage infestation incidence.

n = No. of infested leaves in which the insects appeared.

N = Total number of leaves (Uninfested + Infested) collected in date.

The percentages of infestation-intensity insects were calculated according to the formula described by Facylate, (1971).

$$D = (t / T) \times 100.$$

As: D = The dominance percentage or infestation intensity.

t = Number of populations in which the insect appeared.

T = Total number of populations taken all over the year

2.2.3. The Rate of Monthly Variation (R.M.V.P) in population density of the red scale insect:

The rate of monthly variation rate was calculated by Serag El-Dien (1998)

(R.M.V.P) = $\frac{\text{Av. count of insects at a month}}$

$\frac{\text{Av. count given in the preceding month}}$

2.3. Estimate the annual field generations of red-scale insect

Number and duration of annual generations under field conditions were recorded on the basis (beginning of total population / leaf and its end) were by integration of the population curves in the Figures. (Audemard and Millare, 1975).

2.4. The Effect of the weather factors on the population density:

The temperature and the relative humidity degree were printed from the Central Laboratory for Agricultural Climate (CLAC), Agriculture Research Center (ARC) and Ministry of Agriculture in Giza to calculate a simple correlation and regression between the weather factors and the numbers of the red scale insect under Aswan Governorate condition.

2.5. Statistical analysis

Statistical analysis was based on MSTATC Program Software (1980). Averages of different stages of insect population, the percentages of intensity and infestation incidence and climatic factors were calculated and shown graphically by the Excel office.

3- Results and discussions

The results are represented in Figs. (1&2) illustrated the population density of *A. aurantii* in different stages counted on lemon leaves at Kom Ombo district, Aswan Governorate during two successive years (2019/2020 and 2020/2021). During this study, in the first year (2019-2020) and the second year (2020-2021), the highest population density of *A. aurantii* in different stages occurred in the autumn season (116.19 and 111.48), respectively and the least population density was in winter season (45.82 and 61.58), respectively.

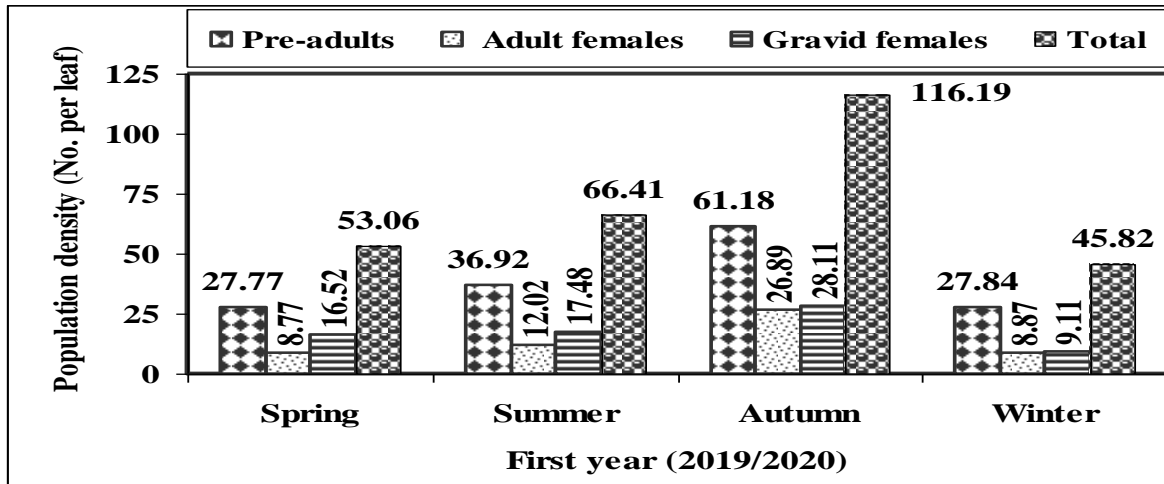


Fig. (1): Population density of *A. aurantii* different stages counted on lemon leaves during the first year.

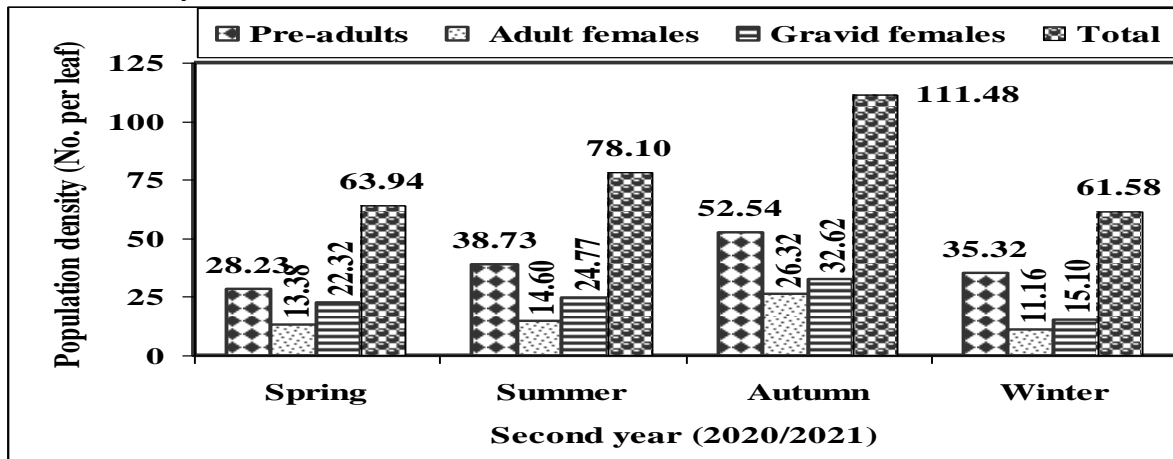


Fig. (2): Population density of *A. aurantii* different stages counted on lemon leaves during the second year.

Results in Figs. (3 &4) showed the infestation intensity and incidence percentages of *A. aurantii* counted on a lemon leaf at Kom Ombo district, Aswan Governorate during the two successive. The highest average infestation intensity during the first and the second years occurred in the autumn seasons (95.42% and 94.17%), respectively and the lowest average of percentage infestation intensity in the first year occurred in the winter season (71.04%). In the second year occurred in spring season (67.29%). The highest average of infestation incidence % in the first and second years of this study occurred in the autumn seasons (6.88% and 5.90 %), respectively, and the lowest average occurred in the winter season of the first and second years (2.71% and 3.26%), respectively. **Balboul and Helmy (2019)** calculated the infestation rates of *A. aurantia*, the highest were in the summer, spring and autumn seasons. While, the low rate of infestation was recorded in the winter season.

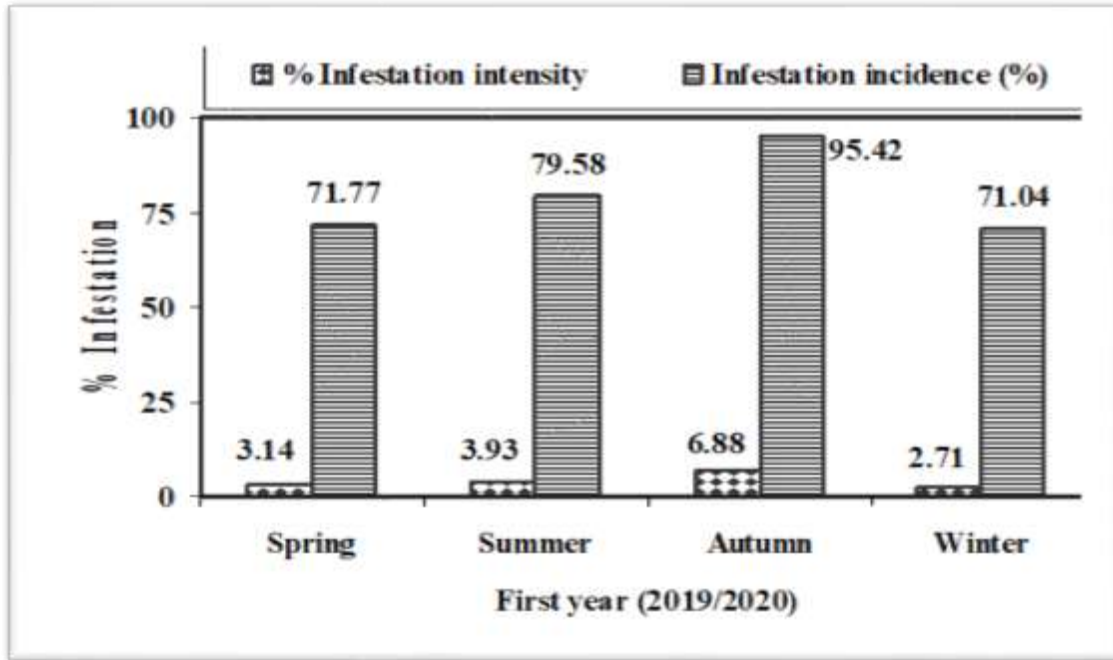


Fig. (3): The infestation intensity and incidence percentages of *A. aurantii* counted on lemon leaves during the first year.

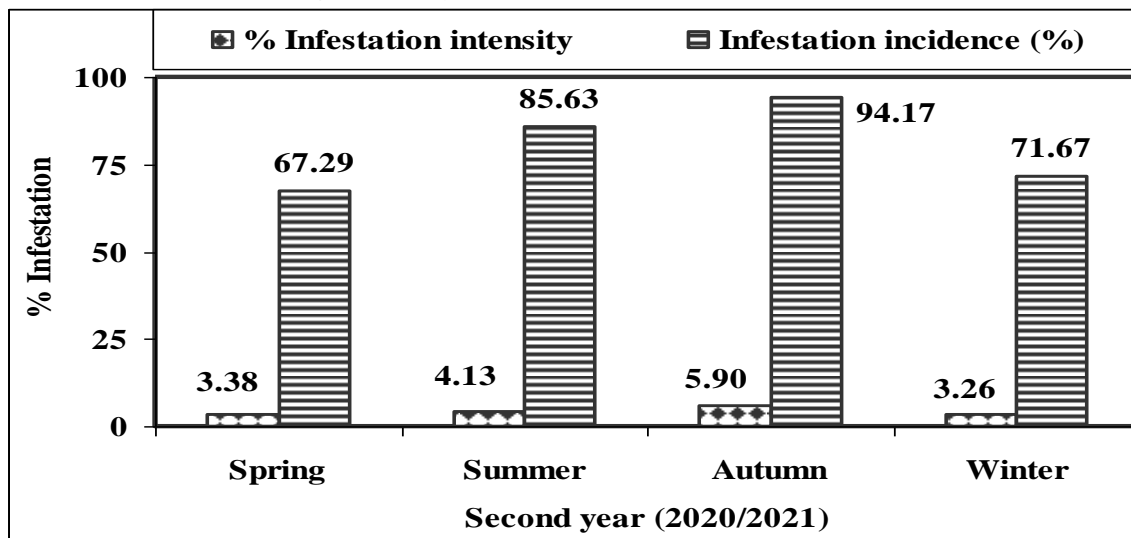


Fig. (4): The infestation intensity and incidence percentages of *A. aurantii* counted on lemon leaves during the second year

Data in Figs. (5 &6) showed the sums and the percentages from the overall final total population of *A. aurantii* on lemon trees at Kom-Ombo district, Aswan Governorate during the first year. The highest total numbers of insects/leaf of each stage during this year, were pre-adults followed by gravid females and adult females (922.30, 427.28 and 339.29), respectively and the total sums of insects of all stages was (1688.87). As well the highest% from the overall final total of each stage were pre-adults followed by gravid females and adult females (54.61%, 25.30% and 20.09%), respectively. The total of % from the overall final total of all stages was 100%.

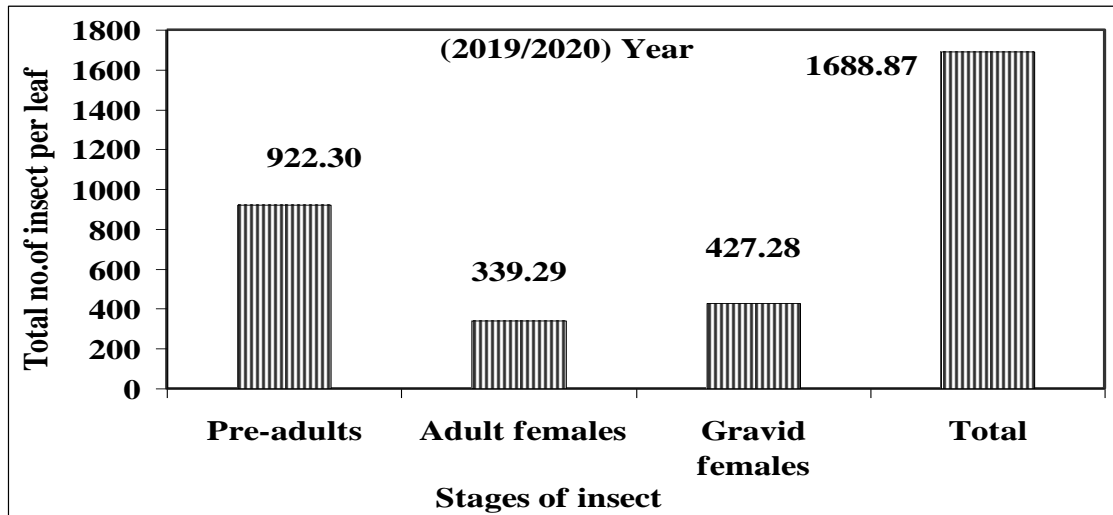


Fig. (5): Total counts and percentages (from the overall final total population) of *A. aurantii* on lemon trees during the first year.

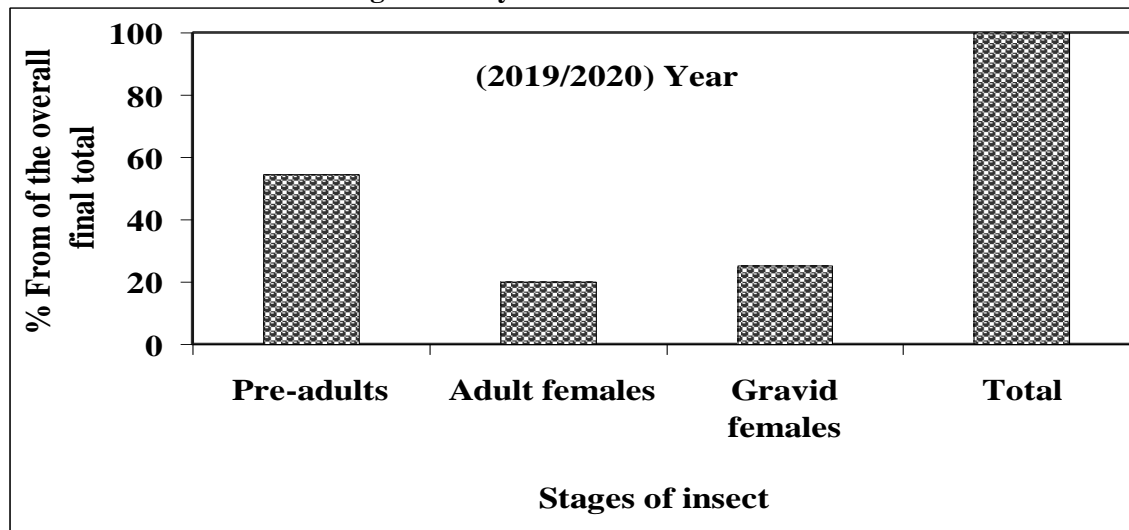


Fig. (6): Total counts and percentages (from the overall final total population) of *A. aurantii* on lemon trees during the first year.

Data in Fig. (7 & 8) showed the sums and the percentages from the overall final total population of *A. aurantii* on lemon trees at Kom Ombo district, Aswan Governorate during the second year, where the highest total numbers of insects per leaf of each stage during the second year, were, pre-adults followed by gravid females and adult females (928.91, 568.95 and 392.78), respectively and the total sums of all stages was (1890.65). The highest % from the overall final total of each stage was pre adults followed by gravid females and adult females (49.13%, 30.09% and 20.78%), respectively. The total of % from the overall final total of all stages was 100%.

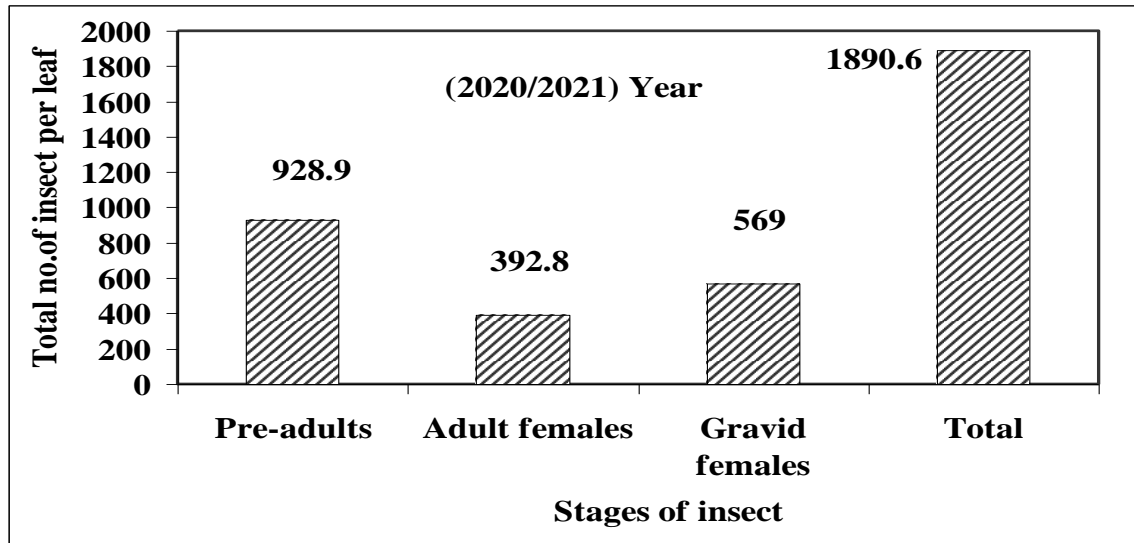


Fig. (7): Total counts and percentages (from the overall final total population) of *A. aurantii* on lemon trees during the second year.

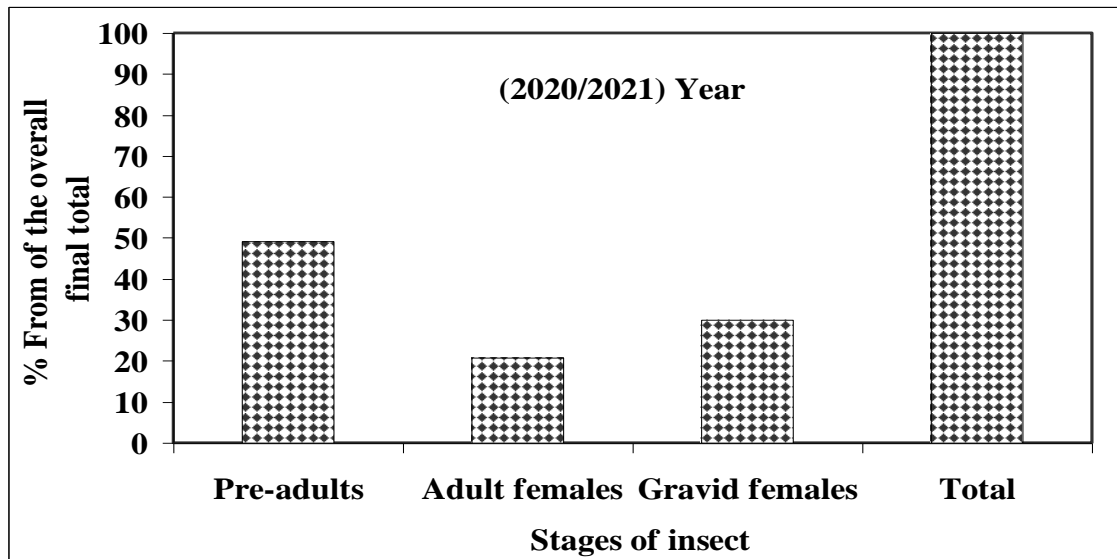


Fig. (8): Total counts and percentages (from the overall final total population) of *A. aurantii* on lemon trees during the second year.

Results in **Table (1)** showed the rate of monthly variation (R.M.V.P) in the mean number of *A. aurantii* and the infestation intensity and incidence percentages counted on lemon trees. In the first year (1st March 2019-February 2020). The highest rate for the pre-adults was in April, (2.16) and the least was in January, (0.51). The highest (R.M.V.P.) of adult females was in August, (3.63). The least was recorded in December, (0.45). The highest rate of gravid females showed in April, (1.82) and the lowest was in February, (0.41). The maximum rate of the total all stages of *A. aurantii* was in April, (1.77). While, the minimum was in January (0.53). Also, the maximum monthly infestation intensity% was in April, (1.77%), and the minimum was in January (0.53%). The highest (R.M.V.P.) infestation incidence % was in April (1.17%) and the least was in February (0.69%).

In the second year (March 2020- Feb. 2021), the highest rate of monthly variation of pre-adults was in November, (1.64) and the least was in February, (0.60).

The highest (R.M.V.P.) of adult females was in August (2.59) and the least was in February (0.54). The highest (R.M.V.P.) of gravid females was in August, (1.76) and the least was in December 2020 and February 2021, (0.61). The highest (R.M.V.P) of the total all stages of *A. aurantii* was in August, (1.67) and the least was in February, (0.59). The highest (R.M.V.P.) of infestation intensity% was in August, (1.67%) and the least was in February, (0.59%). The highest (R.M.V.P.) infestation incidence% was in June, (1.36%) and the least was in January, (0.83%). **El-Agamy et al. (1993)** found that the maximum value of the monthly variation rate in the population density was in June and July during two successive years of the study.

Table (1): Rate of monthly variation (R.M.V.P) in the mean number of *A. aurantii* and the infestation intensity and incidence percentages counted on lemon trees through the two successive year 2019/2020 and 2020/2021).

Years	Month of inspection	Immature stages (Pre-adults)	Mature stages		Total	Infestation intensity (%)	Infestation incidence (%)
			Adult Females	Gravid females			
2019/2020	Mar.	—	—	—	—	—	—
	April	2.16	0.98	1.82	1.77	1.77	1.17
	May	0.70	0.79	0.58	0.67	0.67	0.97
	June	1.22	1.18	1.50	1.29	1.29	1.01
	July	1.18	0.67	0.72	0.96	0.96	1.04
	Aug.	1.02	3.63	1.17	1.31	1.31	1.11
	Sept.	1.58	1.30	1.43	1.47	1.47	1.11
	Oct.	0.93	0.87	1.41	1.02	1.02	1.01
	Nov.	1.10	1.18	0.72	1.00	1.00	0.97
	Dec.	0.71	0.45	0.66	0.64	0.64	0.94
	Jan.	0.51	0.66	0.46	0.53	0.53	0.84
	Feb.	0.67	0.59	0.41	0.61	0.61	0.69
2020/2021	Mar.	—	—	—	—	—	—
	April	1.37	0.81	1.14	1.15	1.15	1.05
	May	0.67	1.03	0.74	0.75	0.75	0.92
	June	1.58	1.15	1.14	1.33	1.33	1.36
	July	0.88	0.56	0.89	0.82	0.82	0.92
	Aug.	1.39	2.59	1.76	1.67	1.67	1.10
	Sept.	1.29	1.32	0.96	1.19	1.19	1.10
	Oct.	0.63	0.75	0.91	0.74	0.74	0.92
	Nov.	1.64	1.45	1.20	1.45	1.45	1.08
	Dec.	0.82	0.60	0.61	0.71	0.71	0.86
	Jan.	0.70	0.55	0.67	0.66	0.66	0.83
	Feb.	0.60	0.54	0.61	0.59	0.59	0.90

Results in **Figs. (9 and 10)** illustrated the stage structure for a population of different stages of *A. aurantii* on lemon trees at Kom Ombo district, Aswan Governorate through two successive years. In the first year (2019/2020), the highest percentage of pre-adults was in winter during the period from 1st December 2019 to

15th February 2020 (60.76). While, spring showed the lowest numbers during the period from March to 15th May 2019 (52.34). The adult females were in a highest percentage in autumn during the period from 1st September to 15th November 2019 (23.15). While, it were (16.53) in spring season during the period from 1st March to 15th May. Also, gravid females recorded a highest percentage in spring season during the period from 1st March to 15th May (31.13), but winter season during the period from 1st December 2019 to 15th February 2020, showed a decrease (19.88).

In the second year 2020/2021, the highest percentage of pre-adults was in winter during the period from 1st December 2020 to 15th February 2021(57.36). The least was in spring during the period from 1st March to 15th May 2020 (44.15). The highest percentage of adult females was in autumn during the period from 1 September to 15th November 2020(23.61), The least was in Winter during the period from 1st December 2020 to 15th Feb. 2021(18.12). The highest percentage of gravid females was in spring during the period from 1 March to 15th May (34.91), and the least was in Winter during the period from 1st December 2020 to 15th February 2021, (24.53). Finally, through the two successive years 2019/2020 and 2020/2021, the results indicated that the highest percentage of different stages was pre –adults followed by gravid females and adult females the least, respectively.

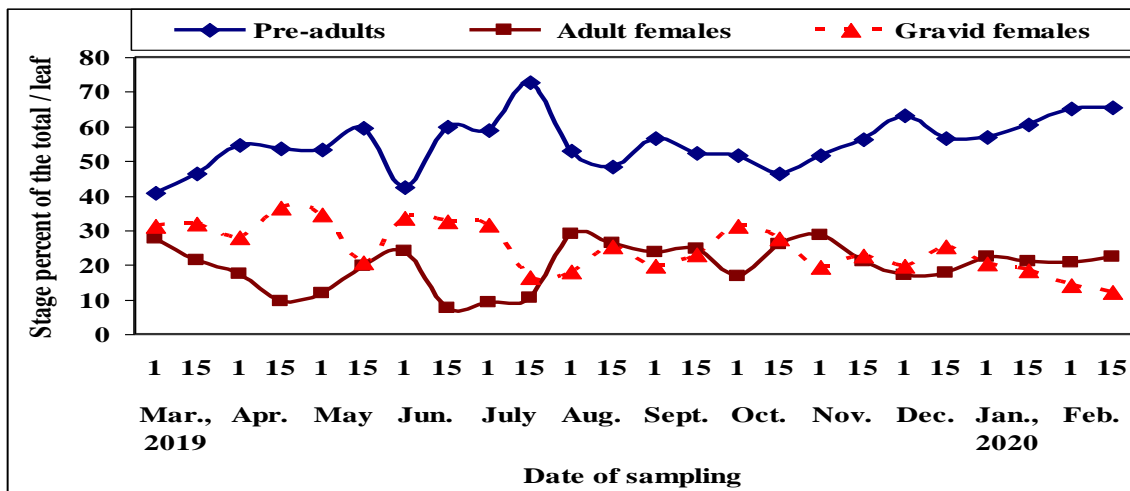


Fig. (9): Stage structure for population different stages of *A. aurantii* on lemon trees during the year (2019/2020).

Data in **Table (2)** illustrates the half-monthly mean counts of the total *A. aurantii* population at Kom Ombo district, Aswan Governorate from March 2019 to February 2020 where the highest total numbers of individuals of *A. aurantii* were from 1st October 2019 (132.87) with mean temp., R.H% and dew point (°C): (33.34 , 26.78% and 15.03), respectively. The least were in 15th February 2020 (18.65) with mean temp., R.H% and dew point (°C): (20.55, 46.58 % and 7.37), respectively. The half-monthly mean counts of the total *A. aurantii* population were average (70.37) with mean Temp., R.H% and dew point (27.53, 30.27% and 10.03), respectively.

Data in **Table (3)** illustrates the half-monthly mean counts of the total *A. aurantii* population at Kom Ombo district, Aswan Governorate from March 2020 to February 2021 where the highest total numbers of individuals of *A. aurantii* were on 15th November 2020 (141.30). With mean temp., R.H% and dew point (°C): (29.39, 9.14%

and 1.57), respectively. The least were in 15th February 2021(33.17) with mean temp., R.H% and dew point (°C): (34.04, 21.07% and 14.29), respectively. The half-monthly mean counts of the total *A. aurantii* population were average 78.78 with mean Temp., R.H% and dew point (25.11, 25.87% and 7.33), respectively.

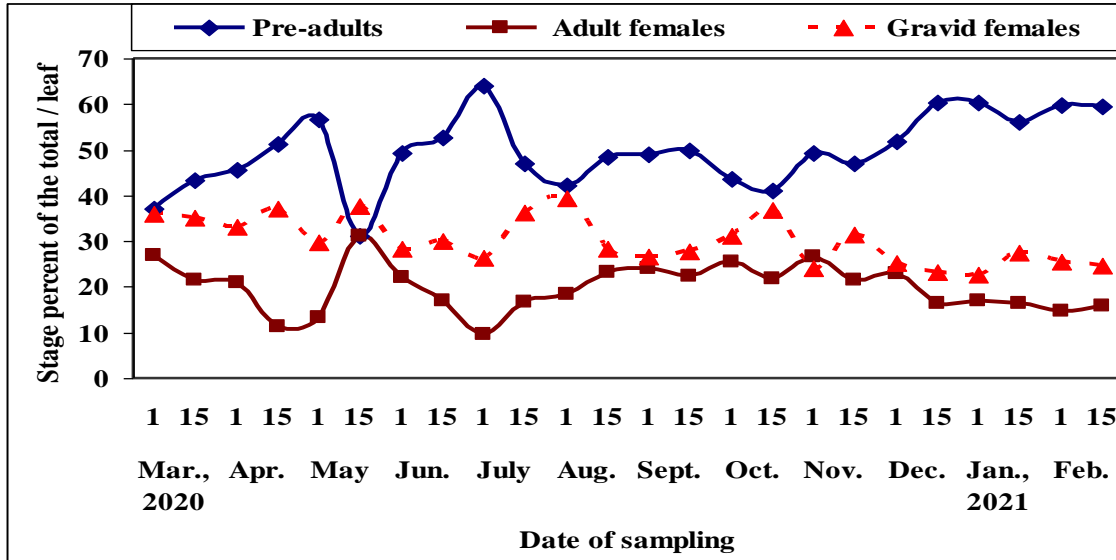


Fig. (10): Stage structure for population different stages of *A. aurantii* on lemon trees during the year (2020/2021).

Results in Tables (2 and 3) showed that the highest half-monthly mean counts of the total *A. aurantii* population were in the second year of studying (2020/02021) average (78.78) with mean Temp., R.H% and dew point (25.11, 25.87% and 7.33), respectively.

Table (2): Half monthly mean counts of the total *A. aurantii* population from March 2019 to February, 2020 year.

Date of inspection	The mean number of individuals /leaf	Max. temp.	Min. temp.	Mean temp.	R.H.%	Dew Point (°C)	
Mar., 2019	1	29.64	27.15	12.68	19.91	43.43	4.88
	15	50.61	28.58	12.00	20.29	31.58	4.58
Apr.	1	64.91	30.26	16.06	23.16	34.03	5.50
	15	77.51	31.80	17.25	24.53	26.40	6.98
May	1	52.56	35.77	19.03	27.40	20.15	6.69
	15	43.12	37.65	21.53	29.59	18.98	7.80
Jun.	1	48.96	40.33	23.22	31.78	19.21	9.82
	15	74.89	43.13	26.85	34.99	18.08	11.40
July	1	65.72	41.21	25.73	33.47	20.54	12.21
	15	52.97	43.79	26.57	35.18	20.78	13.43
Aug.	1	66.10	43.91	29.59	36.75	21.06	14.33
	15	89.83	42.95	29.09	36.02	21.90	14.78
Sept.	1	104.76	44.16	28.84	36.50	22.79	15.63
	15	124.77	42.30	25.65	33.98	24.83	14.78
Oct.	1	132.87	41.67	25.00	33.34	26.78	15.03
	15	100.56	40.50	23.78	32.14	26.93	13.65
Nov.	1	101.65	39.47	22.17	30.82	28.29	13.03
	15	132.50	34.65	17.85	26.25	35.33	12.30
Dec.	1	84.74	33.27	16.93	25.10	37.67	11.22
	15	64.16	26.93	11.10	19.01	40.43	7.13

Date of inspection		The mean number of individuals /leaf	Max. temp.	Min. temp.	Mean temp.	R.H.%	Dew Point (°C)
Jan., 2020	1	43.36	26.50	9.39	17.94	41.81	5.31
	15	35.14	23.18	7.73	15.45	50.70	6.53
Feb.	1	28.89	24.46	8.65	16.55	48.18	6.11
	15	18.65	27.90	13.20	20.55	46.58	7.73
Average		70.37	35.48	19.58	27.53	30.27	10.03

Table (3): Half monthly mean counts of total *A. aurantii* population from March 2020 to February, 2021.

Date of inspection		The mean number of individuals/leaf	Max. temp.	Min. temp.	Mean temp.	R.H.%	Dew Point (°C)
Mar., 2020	1	55.59	39.82	24.82	32.32	20.88	12.82
	15	71.27	38.50	24.57	31.54	24.64	13.57
Apr.	1	81.52	37.69	22.50	30.09	26.31	13.31
	15	64.99	36.36	20.64	28.50	26.71	12.21
May	1	50.60	33.00	18.41	25.71	33.71	12.12
	15	59.69	29.07	12.71	20.89	34.00	7.71
Jun.	1	81.06	24.13	10.25	17.19	40.56	6.63
	15	65.66	24.64	7.29	15.96	43.00	5.79
July	1	53.87	23.47	7.71	15.59	45.65	5.88
	15	66.64	19.71	5.36	12.54	44.57	3.29
Aug.	1	92.02	21.82	6.06	13.94	42.41	3.65
	15	109.36	24.79	9.29	17.04	29.57	2.57
Sept.	1	118.71	25.33	9.87	17.60	33.40	4.80
	15	120.07	27.07	11.00	19.04	21.07	0.64
Oct.	1	95.79	27.47	11.29	19.38	18.76	-0.18
	15	80.02	34.93	17.86	26.39	11.57	0.71
Nov.	1	113.01	36.44	18.38	27.41	8.50	-1.44
	15	141.30	37.79	21.00	29.39	9.14	1.57
Dec.	1	101.94	39.88	24.47	32.18	9.82	4.29
	15	77.79	41.43	24.50	32.96	14.14	8.36
Jan., 2021	1	72.56	42.06	27.13	34.59	18.81	13.69
	15	46.53	40.71	26.07	33.39	20.93	14.29
Feb	1	37.48	42.65	27.18	34.91	21.65	15.41
	15	33.17	41.64	26.43	34.04	21.07	14.29
Average		78.78	32.93	17.28	25.11	25.87	7.33

Table (4) illustrates the different models of correlation and regression analyses between the weather factors and the total population, of *A. aurantii* on lemon trees during the two successive years of (2019/2021).

Statistical analysis revealed that the simple correlation (r) and simple regression (b) between the maximum, minimum temperature and (total population, were significantly positive in both years. There was a significantly negative correlation and regression between the humidity and total population of *A. aurantii*, for the first and second years. **Selim (2014) & Balboul and Helmy (2019)** found that Temperature gave a positive significant relation with the total population of *A. aurantii*.

Table (4): The correlation and regression analyses between the weather factors and the total population of *A. aurantii* on lemon trees during the two successive years.

Years	Dependent variables (Y)	Independent variables (X)	Simple correlation and regression values	
			R	b
First (2019/2020)	Total population	Maxi. temp.	0.58**	2.67
		Min. temp.	0.55**	2.57
		R.H.%	-0.39	-1.23
		Dew Point	0.74**	6.41
Second (2020/2021)		Maxi. temp.	0.36	1.55
		Min. temp.	0.39	1.68
		R.H.%	-0.08	-0.21
		Dew Point	0.58**	4.26

r = Simple correlation
 b = Simple regression

** Highly significant
 * Significant

Results represented in **Fig. (11)** showed the approximated number, duration and size of *A. aurantii* generations recorded on lemon trees under field conditions at Kom Ombo district, Aswan Governorate during the two years of (2019/2020 and 2020/2021) where that *Aonidiella aurantii* recorded on lemon trees four overlapping generations in both year (2019/2020 and 2020/2021), had four peaks of generations and it had four durations in weeks.

In the first year (2019/2020) the First generation was from Early March to Early June, the peak of generation was in mid –April and the duration in weeks was 7. The second was from mid-May to early August, the peak of generation was in mid-June June and the duration in weeks was 8. The 3rd was from mid-July to early November, the peak of generation was in early October and the duration in weeks was 8. The 4th was from early of October to mid-February, the peak of generation was in mid-November and duration in weeks was 10. The highest total of generation size per leaf was in the Fourth generation and the least was in the second generation.

In the second year (2020/2021) the first generation was from early March to mid-May, the peak of generation was in early April and the duration in weeks was 6. The 2nd was from, peak of generation was mid-April to mid-July and duration in weeks was 7. The third generation was from mid-June to early November, the peak of generation was in mid-September and duration in weeks was 10. The fourth generation was from mid-September to mid-February, the peak of generation was in mid-November and the duration in weeks was 10. The highest total of generation size per leaf was in the Fourth generation and the least was in the second generation.

These results indicated that the total size of *A. aurantii* generations in the second year of study (2020/2021) was more than the total size of *A. aurantii* generations in the first year (2019/2020).

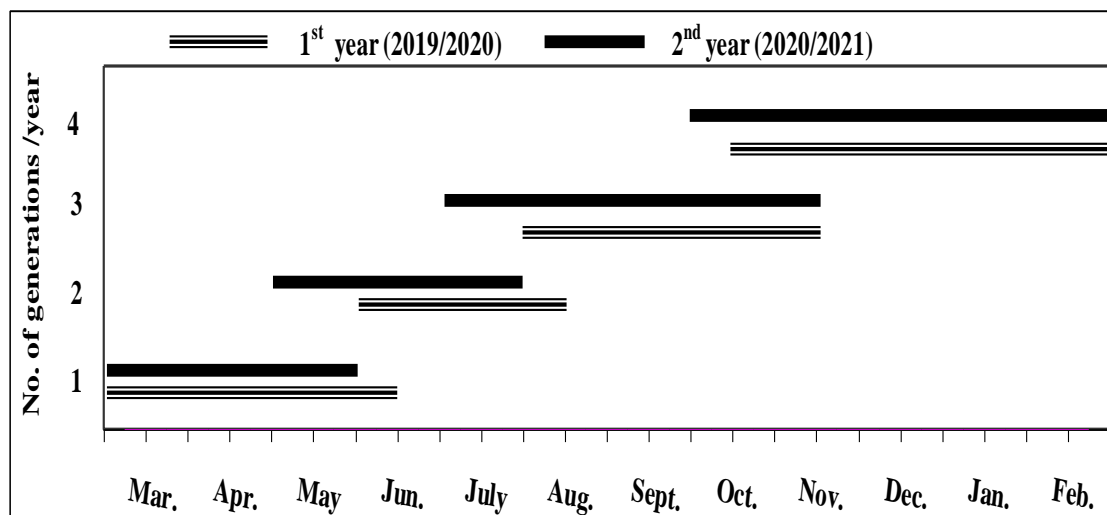


Fig. (11): Estimated number and duration of generations of *A. aurantii* recorded on lemon trees under field conditions during the two years of (2019/2020 and 2020/2021).

4- Conclusion

The population of the California red scale insect, *A. aurantii* occurred on lemon trees all the year round and had four peaks of seasonal activity per year. **In the first year**, they occurred in mid –April 2019, mid- June 2019, early of October 2019 and mid-November 2019. **In the second year**, these peaks were in early of April 2020, early of June 2020, mid-September 2020 and mid-November. The percentages of infestation intensity and its incidence by insect showed. Also, had four peaks per year. The effect of the weather factors (daily mean maximum air temperature, daily mean minimum air temperature, mean of relative humidity and mean of dew point) on the insect population and on the percentages of infestation intensity and its incidence by *A. aurantii* were, highly significant during the two successive years. The dew point was the most effective variable for the changes in the insect population and the percentages of infestation intensity and its incidence under the studied years.

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