Menoufia J. Plant Prot., Vol. 3 December (2018): 193 - 205

ECOLOGICAL STUDIES ON *PARLATORIA ZIZIPHI* (LUCAS) INFESTING NAVEL ORANGE TREES IN MENOUFIA GOVERNORATE, EGYPT

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Received: Oct. 28 , 2018 Accepted: Oct. 31 , 2018

ABSTRACT: ***Ecological studies were carried out on the Parlatoria black scale, Parlatoria ziziphi (Lucas) (Hemiptera: Diaspididae) and its associated parasitoid on navel orange trees at Faculty of Agriculture farm in Shebin El-Kom, Menoufia Governorate, Egypt during two successive years from June 2015 until May 2017. The seasonal abundance and activity periods of different stages of P. ziziphi and its associated parasitoid on navel orange trees and the effects of some weather factors on both insect and parasitoid were considered. The obtained results revealed that the total numbers of alive stages had two peaks of activity during the first year (2015-2016) they took place at September and January. While, during the second year (2016-2017) the total number of alive stages showed one peak of activity there was in September. Aphytis sp. (Hymenoptera: Aphelinidae) was recorded as a parasitoid of P. ziziphi which appeared two peaks of parasitism during the first year (2015-2016) in November and May. While, during the second year one peak was occurred in November. The total effects of some weather factors (Temp.ºC, RH% and solar radiation) in this study on the total numbers of alive stages of P. ziziphi during the two successive years were 89.47 and 85.30%, successively. The obtained results revealed that P. ziziphi had two to three annual generations on navel orange trees, the generation durations were varied from three to five months.***

Key words: ***Ecology, Parlatoria ziziphi, Parlatoria black scale, navel orange, Aphytis sp.***

INTRODUCTION

In Egypt, navel orange, *Citrus sinensis* (L.) is represented one of the most economically crops. A great attention has been done to increase the production and improve the quality and quantity of this crop. Now, the policy strategy of Egypt is to increase the quality level of exported crops to certain European countries.

Scale insects have been reported as serious pests attacking a huge number of host plants around the world (Miller *et al.* 2002; Miller 2005; Germain 2008; Kondo *et al.* 2008; Franco *et al.* 2009; Pellizzari & Germain 2010 and Mazzeo *et al.* 2014). These insects are found on various parts of their hosts, and may infest leaves, twigs, branches and roots, and some live inside plant domatia. However, some species feed on the parenchyma tissue by directly feeding on the contents of parenchyma cells (Kondo *et al.* 2008). They feed almost exclusively on the phloem of their host plants to which they cause direct damage, but they can also cause indirect damage by transmitting plant pathogens through injection or through the build-up of honeydew, promoting the attack of plant pathogens (Ross *et al.* 2010).

The Parlatoria black scale, *Parlatoria ziziphi* (Lucas) was discovered infesting citrus in southern Florida in 1985. It is considered a major pest in countries bordering the Mediterranean, Tropical

Asia, Parts of South America, and the Caribbean. Scales infest leaves, twigs, and fruits and because they adhere so strongly, cause rejection of fresh fruit in markets. Large populations cause chlorosis and early drop of leaves, dieback of twigs and branches, and distortion of fruit. The scale had 2 to 3 generations per year (Helmy, 2000; Capinera, 2008; Tawfeek and Abu-Shall, 2010 and Hassan *et al.*, 2012).

Therefore, the present investigation was planned to study:

1. **Seasonal abundance and activity periods of different stages the Parlatoria black scale, *P. ziziphi* (Lucas) on navel orange.**
2. **The associated parasitoid as well as their role as biological control agents in reducing the infestation by the insect pest.**
3. **Evaluate the effects of some weather factors on the insect pest and its associated parasitoids.**
4. **Studying the number of the insect generations and their durations on navel orange trees under field conditions.**

MATERIALS AND METHODS

Field experiments were carried out in citrus horticulture, Faculty of Agriculture in Shebin El-Kom, Menoufia Governorate. The study was continued for two successive years, from June 2015 until May 2017. The farm received normal agricultural practices and no chemical control was applied.

1. Population densities and seasonal abundance

The study was started from June 2015 until May 2017, in an area of about one feddan of navel orange, *Citrus sinensis* (L.). Five trees of were selected and labeled. These trees were nearly similar in size, age and vegetation. Each tree was divided into four main directions (East, West, North and South).

For sampling, five leaves were picked up at random twice a month from each direction, *i.e.* 100 leaves per sample (5 trees × 4 directions × 5 leaves). The samples were put in polyethylene bags and transferred into the laboratory for carefully inspection. These samples were examined in the same day by the aid of stereomicroscope. The stages of scale insects and their associated natural parasitoids were counted and recorded.

These samples were examined in the same day by the aid of stereomicroscope. The stages of scale insects and their associated natural parasitoids were counted and recorded. The annual generations of scale insects were determined according to Audemard and Milaire (1975) and emended by Jacob (1977).

2. Estimation of parasitism ratios

To study the parasitism ratios of scale insects the previously collected samples for surveying studies were carefully inspected and sorted. Then, samples were separated into healthy alive insects and parasitized ones which appearing emerging holes of adult parasitoids or including parasitoid immature stages (larvae or pupae). Each healthy alive insect and parasitized ones were counted and recorded. Parasitized insects were preserved in glass jars covered with muslin cloth by the aid of rubber bands and kept under laboratory conditions until parasitoids emergence. Percentage of total parasitism for each sample was estimated. All emerging parasitoids were mounted in canada balsam and photomagnified under stereomicroscope camera. Parasitoid was identified with helping of Prof. Dr. S. Abd-Rabou, Chief Researcher, Scale Insects and Mealybugs Department, Plant Protection

Research Institute, Agricultural Research Center, Egypt.

3. Effect of climatic factors on the insect population and parasitism ratios

The prevailing means of air temperature (ºC), relative humidity (RH%) and solar radiation (MJ/m^2) in the experimental area during the periods of the present study were obtained from the Central Laboratory for Agricultural Meteorology, Agricultural Research Center, Ministry of Agriculture. The relationships between climatic factors and each of population densities of predominant scale insects, parasitism ratios and total insect populations were studied. Simple correlation, partial regression values and explained variance (E.v%) were calculated using COSTAT Computer Program (2005).

RESULTS AND DISCUSSION

Seasonal abundance of The Parlatoria black scale, *Parlatoria ziziphi* (Lucas) on navel orange trees

Females population

Data in Tables (1 and 2) showed that the females population had two peaks of females activity in the first and second years (2015-2016 and 2016-2017) there were in September (283 females/ 200 leaves) and in January (733 females) during the first year. While, during the second year females activity recorded two peaks of activity in September (956 females) and in November (838 females).

Generally, the total number of females during the second year (5326 females) was obviously higher as compared with that recorded during the first one (4043 females).

Males population

Data presented in Tables (1 and 2) showed that the males population had three peaks of activity during the first years (2015-2016) there were in September (23 males), November (48 males) and March (67 males). While, during the second year (2016-2017) males population showed one peak of activity there was in October with value of (65 males).

In general, the male population during the first year (424 males) was obviously higher in comparison with that recorded during the second one (416 males).

Nymphs population

Data given in Tables (1 and 2) showed the nymphs population had five peaks of activity during the first year (2015-2016) there were in July, October, December, February and April with values of (16, 15, 156, 56, 52 nymphs), respectively. While, during the second year (2016-2017) nymphs population showed two peaks of activity there were in September (361 nymphs) and in February (33 nymphs).

Generally, the total number of nymphs population during the second year was clearly higher than that recorded during the first one with counts of 1015 and 441 nymphs, successively.

Total number of alive stages

As shown from obtained data in Tables (1 and 2) the total number of alive stages showed two peaks of activity during the first year (2015-2016) they took place at September (316 individuals) and January (819 individuals). While, during the second year (2016-2017) the total number of alive stages showed one peak of activity there was in September (1374 individuals).

In general, the population of total alive stages during the second year (6757 individuals) was obviously higher in comparison with that recorded during the first one (4908 individuals).

Table (1): Seasonal abundance of *Parlatoria ziziphi* and associated parasitoids on navel orange trees in Shebin El-Kom distract, Menoufia Governorate during the first year (2015-2016).

Months	Number of insects / 200 leaves								Monthly average of climatic factors		
	Alive stages				Dead stages	Mortality %	Parasitoids		temp. (°C)	RH (%)	Solar radiation (MJ/m²)
	Females	Males	Nymphs	Total			No.	%			
Jun.	19	6	10	35	17	32.69	6	11.54	29.3	52.4	19.5
Jul.	20	10	16	46	17	26.98	3	4.76	30.4	55.7	20.2
Aug.	32	14	9	55	42	43.30	4	4.12	31.9	55.4	15.0
Sep.	283	23	10	316	157	33.19	11	2.33	30.8	53.7	11.4
Oct.	165	21	15	201	148	42.41	17	4.87	25.4	60.1	9.0
Nov.	438	48	14	500	370	42.53	46	5.29	22.0	72.2	8.2
Dec.	586	45	156	787	275	25.89	50	4.71	17.0	74.2	6.8
Jan. 2016	733	63	23	819	423	34.06	67	5.39	17.0	67.1	7.2
Feb.	648	64	56	768	706	47.90	162	10.99	19.7	62.7	8.5
Mar.	569	67	38	674	460	40.56	155	13.67	22.3	50.7	13.3
Apr.	428	46	52	526	413	43.98	155	16.51	24.2	47.0	17.5
May	122	17	42	181	106	36.93	55	19.16	27.3	44.0	19.2
Total	4043	424	441	4908	3134		731				
Mean						38.97		9.09			

Table (2): Seasonal abundance of *Parlatoria ziziphi* (Lucas) and its associated parasitoids on navel orange trees in Shebin El-Kom distract, Menoufia Governorate during the second year (2016-2017).

Months	Number of insects / 200 leaves								Monthly average of climatic factors		
	Alive stages				Dead stages	Mortality %	Parasitoids		Temp. (°C)	RH (%)	Solar radiation (MJ/m²)
	Females	Males	Nymphs	Total			No.	%			
Jun.	19	7	14	40	21	34.43	4	6.560	29.9	47.5	20.6
Jul.	119	21	30	170	47	21.66	5	2.300	30.8	56.5	19.3
Aug.	332	39	66	437	152	25.81	29	4.920	31.2	57.9	15.1
Sep.	956	57	361	1374	354	20.49	121	7.000	29.9	55.6	11.6
Oct.	824	65	226	1115	703	38.67	255	14.03	26.9	62.4	10.8
Nov.	838	52	176	1066	1306	55.06	476	20.07	26.3	60.4	7.40
Dec.	642	54	55	751	1236	62.20	397	19.98	20.1	65.7	7.80
Jan.2017	539	42	27	608	1065	63.66	319	19.07	18.4	63.2	8.00
Feb.	530	31	33	594	1931	76.48	639	25.31	21.6	63.5	10.8
Mar.	271	30	14	315	928	74.66	323	25.99	24.8	55.9	13.6
Apr.	162	14	7	183	407	68.98	176	29.83	28.0	51.0	16.6
May	94	4	6	104	131	55.74	108	45.96	28.5	45.7	18.3
Total	5326	416	1015	6757	8281		2852				
Mean						55.07		18.97			

These finding were in agreement with those of following investigators Helmy (2000) and Moustafa (2012) who noticed that the peaks of activity were occurred in April, August and October.

Total number of dead stages

Data presented in Tables (1 and 2) the total number of dead stages showed three peaks during the first year there were in September, November February with counts of 157, 370 and 706 individuals, respectively.

While, during the second one the total number of dead stages recorded two peaks occurred in November (1306 individuals) and February (1931 individuals).

Generally, the total number of dead stages during the second year (2016-2017) was clearly higher than those recorded during the first year (2015-2016) with counts of 8281 and 3134 individuals, consecutively.

Percentages of total mortality

As shown from obtained data in Tables (1 and 2), the percentages of total mortality indicated four peaks during the first year. They occurred in August (43.30%), November (42.53%), February (47.90%) and finely in April (43.98 %). On the other hand, during the second year the percentages of total mortality showed two peaks they took place in August and February with 25.81 and 76.48% mortalities, successively.

The mean percentage of total mortality during the second year (55.07%) was more that that during the first one (38.97%).

Percentages of parasitism

During the course of this work, one hymenopterous specie was recorded as parasitoid of *P. ziziphi*. There was *Aphytis* sp. (Aphelinidae). The seasonal abundance of the parasitoid was represented as percentages of parasitism.

Data presented in Tables (1 and 2) showed that the percentages of parasitism occurred two peaks of parasitism during the first year (2015-2016) and one peak during the second year (2016-2016). The peaks took place in November (5.29 %) and May (19.16 %) during the first year and in November (20.07 %) during the second one. The mean percentages of parasitism were 9.09 and 18.97% during the first and second years, successively.

This finding were in agreement with those of Rosen (1986) who recorded parasitic hymenopterous species mainly *Aphytis* spp. have proved to be quite useful for controlling diaspidids population. Kamel *et al.* (2003) reported that the parasitism rates of *Aphytis* species, were between 0.8 and 14.6%. Darwish (2016) who revealed *Aphytis lingnanensis* and *Encarsia citrine* (Aphelinidae), were recorded as parasitoids of *P. ziziphi*. The mean of parasitism rate reach to 12.69 % and 14.8% for *A. lingnanensis* in 2014 and 2015 years, respectively.

Effect of climatic factors

On females

Data in Tables (3 & 4) showed that during the first year (2015-2016) temperature and solar radiation showed negative highly significant effects on females population whereas r= -0.908 and -0.723**. While, during the second year (2016-2017) relative humidity and solar radiation showed positive significant and negative highly significant effects where r= 0.677* and -0.845**. Explained variance (E.V.%) affected this stage by 88.13 and 89.21% during the first and second years.**

Table (3): Correlation coefficient (r) and explained variance (E.V.%) represent the effects of climatic factors on *Parlatoria ziziphi* stages and its associated parasitoid on navel orange trees, in Shebin El-Kom, Menoufia Governorate during the first year (2015-2016)

Parlatoria ziziphi stages	Temp. (ºC)	RH (%)	Solar radiation (MJ/m^2)	Explained variance (E.V. %)	Combined effect		
						RH (%)	Solar radiation (MJ/m^2)
Females	-0.908**	0.507	-0.723**	88.13	Temp. ºC	-0.634*	0.718**
Males	-0.848**	0.392	-0.631*	80.02	RH (%)		-0.815**
Nymphs	-0.611*	0.384	-0.337	41.03			
alive stages	-0.924**	0.515	-0.713**	89.47			
Mortality %	-0.061	-0.162	-0.153	26.82			
Parasitism %	-0.057	-0.646*	0.503	84.68			

Table (4): Correlation coefficient (r) and explained variance (E.V.%) represent the effects of climatic factors on *Parlatoria ziziphi* stages and its associated parasitoid on navel orange trees, in Shebin El-Kom, Menoufia Governorate during the second year (2016-2017)

Parlatoria ziziphi stages	Temp. (ºC)	RH (%)	Solar radiation (MJ/m^2)	Explained variance (E.V. %)	Combined effect		
						RH (%)	Solar radiation (MJ/m^2)
Females	-0.317	0.677*	-0.845**	89.21	Temp. ºC	-0.662*	0.722**
Males	-0.310	0.788**	-0.822**	90.17	RH (%)		-0.839**
Nymphs	-0.222	0.234	-0.406	72.31			
alive stages	-0.191	0.595*	-0.763**	85.30			
mortality %	-0.731**	0.202	-0.365	67.72			
Parasitism %	-0.343	-0.247	-0.060	57.04			

On males

Data presented in Tables (3 and 4) showed that during the first year (2015-2016) temperature and solar radiation showed negative highly significant and negative significant effects on males population whereas r= -0.848** and -0.631**, respectively. On the other hand, during the second year (2016-2017) relative humidity and solar radiation showed positive highly significant and negative highly significant effects where r= 0.788** and -0.822**, consecutively. Explained variance (E.v.%) affected this stage by 80.02 and 90.17% during the first and second years, successively.

On nymphs

Data given in Tables (3 and 4) showed that during the first year, there was a negative significant effect between nymphs population and temperature whereas r = -0.611*. E.v.% affected nymphs population by 41.08 and 72.31% during the first and second years.

On total number of alive stages

Data presented in Tables (3 and 4) showed that during the first year (2015-2016), there were a negative highly significant effect between the total number of alive stages and temperature and solar radiation whereas r = -0.924 and -0.713**. While, during the second year (2016-2017) relative humidity and solar radiation showed positive significant and negative highly significant effects on the total number of alive stages whereas r = 0.595* and -0.763**, respectively. E.v.% affected this stage by 89.47 and 85.30% during the first and second years.**

On percentages of total mortality

Data given in Tables (3 and 4) cleared during the first year no significant effects were recorded on this stage. While, during the first year temperature had negative highly significant effect on the percentage of total mortality whereas r = -0.731.**

Statistical analysis showed that E.v.% affected percentages of total mortality by 26.82 and 67.72% during the first and second years.

On percentages of parasitism

As shown from obtained data in Tables (3 and 4) during the first year, temperature showed negative significant effects whereas r = - 0.646*. Statistical analysis showed that E.V.% affected parasitism percentage by 84.68 and 57.04% during the two successive years.

Combined effect of climatic factors

Data given in Tables (3 and 4) indicated that there were negative significant effects between temperature and relative humidity whereas (r) values were -0.634* and -0.662* during the first and second years, respectively. Also, temperature showed positive highly significant effects with solar radiation whereas (r) values were 0.718 and 0.722** during the first and second years, respectively. During the first and second years relative humidity showed negative highly significant effects with solar radiation where r = -0.815** and -0.839**, consecutively. Generally, it was clear that temperature and solar radiation had positive significant effects in all cases.**

This finding was in agreement with those of (Nabil and Shahein 2014) who mentioned that there was a strong correlation between temperature and both insect population of, *Aonidiella aurantii* (Maskell) and its parasitoids. They added that the light intensity effects appeared significant in peripheral zone only on percentage of parasitism.

Number of generations

As *P. ziziphi* is known to have overlapping generations, it was necessary to utilize the formula of Audemard and Milaire (1975) and emended by Jacob (1977) for estimating the number of generations and durations.

As shown from the obtained data in Table (5) and Fig. (1), during the first year (2015-2016) *P. ziziphi* had two annual generations on navel orange. The first generation took about 6 months was during the beginning of June till the end of November. While, the second generation beginning from December till the end of May. On the other hand, during the second year (2016-2016) *P. ziziphi* had three generations the first generation took about three months was during from the beginning of June till the end of

August. While, the second generation lasted about four months, from September till the end of December. The third generation occupied five months from the beginning of January till the end of May.

These results were in accordance with those of Helmy (2000) who reported that *P. ziziphi* had three generations a year on four citrus varieties (*i.e.* mandarin, baladi orange, grape fruit, and trifoliate orange trees).

Table (5): Annual generations and durations of *Parlatoria ziziphi* (Lucas) on navel orange trees, in Shebin El-Kom distract, Menoufia Governorate during the two successive years

Months	Number of insects / 200 leaves			
	Accumulated days of investigation	Monthly counts of nymphs	Accumulated monthly counts	Accumulated insects %
first year (2015-2016)				
Jun.	30	10	10	2.27
Jul.	61	16	26	5.90
Aug.	92	9	35	7.94
Sep.	122	10	45	10.20
Oct.	153	15	60	13.61
Nov.	183	14	74	16.78
Dec.	214	156	230	52.15
Jan. 2016	245	23	253	57.37
Feb.	274	56	309	70.07
Mar.	305	38	347	78.68
Apr.	335	52	399	90.48
May	366	42	441	100.00
first year (2016-2017)				
Jun.	30	14	14	1.38
Jul.	61	30	44	4.33
Aug.	92	66	110	10.84
Sep.	122	361	471	46.40
Oct.	153	226	697	68.67
Nov.	183	176	873	86.01
Dec.	214	55	928	91.43
Jan. 2017	245	27	955	94.09
Feb.	273	33	988	97.34
Mar.	304	14	1002	98.72
Apr.	334	7	1009	99.41
May	365	6	1015	100.00

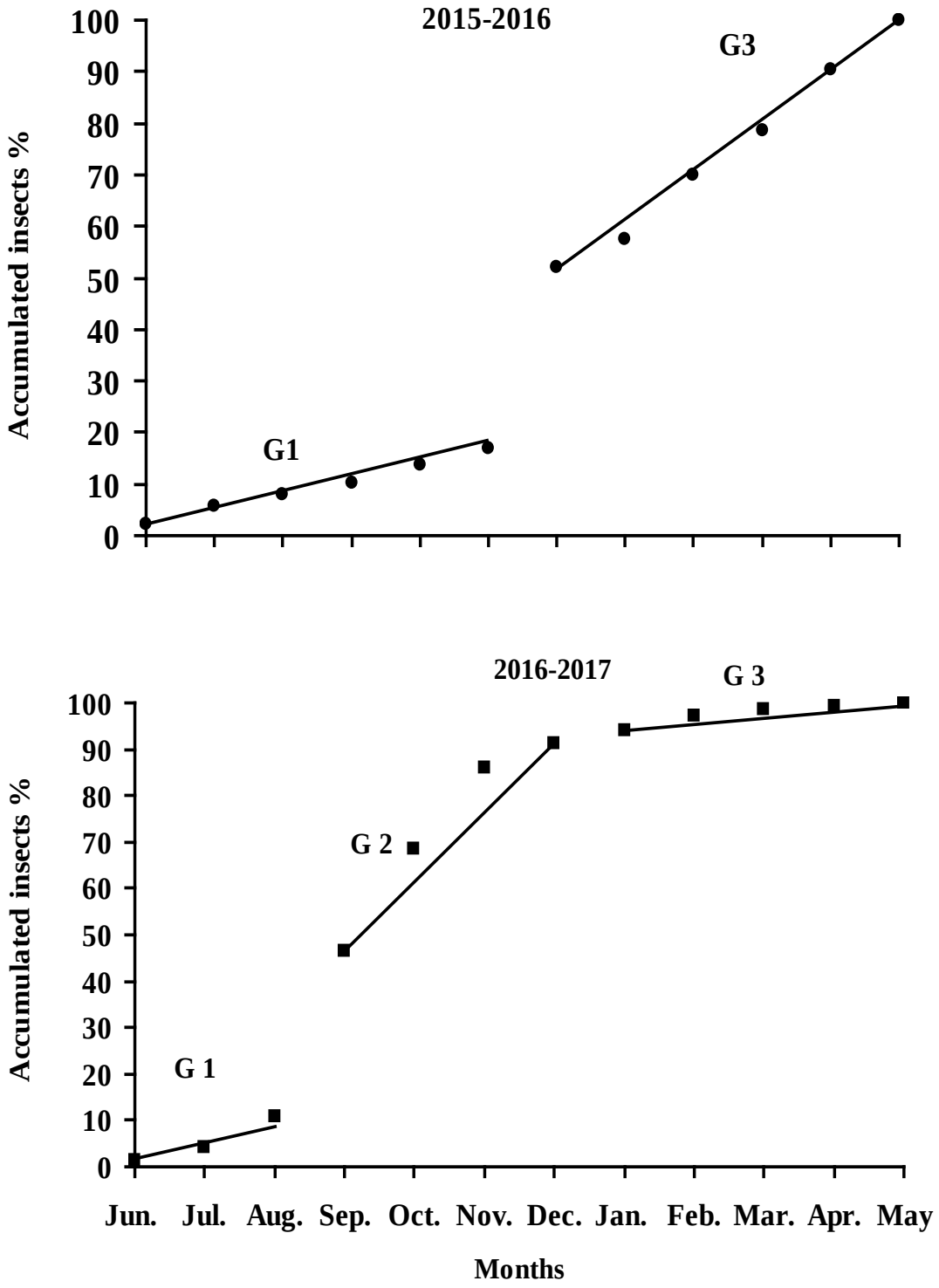

Fig. (1): Annual generations and their durations of *Parlatoria ziziphi* (Lucas) on navel orange trees, in Shebin El-Kom district, Menoufia Governorate during the two successive years.

Hassan *et al.* (2012) who mentioned that the scale had 2 to 3 generations / year there were begin in June to October and the second started in April to May.

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دراسات إيكولوجية على حشرة البرلاتوريا السوداء *Parlatoria ziziphi* (Lucas) التى تصيب أشجار البرتقال أبوسرة بمحافظة المنوفية – مصر

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الملخص العربى

أُجريت هذه الدراسة بمزرعة كلية الزراعة بشبين الكوم بمحافظة المنوفية مصر على حشرة البرلاتوريا السوداء *Parlatoria ziziphi* (Lucas) والطفيل المصاحب لها على أشجار البرتقال أبو سرة خلال الفترة من يونيو ٢٠١٥ وحتى مايو ٢٠١٧ لدراسة الوفرة الموسمية وفترات النشاط والأطوار المختلفة للحشرة والطفيل المصاحب لها وكذا تأثير بعض العوامل الجوية عليهم، أظهر إجمالى تعداد الأطوار الحية للحشرة فترتين من النشاط خلال عام الدراسة الأول (٢٠١٥-٢٠١٦) وكانتا خلال سبتمبر ويناير، بينما تم تسجيل ذروة واحدة للنشاط خلال العام الثانى (٢٠١٦-٢٠١٧) خلال شهر سبتمبر، سُجل الطفيل *Aphytis* sp. (Hymenoptera: Aphelinidae) على الحشرة وكان له ذروتين للنشاط (٪ تطفل) خلال عام الدراسة الأول فى نوفمبر ومايو ، وذروة واحدة خلال العام الثانى كانت فى ديسمبر، وجد أن العوامل الجوية (الحرارة – الرطوبة- الاشعاع الشمسى) تؤثر فى العدد الكلى للأطوار الحية للحشرة بنسب ٨٩,٤٧ و ٨٥,٣٠٪ خلال عامى الدراسة. وجد أن للحشرة من جيلين إلى ثلاثة أجيال فى العام تراوحت مدة الجيل من ٣- ٥ شهور.

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