Current Science International
ISSN 2077-4435

Volume : 05 | Issue : 01 | Jan-Mar. | 2016
Pages: 36-43

The Seasonal Population Dynamics of the California Red Scale Insect, Aonidiella Aurantii (Maskell) (Homoptera: Diaspididae) and its Parasitoids in Middle Egypt.

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Received: 1 January 2016 / Accepted: 4 February 2016 / Publication date: 15 February 2016

ABSTRACT

Field studies were conducted on citrus orchard in Middle Egypt. The seasonal abundance and parasitism of California red scale, *Aonidiella aurantii* (Maskell) (Homoptera: Diaspididae) were estimated from10th March, 2011 till 25th February, 2013 *Aonidiella aurantii* had 3 generations and four peaks of parasitism during the two seasons of investigation. Three species of parasitoids, *Aphytis* sp. & *Aphytis melinus* of family Aphelinidae and *Habrolepis asidioti* of family Encyrtidae were obtained from different stages of this pest.

Key words: *Aonidiella aurantii*, Parasitism, Middle Egypt and Citrus

Introduction

Citrus come second only to grapes in planting and production of fruit trees worldwide (Spiegel-Roy and Goldschmidt, 1996) and the most important fruit crops in Egypt. Its plantations reached nearly 395,731 feddans producing 3,730,685 tons in Egypt and 5847 feddans producing 51,302 tons of citrus fruits in Beni-Suif governorate, according to the 2011 statistics of the Egyptian Ministry of Agric.

The California red scale is one of the most important pest infested citrus trees in different parts of the world (Karaca, 1998; Claps *et al*. 2001 and Abd-Rabou, 2009). This pest inserts its mouthparts deep into plant tissue and sucks sap from parenchyma cells. Prolonged infestation may cause leaf drop and defoliation and dieback of twigs and eventually large branches. 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 tend to dry out and fall off. Even the trunk can become heavily infested (Bedford, 1998).

Considerable differences in the population densities of this pest were recorded in different parts of the world (Selim (1993), Morsi (1999) in Egypt, Yarpuzlu *et al.* (2008) in Turkey, Kaiju (2013) in Youxi county of Fujian province, Chinese.

Occasionally *Aphytis hispanicus* (Mercet) has been described as parasitoid of CRS(Pina and Verdú, 2007, Pekas *et al.*, 2010b).

In Eastern Spain, like in many citrus areas around the world, CRS constitutes an invasive pest that has spread during the last decades, being present in most citrus orchards (Castaño *et al.*, 2008; Sorribas *et al*., 2010). Latest studies show the introduced *Aphytis melinus* DeBach and the Mediterranean basin native *Aphytis chrysomphali* (Mercet) coexisting in similar proportion as the most important parasitoids (Pina and Verdú, 2007; Sorribas *et al*., 2008; Sorribas *et al*., 2010).

The present study was conducted throughout two successive seasons from10th March, 2011 till 25th February, 2013. The scope of the study included the following aspects:

1- The seasonal changes in the population dynamics of the CRS insect, *A. aurantii* on citrus in Beni-Suif governorate.
2- Survey of *A. aurantii* parasitoids on citrus in Middle Egypt.
3-Evaluation of the rate of natural mortality of the red scale insect that caused by parasitoids.
4- Effect of biotic factor on the population dynamics of the red scale insect.

Materials and Methods

I. The fluctuation in the population activity of A. aurantii on citrus:

Estimation of the population dynamics, seasonal abundance and number of generations of CRS insect, *A. aurantii* on citrus were carried out for two seasons extending from 10th March, 2011 till 25th February, 2013.

For estimation of the CRS insect population, the following stages were considered:

a- Nymphs: represented by the first and second nymphal instars
b- Males: represented by the pre-pupa and pupal stages.
c- Females: represented by the adult females.

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The citrus orchard 15 years old, that was selected for this study, located in Beba District (Beni Suif governorates), contained an area of 5 feddans [Baladi orange trees, *Citrus sinensis* var *baladi*] infested by CRS insect, *A. aurantii.* In this orchard, no chemical treatments were applied during the two years prior to the present study and throughout the investigation period.

Half-monthly samples of 100 leaves was taken at random from the different directions of the orchard. The leaves represented the different sides, the peripheral, inner zones, the lower and middle strata of the tree. These leaves were kept in a paper bag and transferred to the laboratory for careful examination using stereo-microscope. The different stages of CRS insect, *A. aurantii* were detected and counted.

Half-monthly percentages of CRS insect, *A. aurantii* nymphs helped in estimating the number of generations. These were indicated by the peaks of nymph stages throughout the two consecutive years of study. This method was followed according to Batra and Sandhu (1981).

II. Survey of parasitoids:

A survey of *A. aurantii* parasitoids was carried out in Beni-Suef, El-Menia and Fayoum Governorates throughout a period of two seasons, extending from 10th March, 2011 till 25th February, 2013.

Samples of infested leaves with *A. aurantii* from different citrus trees; orange, *Citrus sinensis*, mandarin, *Citrus reticulata* var. Blanco and lime *Citrus aurantifolia* were randomly collected from different orchards in different months of the year. Immediately after collection, the samples were packed in paper bags, taken to the laboratory for examination.

These specimens were carefully examined and a needle was used to remove all the insects except only of *A. aurantii* which its natural enemies were desired to be surveyed. Those samples were enclosed in plastic jars of 15 cm. diameter and 20 cm. height covered with muslin held in position by a rubber band and kept under preferential conditions for securing any emerging parasitoids.

The pupae were placed on wetted filter paper in Peteri-dishes of 9 cm and kept under preferential conditions until emergence of adult parasitoids according to Eid (1998).

All emerged parasitoids were collected, sorted into species and preserved in vials containing 70% ethanol and glycerin, the slide mounting of represented specimens, was conducted as well. The labeled data included; location, date of collection, host insect and host plant.

The parasitoids species were identified in Biological Control Res., Dept., Plant Prot. Res. Inst., ARC, Ministry of Agric., Giza, Egypt.

III. Rate of parasitism and seasonal abundance of A. aurantii parasitoids in Beni-Suef Governorate, Egypt:

The rates of parasitism of the different *A. aurantii* parasitoids was carried out at Beni-Suef Governorate during two successive seasons 2011/2012 and 2012/2013 (from 10th March, 2011 until 25th February, 2013).

Half- monthly specimens of 100 randomly individuals of *A. aurantii* were collected from citrus orchards at random from various localities during the two years of study.

Immediately after collection, all these samples were placed in paper bags and transferred to the laboratory. These specimens were carefully examined and with a small needle was used to dissect all collected individuals of *A. aurantii*.

Each specimen was put on a slide and covered with a water film, to be examined under a stereo-microscope, and classified as following: alive unparasitized, parasitized *A. aurantii* having (larval or pupal) parasitoids. The emergence holes of parasitoids were detected. Percentages of parasitism on *A. aurantii* were calculated.

IV. Statistical analysis:

Simple correlation and regression values between the mean number of nymphal stages of *A. aurantii*/100 leaves and the percentage of parasitism were calculated to obtain information about the relationship between them. The half-monthly mean counts of *A. aurantii* nymphal stages were considered as the dependent variable (y), while the corresponding percentage of parasitism represented the independent variable (x).

The simple correlation and regression values helped in detecting the relationship between the (y) and each of the (x) variables. Analysis of variance (F- test) and the percentage of explained variance (E. V. %) were estimated by applying "the C- multipliers formula "as described by Fisher (1950).

Significant differences among the treatments that used in biological studies were tested by analysis of variance of the complete randomized design.

Results and Discussion

I. Seasonal Population Dynamics of CRS, *A. aurantii:*

Data illustrated in figs., 1& 2 showed changes in the population density of California red scale insect , *A. aurantii*, as indicated by the total half monthly number of different stages/100 leaves during two successive

seasons (2011/2012 and 2012/2013). The survey was carried out from 10th March 2011 to 25th Feb. 2013 by direct count of different stages in 100 random leaves of citrus.

Results suggest constant patterns in *A. aurantii* community structure over the two seasons, although there was substantial overlap of the nymphs between seasons with variable numbers as shown in fig.3 Population density was high and exhibited outbreaks which include extensive infestation from March to October during the two seasons of study. The highest infestation occurred in the first, followed by second seasons of investigation, although the highest count of individuals/100 leaves occurred in the second season. The rate of infestation was 61-327 and 33-345 individuals /100 leaves during the two seasons, respectively.

The seasonal abundance of the red scale *A. aurantii* was studied for two successive seasons from 10th March 2011 to 25th Feb.2013 on citrus trees in Beni-Suef .The obtained results in Figs (1 and 2) showed that, the insect population reached maximum during fall (327 individuals/100 leaves) in 25th Oct in the first year of study while in second year (345 individuals/100 leaves) it reached max. level in spring in 10th June, 2012. The pest population reached its min. level in winter (61 individuals/100 leaves) in 10th Jan., 2011/2012 while reached its min. level in winter (31 individuals/100 leaves) in 25th December, 2012/2013

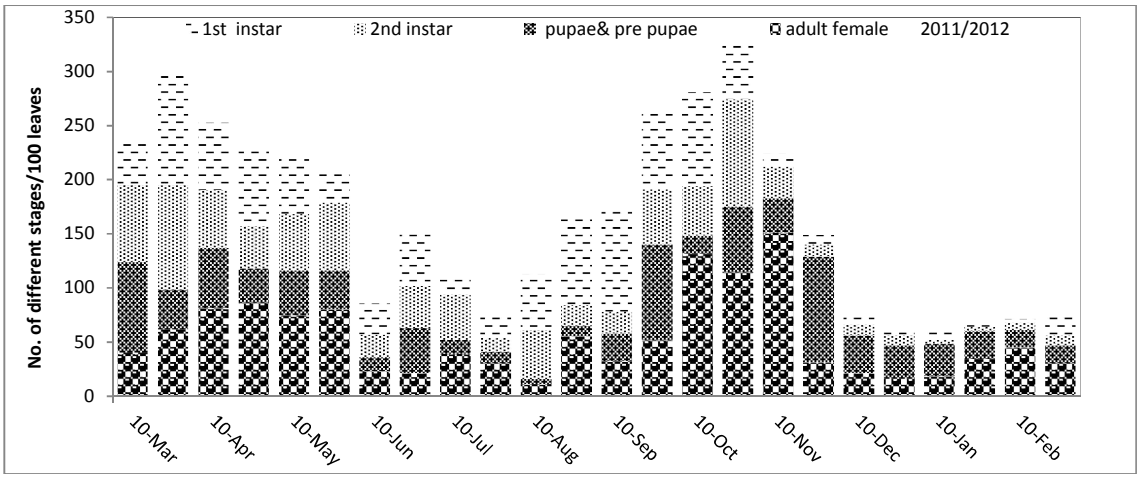

Fig. 1: The fluctuation in numbers of different stages /100 leaves of *Aonidiella aurantii* collected from citrus orchards (100 leaves examined per sample) in Beni-Suef Governorate, during the season 2011/2012.

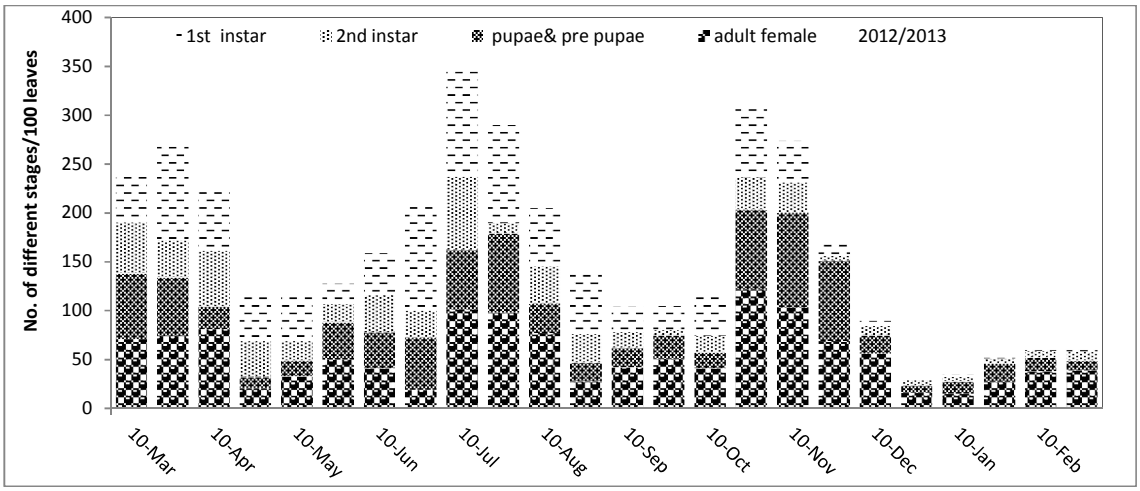

Fig. 2: The fluctuation in numbers of different stages /100 leaves of *Aonidiella aurantii* collected from citrus orchards (100 leaves examined per sample) in Beni-Suef Governorate, during the season 2012/2013.

This pest had three generations, that were in spring, summer and fall. No significant variation between the total numbers of individuals over the two seasons at probability level 0.05. The total number of 1st nymphal instar was higher than the 2nd nymphal instar during the two seasons. Generally, this pest seems to prefer infecting the upper surface of leaves than the lower.

During the first season of investigation, this pest had three peaks of nymphs representing overlapping generations per season, which occurred in 2011/2012. The 1st peak appeared in 25th March (198 nymphs/100 leaves). The 2nd peak was observed in 25th June (89 nymphs /100 leaves). The 3rd peak was in 25th Oct. (152 nymphs /100 leaves) (figs. 3). Mona (2012) studied the seasonal abundance of the red scale *A. aurantii* for two successive years from 2010 to 2011 on citrus trees in Beni-Suef and the results showed that, the insect population reached maximum during April (1750 and 2280/ 30 leaves and 15 twigs) in the first and second years, respectively.

Three peaks have been observed in the second season 2012/2013, one in each of spring, summer and fall. The 1st peak appeared in 25th March (135 nymphs/100 leaves).The 2nd peak was in 10th June (183 nymphs /100 leaves. The 3rd peak was in 25th Oct. (106 nymphs /100 leaves) (figs. 3).

This results was agreed with Selim (1993) & Morsi (1999) in Egypt, who found that this insect had 3-4 generations per year on citrus, Yarpuzlu *et al.* (2008) in Turkey, Kaiju (2013) in Youxi county of Fujian province, Chinese, mentioned that three generations of red scale may develop annually on citrus.

Battaglia and Viggiani (1982) recorded 3 peaks of young nymphs for *A. aurantii* on citrus in the Campania region of Italy .

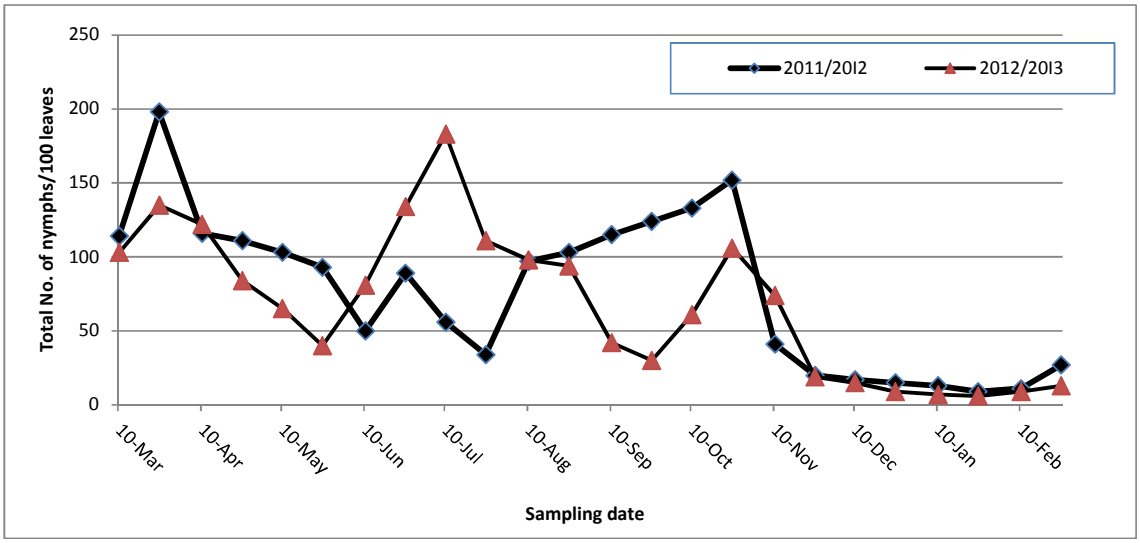

Fig. 3: The fluctuation in the total numbers of *Aonidiella aurantii* nymphs/100 leaves in Beni-Suef Governorate, during 2011/2012 and 2012/2013 seasons.

II. Survey of parasitoids:

Samples of *A. aurantii*, collected from citrus orchards in Beni-Suef, El-Menia and El-Fayoum Governorates during the two seasons 2011/2012 and 2012/2013 of investigation give rise to the following species of parasitoids:

Three species of parasitoids, *Aphytis* sp. & *Aphytis melinus* DeBach of Aphelinidae and *Habrolepis aspidioti* Comp. & Annecke of Encyrtidae were reared from different stages of this pest.

Morsi (1999) recorded 3 species that were *H. aspidioti*, *Coccophagoids sp* and *A. melinus* reared from *A. aurantii*in Egypt. Mona (2012) recorded two parasitoids associated with red scale, *A. aurantii* in Beni-Suef governorate. Theses are *Aphytis lingnanensis* Compere and *Habrolepis aspidioti* Compere and Annecke.

Hoda and Abd-Rabou (2010) recorded 12 species of parasitoids of *A. aurantii.* (10 species belonging to Family Aphelinidae and the rest of species belonging to Family Encyrtidae) and 9 species of predators (6 species belonging to Family: Coccinellidae, one species belonging to Family: Anthocoridae, one species belonging to Family Chrysopidae and one species belonging to Family: Syrphidae) were identified and collected associated with *A. aurantii.* In this respect, many workers recorded and collected the natural enemies of this pest in Egypt for example: Abd-Rabou (1999,2001, 2002 and 2004a,b) and Abd-Rabou and Hayat (2003),

III. Rate of parasitism and Seasonal abundance of the parasitoids of *A. aurantii* on citrus trees:

Data illustrated figs, (4 & 5) showed the changes in the population density of the parasitoids of the California red scale insect *A. aurantii*, based on 100 dissected individuals. This study extended for two successive seasons from 10th March, 2011 until 25th February, 2013. The experiment was carried out by the total half monthly direct count of different immature stages of parasitoids of *A. aurantii* and immergence holes. The mean rate of the total percentage of parasitism in the two years were 24.79 and 15.46, respectively. The second season showed the lower rate of parasitism. There were high levels of parasitism of *A. aurantii*. No significant

variation between the numbers of larvae, pupae or total count of them over the two years at probability level 0.05.

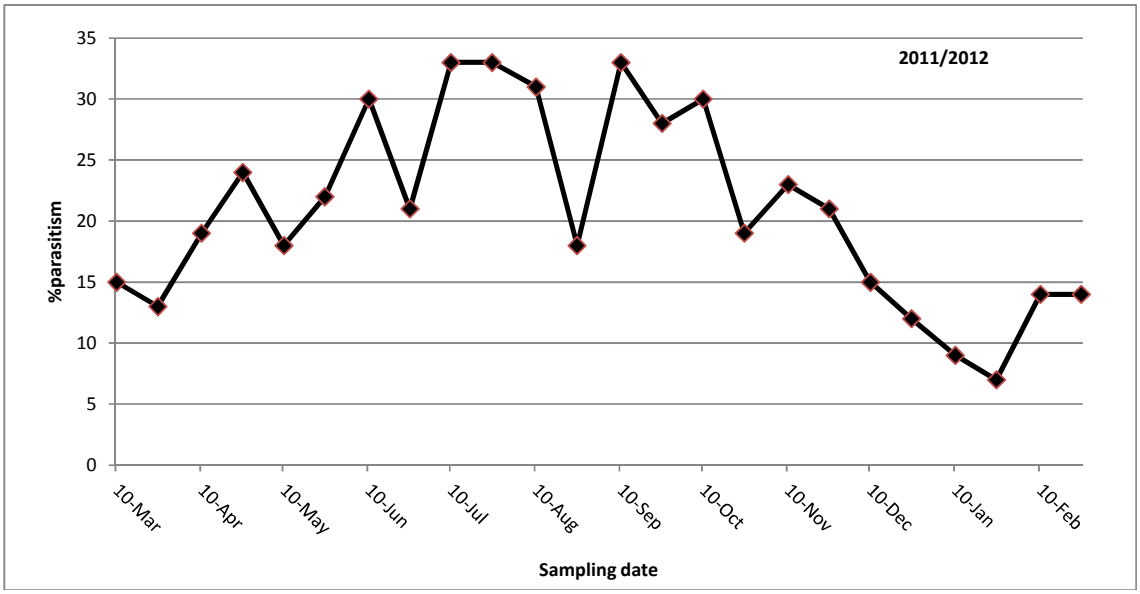

Fig. 4: Percentages of parasitism of the California red scale insect, *Aonidiella aurantii* (Maskell) collected from citrus horticulture (based on 100 dissected individuals) in Beni-Suef Governorate, during 2011/2012 season.

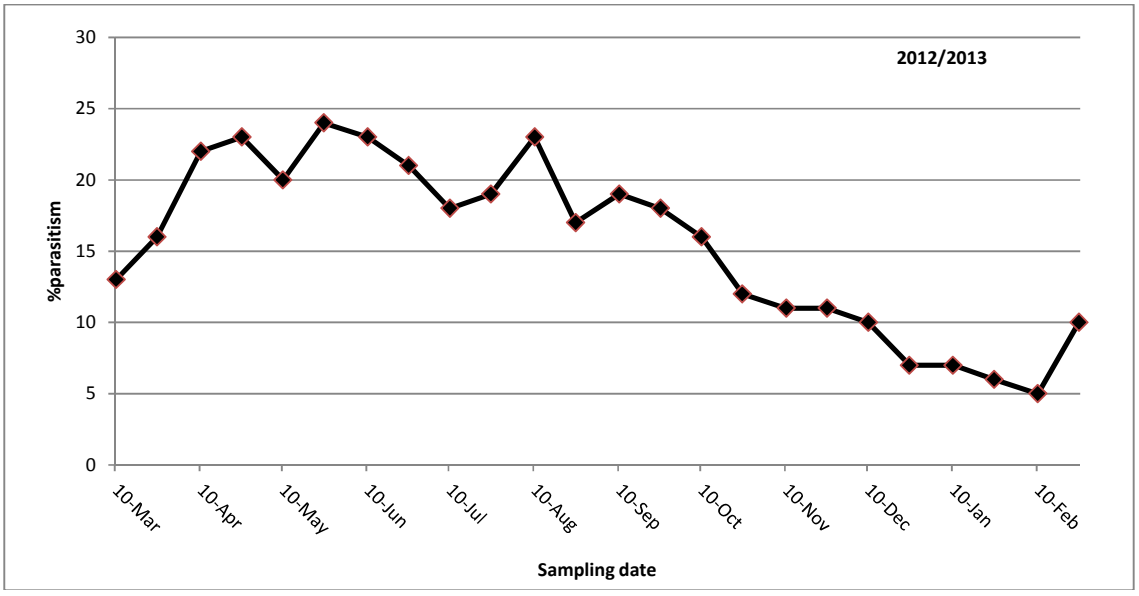

Fig. 5: Percentages of parasitism the California red scale insect, *Aonidiella aurantii* (Maskell) collected from citrus horticulture (based on 100 dissected individuals) in Beni-Suef Governorate, during 2011/2012 season.

The percentage of parasitism reached its maximum level (48% parasitism) during the third generation at 25th July, 2011 (48% parasitism). While in the second season reached its maximum level (24% parasitism) in spring during the 2nd generation on 25th of May, 2012.

During the first season of investigation 2011/2012, the activity of parasitism had six peaks representing overlapping generations per season. The 1st peak representing the first generation appeared on 25th April, 2011 (24% parasitism). The 2nd peak was on 10th of June, 2011 (40% parasitism). The 3rd peak was observed on 25th July, 2011 (48% parasitism). The 4th beak was on 10th of October, 2011 with (30% parasitism). The 5th peak was

observed on 25th November, 2011 (34% parasitism) while the 6th beak was on 25th of January, 2012 with (20% parasitism) (fig. 4).

The percentage of parasitism fluctuated forming variable numbers during this season of study ranged from (13-48%). The parasitoids population reached minimum level (13% parasitism) twice at 25th March 2011 and 10th January, 2012. It reached its maximum level (48% parasitism) during the third generation at 25th July, 2011 (48% parasitism)

Collected data for 2012/2013 season are illustrated in (fig. 5). Four peaks had been observed in this season. The 1st peak occurred on 25th April represented by (23% parasitism). The 2nd peak appeared on 25th of May with (24% parasitism). The 3rd peak was observed on 10th August (23% parasitism) while the 4th beak was on 10th of September with (19% parasitism).

Abd-Rabou (1997) mentioned that total parasitism of *A. aurantii* by *A. chrysomphali, A. lingnanensis, E. citrina* and *E. lounsburyi* reached a maximum during September with parasitism rates 77 and 80% at South Sinai and Qalyubiya. Morsi (1999) recorded fourteen hymenoptrous parasitoid species of some armored scale insects. He mentioned that the highest percentage of parasitism on A. aurantii ranged between 20-45%.

IV. Effect of biotic factor; (percentage of parasitism) on the abundance of the CRS, *A. aurantii:*

As shown in table (1), statistical analyses of data indicated that, the simple correlation and regression coefficient were positive and significant at probability level 0.05 in the second season, but negative and insignificant in the first year of investigation. The correlation coefficient values were 0.16 and 0.58 for the two years respectively, whereas the regression coefficient values were equivalent -0.92 and 4.8 for the two years respectively, in case of the total population of nymph stages.

The regression equation of total population of *A. aurantii* (Y) with the parasitoids factor (X) for the second year was:

Y= 4.8 X - 5.82

The population density of *A. aurantii* nymphs increased 4.8 when total population of parasitoids increased one degree %. That may be due to another unconsidered factors affecting on the population density of *A. aurantii* and its parasitoids together during the second year of investigation.

On the other hand, the accurate effect of the calculated percentage of explained variance values were, 2.6% and 33.7%, for the two years, respectively. The remaining unexplained variance as assumed to be due to the influences of other unconsidered factors in addition to the experimental error.

Table 1: Simple correlations (r), simple regressions (b), t-values (t) and analysis of variance of total counts of *Aonidiella aurantii* nymphal stages/ 100 leaves as affected by number of parasitoids and the corresponding Analysis of variance (F- test and percentage of explained variance E.V.%) throughout two successive seasons 2011/2012 and 2012/2013, in Beni-Suef Governorate.

Season	Statistical analysis				
				Analysis of variance	
	R	b	t	F.	E.V.%
2011/2012	0.16	-0.92	-0.76	0.58	2.6
2012/2013	0.58	4.8	3.35	11.19*	33.7

** Significant (at probability level 0.05)*

Mona (2012) showed that the simple correlation between the population of parasitoids *Aphytis lingnanensis*, *Habrolepis aspidioti*, maximum, minimum temperatures and % of relative humidity and the mean number of pest were significant or highly significant (r = 0.77, 0.54, 0.87, 0.71 and 0.50), respectively during 2011. Also showed that the simple regression for changing the population of parasitoids *Aphytis lingnanensis*, *Habrolepis aspidioti*, maximum, minimum temperatures and % of relative humidity and the mean number of pest were significant or highly significant (b = 0.75, 0.51, 0.86, 0.72 and 0.52), respectively during 2011. She also indicated that the populations of red scale has two peaks one in April and the second one in October.

The peaks of this pest recorded by Abul-Nasr *et al.* (1975) reported the population peaks of *A. aurantii* occurred during the period, October, December, January-Febrauray, April-June and August-September, Darwish (1976) found that *A. aurantii* had 3 annual peaks of abundance, the first occurred during November, the second during May and the third in July. Osman (1996) mentioned that the ectoparasitoid, *A. lingnanensis* had four overlapping activity periods with four peaks in Qalyubiya governorate. The highest rate of parasitism took place in spring in the two years under investigations (25.4 and 28.1%, respectively) who also added that the same parasitoid had four overlapping activity periods with four annual peaks in Beni-Suef. The highest parasitism rate occurred during spring in the two years under investigations (17.5 and 23.5%, respectively on *A. aurantii*). While *A. chrysompahli* manifested the highest parasitism rate on *C. aonidum* during autumn season in both years under consideration (16.3 and 19.5%, respectively).

Later Abd-Rabou (1997) studied the parasitoids attacking some species of scale insects. He mentioned that total parasitism of *A. aurantii* by *A. chrysomphali, A. lingnanensis, E. citrina* and *E. lounsburyi* reached a maximum during September with parasitism rates 77 and 80% at South Sinai and Qalyubiya. Morsi (1999)

recorded fourteen hymenoptrous parasitoid species of some armored scale insects. He mentioned that the highest percentage of parasitism on *A. aurantii* ranged between 20-45%.

Acknowledgment

Deep appreciation and thanks are due to the members of Sids Agriculture of Research. Station, Biological control Department, Plant Protection Res. Institute, Ministry of Agriculture, Egypt. Also, deep thanks to Prof. Dr. Abd-Elhameed M. Saleh, Researcher (Sids Agric. St., Agr. Eng. Dep. Plant Protection Res. Inst., Agric. Res. Center, Beni Suef, Egypt) and Dr. Ahmed M. Abd El-Aziz, Head Researcher, (Agric. Econ. Res. Inst., Cairo, Egypt) for great help throughout the statistical analysis of data.

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