SUMMARY

The scale insects are important pests of fruit trees in Egypt. They cause defoliation, drying up of young twigs, poor blossoming, premature dropping of heavily infested fruits and small size of fruits together with lack of juice in case of heavy infestation.

The main objective of this work was to study the following aspects:

(1) Survey of natural enemies of certain scale insects infesting fruit trees in Beni-Suef Governorate .

(2) Ecological studies on the California red scale, the Oriental yellow scale and the Florida red scale from April, 15th 1995 till April, 1st 1998.

(3) Field studies to evaluate the role of parasitoids in suppressing the population of the California red scale, the Oriental yellow scale and the Florida red scale and studying the rate of parasitism and percentages of total mortalities on these scale insects.

(4) Biological studies on two parasitoids, *Aspidiotiphagous citrinus* and *Habrolepis pascuorum* which were found during the survey parasitized on the Oriental yellow scale, especially that, the ecological and biological control information about the Oriental yellow is lacking in Egypt.

The obtained results were summarized as follows.

1. The natural enemies of certain scale insects:

The following entomophagous insects and predacious mites were recorded on the following scale insects.

a. The California red scale, *Aonidiella aurantii* :

The following parasitoids and predators were recorded on the California red scale on citrus:

Parasitoids:

Aphytis melinus , *Coccophagoids* sp. and *Habrolepis aspidioti.*

Predators:

Scymnus includens, S. subfasciatus ab *jumperi, S. syriacus, Stethorus puncutellum* and *Chrysoperla carnea.*

Two predacious mites were also recorded namely:

Euseins scutalis and *Proctolaelaps orientalis.*

b.The Oriental yellow scale, *Aonidiella orientalis :*

The following parasitoids and predators were recorded for the first time in Egypt, since the biological control information on this scale is lacking.

Parasitoids;

Aphytis melinus, Aspidiotiphagus citrinus, Habrolepis pascuorum and *Marietta picta* .

Predacious insects:

Pharoscymnus varius, Scymnus syriacus and *Chrysoperla carnea* .

Predacious mites:

Euseins scutalis and *Kleemannia pulmosus*.

c. The mango scale, *Aulacaspis tubercularis:*

The following parasitoids and predators were recorded for the first time on this scale insect in Egypt.

Parasitoids:

Aphytis sp., *Aspidiotiphagus citrinus, Encarsia* sp., *Habrolepis aspidioti ,Habrolepis obscura, Metaphycus flavus* and An unidentified encyrtid sp. .

Predacious insects:

Chilocorus bipustulatus, Exochomus nigromaculatus, S. syriacus , S. puncutellum and *C. carnea* .

Predacious mites:

Cheletogenus ornatus, E. scutalis, K. pulmosus and *Tydeus californicus* .

It is to be noted that the parasitoid *H. obscura* recorded for the first time in Egypt during the course of these studies.

d.The fig soft scale, *Ceroplastis rusci* :

The following parasitoids were surveyed on the fig soft scale in Beni-Suef Governorate:

Habrolepis sp., *Metaphycus helvolus, M. zebratus, Microtyres flavus, Microtyres* sp., *Scutellista cyanea , Marietta extiosa* and *Marietta* sp. .

The predator:

Scymnus syriacus

The above mentioned parasitoids and predators did not survey in Egypt on this scale up till now except the parasitoid, *Scutellista cyanea*

e.The Florida red scale ,*Chrysomphalus ficus*:

The following parasitoids were surveyed:

Aphytis chrysomphali , A. lingnanensis ,A. citrinus, Encarsia sp. ,*H. pascuorum* , and *M. picta* .

Predacious insects:

S. syriacus, C. bipustulatus, E. nigromaculatus, P. varius, Rodalia cardinalis and *C. carnea* .

Predacious mites:

Agistemus excertus ,Blattisocius tarsalis and *T. californicus* .

It is the first record of the parasitoid, *Encarsia* sp. on this scale insect in Egypt up till now.

f. *Lecanodiaspis africana* :

The following parasitoids and the predator were recorded on this scale insect for the first time in Egypt.

Parasitoids:

H. aspidioti, M. flavus , Cheiloneurus sp. ,*Anagyrus pseudococci* and *Allotropa kamburovi* .

Predators:

S. syriacus.

g. The mango scale, *Lepidosaphes pallidae* :

Only one parasitoid *Aphytis* sp., was recorded on this scale insect. *S. syriacus, P. varius ,S. puncutellum* and *C. carnea* were surveyed as predacious insects and *Saniosulus nudus , A. excertus* and *E. scutalis* as predacious mites .

h.The olive scale, *Leucaspis riccae* :

Two parasitoids were surveyed:

A. citrinus and *Aphytis* sp.

i. The parlatoria palm, *Parlatoria blanchardii* :

Two parasitoids were recorded:

Aphytis sp., and *Encarsia* sp..

Also six predacious insects were recorded namely;

C. bipustulatus, P. varius, S. syriacus, Cybocephalus sp. *S. puncutellum* and *C. carnea* .

2. Seasonal abundance of some scale insects in Beni-Suef Governorate :

The present studies were conducted throughout three successive years with the object of studying the population fluctuations, the number of generations and in addition, a quantitative study has been made in an attempt to study the effect of maximum temperature, minimum temperature, mean relative humidity and predators on the activity of *A. aurantii* on baladi orange, *A.orientalis* on guava and *C. ficus* on mandarin in Beni-Suef Governorate .

The primary effect of each of the three tested weather factors as well as predators on the population of the three studied scale insects was determined by calculating the simple correlation and regression. The precise effect of each factor and the combined effect of the four factors on the three scale insects were worked out as explained variance.

The obtained results can be summarized as following:

a. The California red scale, *A. aurantii* .:

This scale insect was found all the year round. The fluctuations in total population revealed 3-4 activity peaks annually .In the first year (1995/96), four

peaks of total population abundance could be detected. Those occurred on mid-May; July, 15th; mid-September and mid-March, 1996 and estimated by (21.32, 46.80, 44.42 and 23.92 individuals/leaf, respectively. However, in the second year 4 peaks of total population abundance could be detected. The first peak was estimated by 25.32 individuals/leaf on mid-May. The second one occurred on August , 1st (30.52 individuals/ leaf). The third (on September, 15th), when 38.04 individuals/leaf were counted. While, the fourth peak was estimated by a mean of 18.32 individuals/leaf that were counted on mid-March, 1997.

In the third year 3 peaks of population abundance could be detected. These peaks were estimated by 36.84 individuals on mid-July, 33.76 individuals on September, 15th, and 27.64 individuals/ leaf on March, 1st 1998.

The number of generations of *A. aurantii* was estimated considering the percentages of nymphs from the total population. Results showed that the California scale insect, *A. anaurtii* , had four overlapping generations annually. In the first year; 4 generations could be detected on May, 1st and September, 1st 1995 and also on the beginning of January and March, 15th 1996 (64.09, 69.00, 61.86 and 56.86%, respectively).However, in the second year; the first in mid-May (62.88 %); the second in mid-September (65.62 %); the third in early-January (61.09 %) and the fourth in mid-March (62.45 %). In the third year, those generations occurred on May, 1st and September , 1st , 1997, and January, 1st and mid-March, 1998 (69.36, 66.38, 68.51 and 61.66 % , respectively.).

The maximum temperature was the factor influencing the activity of the insect. The minimum temperature, the daily mean relative humidity and the number of captured predators were almost insignificant influences.

The percentage of explained variance by combination the four tested factors ranged between 54.70 and 79.32 %.

b. The Oriental yellow scale, *A. orientalis*:

Ecological information about this scale insect is lacking in Egypt. The seasonal fluctuations in the population density of the Oriental yellow scale showed

that the *A. orientalis* had 5 peaks; in the first year (1995/96), were estimated by 94.56, 80.28, 92.52, 73.92 and 53.32 individuals/ leaf and occurred on August , 1st September, 15th , November, 1st 1995, mid- January and March , 15th 1996, respectively. Also, 5 peaks of population abundance may be detected in the second year. These peaks were estimated by 35.40 individuals/ leaf on June, 1st 1996; 50.00 individuals/leaf on September, 1st, 64.00 individuals/ leaf on early-December; 47.04 individuals / leaf on February, 1st 1997; and 53.60 individuals/leaf at the beginning of March. In the third year, 5 peaks of population abundance may be detected. These peaks were estimated by 26.00, 38.28, 53.64, 55.52 and 50.20 individuals/leaf on May, 1st, mid-July, November, 1st , the beginning of January and mid-March, respectively.

Concerning the number of generations; 4 peaks of abundance were recorded. In the first year; those occurred on June, 15th (69.54%), October, 15th (89.87%) , January, 1st (90.73%) and March, 15th 1996 (88.90 %).In the second year ; 4 overlapping generations were recorded and estimated by 71.77, 72.82, 60.69 and 67.46 % on mid-May, October, 1st , January, 1st and March, 1st , respectively. However, in the third year; the four peaks were estimated by 71.13, 67.61, 65.38 and 59.63 % could be detected on early-July, early-October, mid-December and early-March, respectively.

The percentage of explained variance by combination of the four tested factors ranged between 21.30 and 67.5 0 %.

c. The Florida red scale, *Chrysomphalus ficus* :

The results indicated 3-4 activity peaks for this pest annually .In the first year, these peaks were estimated by 17.44, 22.96, 16.12 and 12.28 individuals/leaf occurred on mid-May, early- August, mid-January and mid-March, respectively. However, in the second year, three peaks of total population could be discerned; 18.24, 18.88 and 14.68 individuals/leaf on mid-May, early- August and early-March, respectively. But, 4 peaks could be detected in the third year, those

occurred on mid-May, early-August, early-September and early-November when the relative population densities were 19.88, 24.54, 20.04 and 15.96, respectively.

This pest had four overlapping generations annually. In the first year; those generations were estimated by 64.22, 67.23, 66.34 and 67.43 % nymphs of the total population and took place on mid-May, mid-October, mid-December and mid-March, respectively. In the second year those generations were estimated by 59.21, 63.26, 61.06, and 58.37 % on mid-May, mid-September, mid-December and mid-March, respectively. However, in the third year the four generations observed on mid-April (64.20 %), early-August (71.64 %), early-November (65.91%) and early-March (67.51%).

The four tested factors simultaneously were responsible for about 65.10 – 78.20 %of the variability of the black scale insect activity.

3. The role of parasitoids in suppressing the populations of scale insects:

The role of the parasitoids and mortality factors in controlling the populations of the scale insects under study was estimated half-monthly by dissecting 100 scale insects. The seasonal activities of these parasitoids were represented by their percentage of parasitism on *A. aurantii* on baladi orange, *A. orientalis* on guava and *C. ficus* on mandarin throughout three yrars of investigations in Beba and Nasser Districts–Beni-Suef Governorate. The results obtained indicated the following:

a. *A. aurantii* :

The highest percentage of parasitism (40%) was recorded in the first year (1995/96) on October , 15th 1995. In the second year (1996/1997), this percentage reached 46% and occurred in mid-December, 1996. While, during the third year (1997/1998) the highest percentage of parasitism was 36% and occurred at the beginning of November , 1996.

Statistical analysis indicated that the simple correlation and regression values significantly negative in the three years of investigation. On the other hand, the partial regression values were significantly positive in the first year, but

insignificant negative in the second and third years. That means this factor was below the optimal range in the first year. While the parasitoids effect in the two latter years was within the optimal range of the California red scale insect population activity, then gave negative and insignificant relation. That means, the parasitism factor somewhat gave balance on population activity of red scale.

The overall yearly means of mortality percentages due to factors other than parasitoids were 7.17, 7.54 and 12.83 % in the three years of study, respectively. The total percentages of mortality (parasitoids and other natural mortality factors) were 27.54, 34.79 and 30.71% in 1995/96 , 1996/97 and 1997/98 , respectively.

The simple correlation and regression values were significant and negative throughout the three years of study .On the other hand, the partial regression values were insignificant but positive in the first year and negative in the second and third years.

b. *A. orientalis*:

The overall yearly means of total parasitism were 21.88, 28.29 and 22.58 % in 1995/96, 1996/97 and 1997/98, respectively. The highest percentage of parasitism reached 63 % on mid-July, in the first year (1995/96). In the subsequent year (1996/97), the highest percentage of parasitism was 74 % on mid-July. Throughout the third year of investigation, the highest percentage of total parasitism was 39 % on mid-September.

Statistical analysis of data indicated that the simple correlation and regression values were significant and negative in the three years of investigation. On the other hand, the partial regression values were insignificant and negative in the first year of study. On the contrary, the same factor negatively influenced the activity of the insect throughout the two latter years. Consequently, it could be concluded that the parasitoids play an important role in reducing the population density of *A. orientalis*.

The yearly overall means of mortality percentages due factors other than parasitoids were 7.25, 7.5 and 9.63 % in the three successive years, respectively,

The total percentages of mortality (parasitoids and other natural mortality factors) were 29.13, 35.79 and 32.21 % in 1995/96, 1996/97 and 1997/98 , respectively.

The simple correlation and regression values were significantly negative effect in the three years of study .On the other hand, the partial regression values were negative and insignificant in the first year. However, in the second and third years, these values were negative and significant That means that the total mortality factors (parasitoids as well as non parasitic agents)regarded among the important factors influencing the activity of *A. orientalis* .In most cases, the precise effect of this factor on the activity was significant.

c. *C. ficus* :

The yearly overall mean percentages of parasitism were 19.71 % in 1995/96, 17.33 % in 1996/97, and 24 % in the third year of study (1997/98). In the first year the highest percentage of total parasitism reached 41 % on mid-January. In the second year it was 36 %on October , 1st. While, in the third year, the highest percentage of total parasitism was 43 % on mid-January, 1998.

Statistical analysis indicated negative and significant correlation and regression between the parasitoids activity and population activity of the Florida red scale, *C. aonidum* in the three years of study. While, the precise effect was negative and insignificant in the second year of investigation. On the contrary, the same factor negatively influenced the activity during the first and third years. That means that the activity was generally influenced by the rate of parasitism.

Data on the percentages of mortality due to factors other than parasitism indicated overall yearly averages of 7.71, 7.38 and 13.71 % in 1995/96, 1996/97 and 1997/98, respectively. The total percentages of mortality were 27.42, 24.71 and 37.71% in 1995/96, 1996/97 and 1997/98, respectively

The calculated simple correlations and regressions, showed that these coefficients were negative and significant in the three years of investigation. The precise effect of the total mortality indicated that, the actual influence was significant in the three years of study. It could be concluded that the parasitoids as

well as the mortality factors other than the parasitoids play an important role in reducing the population density of *C. ficus* during the second and third years.

4. Biological studies *on Aspidiotiphagus citrinus* and *Habrolepis pascuorum* :

The morphology and biology of the two endoparasitoids, *A. citrinus* and *H. pascuorum* were conducted on *A. orientalis* reared on guava seedlings and pumpkin under laboratory conditions. The different developmental stages of the two parasitoids were described.

a. *A. citrinus* :

Results of biological studies showed that the incubation period of egg lasted 2.7± 0.11 days . This species had three larval instars; the duration of first, second and third instar larva lasted 2.75±0.1, 2.65±0.11 and 3.15±0.12 days, respectively .The total larval duration lasted 8.15± 0.15 days .The prepupal period lasted one day; while the pupal period lasted 5.56± 0.11 days. The total duration lasted 17.90± 0.22 days.

It was found that the number of deposited eggs, larvae and pupae on a single host in the laboratory averaged 1.54, 1.24, 1.00, 1.00 and 1.00, respectively. However, in the field these numbers were 1.43, 1.10, 1.00, 1.00 and 1.00 for the aforementioned instars or stages ,respectively.In general only one egg is laid in a single host and only one parasitoid emerged.

The sex-ratio was determined under both the field and laboratory conditions, since the all produced individuals were females. As *A. citrinus* is a Thelytokous species (adults reproduce parthenogenitically and all the offspring are females).

The host range was determined, the results show that *A. citrinus* did not oviposit in *A. aurantii*. Furthermore, the parasitoid deposited a large number of eggs in *A. orientalis,* however, in *A. tubercularis* and *C. ficus* the number of eggs were moderately. Those eggs hatched and the immature forms developed normally till the emergence of adult parasitoids. It was found that *A. citrinus* prefer the second nymphal instar of the Oriental yellow scale insect. The percentages of

parasitism in the field were 0, 42, 12, 13,0 and 8% for *A. aurantil,A. orientalis, A. tubercularis, C. ficus, L. pallidae* and *L. riccae*, respectively.

The effect of different diets on the adult parasitoid was investigated .The type of food provided to adults had highly significant effects on oviposition periods, fecundity and longevity of females .The shortest preoviposition period occurred when females were deprived being 0.60±0.16 days. Then, this period prolonged when females were provided with water being 0.80±0.23 days .The preoviposition period reached 1.00±0.21 days when the females fed on 10 %sucrose. This period prolonged when females fed on honey and honey and water being 1.20±0.25 and 1.60±0.38 days, respectively. The oviposition period reached its maximum means when females fed on honey and water and honey; being 17.70±0.61 and 17.60±0.81 days, respectively. When females fed on 10 % sucrose this period lasted 12.40±0.86 days only; while it lasted 4.00±0.47 and 1.60±0.35 days for females provided with water or confined without food or water, respectively. The longest postoviposition period was 2.20±0.33 and 1.70±0.24 days when females were fed on honey or honey and water, respectively. This period lasted 1.5±0.26 days, when females fed on 10 % sucrose; when females prevented from the feeding or provided with water only this period was 0.90 ±0.29 and 1.30±0.24 days, respectively. The daily means of laid eggs per female were 3.22±0.08, 3.73±0.11 and 2.56±0.05 eggs when females fed on honey, honey and water and 10% sucrose, respectively. The mean number of laid eggs/♀ decreased to 1.40±0.14 and 1.04±0.23 eggs/♀ when the female was provided with plain water or left without food or water, respectively .The total mean number of eggs/female followed the same trend. The highest mean were 60.10±3.42 eggs/♀; when females were fed on honey and water; followed by those fed on honey or 10 % sucrose; being 56 .60±2.75 and 31.60±2.05 eggs/♀ , respectively .The total number of eggs decreased to 6.10±0.69 and 2.80±0.63 eggs/♀ for those females supplied with water or fasting, respectively. The females longevity reached its maximum

21.40±0.79 days, when adult females were fed on honey; while, when it fed on honey and water or 10 % sucrose, longevity was 20.20±0.66 and 14.90±0.93 days, respectively, this period decreased to 6.50±0.37 and 3.10±0.66 days when the adult females were supplied with water only or deprived from the food , respectively .

b. *H. pascuorum* :

Results of biological studies showed that the incubation period of egg lasted 2.8±0.09 days. This species had four larval instars; the duration of first, second, third and fourth instar larva lasted 1.50±0.12, 1.70±0.11, 2.70±0.10 and 2.55±0.11 days, respectively .The total larval stage lasted 8.45± 0.21 days .The prepupal period lasted 1.55±0.11; while the pupal period lasted 5.45± 0.11 days for males and 5.25±0.09 for females. The total duration lasted 18.30± 0.31 and 18.05 ± 0.29 days for males and females, respectively.

Mating usually occurs after adult emergence. It was found that the number of deposited eggs, larvae and pupae in a single host in the laboratory averaged 1.28 , 1.35 , 1.22 , 1.06 , 1.00 and 1.00, respectively . However, in the field these numbers were 1.42, 1.37, 1.19, 1.04,1.01, 1.00 and 1.00 for the aforementioned instars or stages, respectively.

The sex-ratio was estimated under both the field and laboratory conditions, since the number of females usually exceeded that of males. The ratio of males to females was 1: 1.36 in the field, however, in the laboratory, vice versa, this ratio was 1:0.95. *H. pascuorum* is an arrhenotokous parthenogenesis , as the unmated females lay eggs which lead to males only .

The host range was determined, the results show that *H. pascuorum* did not parasitize both *A.aurantii* and *A. tubercularis*. However, the parasitoid deposited, approximately the same eggs in *A. orientalis* and *C. ficus*. The preferred instar or stage was determined for the parasitoid, it is clear that *H. pascuorum* cannot parasitise both nymphs and male's prepupae and pupae, it parasitises the newly adult females and full grown adult females. The percentages of parasitism were

estimated in the field, to determine the preferred host, these percentages were, 0, 67, 0, 58,0 and 0 % for *A. aurantii, A. orientalis ,A. tubercularis ,C. ficus L. pallidae and L. riccae,* respectively.

The effect of different diets on the adult parasitoid was investigated .The type of food provided to adults had highly significant effects on oviposition periods, fecundity and longevity of both males and females .The shortest preoviposition period occurred when females were deprived being 0.50±0.12 days. Then, this period prolonged when females were provided with water being 0.70± 0.20 days .The preoviposition period reached 0.80±0.18 days when the females fed on 10 % sucrose, and prolonged to 1.20±0.38 and 1.10±0.27 days when females fed on honey and honey and water, respectively. The oviposition period reached its maximum when females fed on honey and water; being 18.20±0.94 days. When females fed on honey and 10 % sucrose, oviposition period lasted 15.80±1.13 and 10.30±0.76 days, respectively. While it decreased to 4.10±0.44 and 1.30±0.28 days for females provided with water or confined without food or water, respectively. The longest postoviposition period was 1.70±0.30 and 1.50±0.30 days when females were fed on honey or honey and water, respectively. This period lasted 0.80±0.18 days, when females fed on 10 % sucrose. When females prevented from the feeding or provided with water only oviposition period was 0.40±0.22 and 0.60±0.19 days, respectively. The daily means of eggs layed per female were 3.23±0.28, 2.93±0.11 and 1.82±0.08 eggs when females fed on honey, honey and water and 10% sucrose, respectively. The means decreased to 1.07±0.10 and 0.86±0.15 eggs/♀, respectively, when the female was provided with plain water or left without food or water. The highest mean was 53.30±3.74 eggs/♀ when females were fed on honey and water; followed by those fed on honey or 10 % sucrose; being 48.20±4.94 and 26.90±2.32 eggs/♀, respectively .The total number of eggs decreased to 4.90±0.56 and 1.60±0.53 eggs/♀ for those females supplied with water or starved, respectively. The longevity of females are longer than males. The females longevity mean reached its maximum of 20.80±0.82 days, when adult

females were fed on honey and water; while, when females fed on honey or 10 % sucrose it reached 18.60±1.25 and 11.90±0.83 days, respectively. It decreased to 5.60±0.34 and 2.20±0.41 days when the adult females were supplied with water only or deprived of the food, respectively. The longevity of males were 12.20±1.13,11.60±1.44 and 8.60± 0.92 days when the males of *H. pascuorum* were supplied with honey, honey and water and 10 %sucrose, respectively. The mean longevity decreased to 1.70±0.18 and 1.20±0.09 days when males were provided with water or deprived of food and water, respectively.

Hyperparasitoids of *H. pascuorum* on *A. orientalis* were also surveyed. Rates of hyperparasitism were estimated. It reached a maximum of 37.68 % on September, 1st 1998 on *H. pascuorum* on *A. orientalis*.