Mansoura University
Faculty of Agriculture
Economic Entomology Department

Mealybug species attacking citrus trees and their associated predatory insects at Mansoura district

By

Mustafa Abbas Jebur Aljbouri

B.Sc. Agriculture Science (Plant Protection), Karbala University, 2012

Thesis

Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science

In

Agricultural Sciences (Economic Entomology)

Supervisors

Prof. Dr.

Labib M. Shanab

Professor of Economic Entomology
Economic Entomology Department,
Faculty of Agriculture,
Mansoura University

Prof. Dr.

Samir S. Awadalla

Professor of Economic Entomology
Economic Entomology Department,
Faculty of Agriculture,
Mansoura University

Dr.

Mohamed H. Bayoumy

Associate professor of Economic Entomology
Economic Entomology Department,
Faculty of Agriculture,
Mansoura University

2016


بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ
﴿ وَأَنزَلَ ٱللَّهُ عَلَيْكَ ٱلْكِتَٰبَ وَٱلْحِكْمَةَ
وَعَلَّمَكَ مَا لَمْ تَكُن تَعْلَمُ ۚ وَكَانَ فَضْلُ ٱللَّهِ
عَلَيْكَ عَظِيمًا ﴾
النساء: جزء الآية ١١٣

Mansoura University
Faculty of Agriculture
Economic Entomology Department

SUPERVISION

Title of Thesis:

Mealybug species attacking citrus trees and their associated predatory insects at Mansoura district

The Researcher:

MUSTAFA ABBAS JEBUR ALJBOURI

The thesis is supervised by:

No	Name	Position	Signature
1	*Prof. Dr. Labib M. Shanab*	Professor of Economic Entomology, Economic Entomology Department, Faculty of Agriculture, Mansoura University.	
2	*Prof. Dr. Samir S. Awadalla*	Professor of Economic Entomology, Economic Entomology Department, Faculty of Agriculture, Mansoura University.	
3	*Dr. Mohamed H. Bayoumy*	Associate Professor of Economic Entomology, Faculty of Agriculture, Mansoura University	

Head of Dept. **Vice Dean of Higher Studies and Research affairs** **Dean**

Prof. Dr. ***Prof. Dr.*** ***Prof. Dr.***
Hala A. EL-Serafi **Yasser M. N. Shabana** **Yasser M. S. EL-Hadid**

APPROVAL SHEET

Title of Thesis:

Mealybug species attacking citrus trees and their associated predatory insects at Mansoura district

The Researcher:

MUSTAFA ABBAS ALJBOURI

The thesis is supervised by:

No	Name	Position
1	*Prof. Dr. Labib M. Shanab*	Professor of Economic Entomology, Economic Entomology Department, Faculty of Agriculture, Mansoura University.
2	*Prof. Dr. Samir S. Awadalla*	Professor of Economic Entomology, Economic Entomology Department, Faculty of Agriculture, Mansoura University.
3	*Dr. Mohamed H. Bayoumy*	Associate Professor of Economic Entomology, Faculty of Agriculture, Mansoura University

Approval Committee:

No	Name	Position	Signature
1	*Prof. Dr. MOHAMED BAHGAT SHAWER*	Professor of Economic Entomology, Economic Entomology Department, Faculty of Agriculture, Kafr El-sheikh University.	
2	*Prof. Dr. Abdel – Badie A. Ghanim*	Professor of Economic Entomology, Economic Entomology Department, Faculty of Agriculture, Mansoura University.	
3	*Prof. Dr. Labib M. Shanab*	Professor of Economic Entomology, Economic Entomology Department, Faculty of Agriculture, Mansoura University.	
4	*Prof. Dr. Samir S. Awadalla*	Professor of Economic Entomology, Economic Entomology Department, Faculty of Agriculture, Mansoura University.	
5	*Dr. Mohamed H. Bayoumy*	Associate Professor of Economic Entomology, Faculty of Agriculture, Mansoura University	

Head of Dept. **Vice Dean of Higher Studies and Research affairs** **Dean**

Prof. Dr. ***Prof. Dr.*** ***Prof. Dr.***

Avowal of Subject Newness

I am the researcher/ **Mustafa Abbas Jebur Aljbouri**, registered for degree of Master in Agricultural Science Economic Entomology Department, Faculty of Agricultural, Mansoura university, certified that the Subject titled (Mealybug species attacking citrus trees and their associated predatory insects at Mansoura district) is new and not plagiarized from any other works.

The thesis is supervised by:

No	Name	Position
1	*Prof. Dr. Labib M. Shanab*	**Professor of Economic Entomology, Economic Entomology Department, Faculty of Agriculture, Mansoura University.**
2	*Prof. Dr. Samir S. Awadalla*	**Professor of Economic Entomology, Economic Entomology Department, Faculty of Agriculture, Mansoura University.**
3	*Dr. Mohamed H. Bayoumy*	**Associate Professor of Economic Entomology, Economic Entomology Department, Faculty of Agriculture, Mansoura University.**

Presented by

Mustafa Abbas Jebur Aljbouri

Acknowledgement

I would like to express my deep grateful thank to ALLAH who give me life, health, science and helped me to carry out and complete this research work.

***Sincere thanks are due to prof. Dr. Labib M. Shanab**, Professor of Economic Entomology, Faculty of Agriculture, Mansoura University, for his great help, fruitful advice, sincere help, encouragement and for revising the manuscript.*

***Thanks and appreciation are also due to prof Dr. Samir Saleh Awadalla**, Professor of Economic Entomology, Faculty of Agriculture, Mansoura University for suggesting the subject, his great supervision, patience, encouragement, providing facilities and finally his helpful criticizing of manuscript.*

***Great thanks are due to Dr. Mohamed Bayoumy,** Associate Professor of Economic Entomology, Faculty of Agriculture, Mansoura university, for his supervision and continuous guidance throughout the experimental work*

*I am grateful indebted to all staff members of Economic Entomology Department, Faculty of Agriculture, Mansoura University for their cooperation and encouragement. Special thanks to **Dr. Hagar Samir Saleh Awadalla,** lecturer of Economic Entomology, Faculty of Agriculture, Damietta University for her help, support and cooperation during my study.*

Finally, I wish to express my deepest thanks to my family members for their blessing, compassion and encouragement.

CONTENTS

CONTENTS

List of Tables

List of Figures

1

INTRODUCTION

1. INTRODUCTION

Egypt comes among the largest citrus producing countries in the world and occupies the third rank among the Mediterranean countries in citrus production (FAO, 1997). But, in 2012 it occupied the fourth rank in citrus production. The total amount of citrus exports is about 25% of the total production according to the Annual Report of the Citrus Research Department, Ministry of Agriculture 2012.

The main cultivated areas of citrus are located in Nile Delta and the Nile Valley when they occupy 72% of the total area, whereas the newly reclaimed sandy soil and desert areas occupy 25%. The most important varieties in the delta and the Valley are Navel, common balady and Succari (sweet) oranges, whereas Valencia Orange, Mandarin and Lime are mainly concentrated in the newly reclaimed soil and desert areas. Orange, Mandarin and Lime plantations represent 62, 26 and 11%, respectively of the total area of citrus (Ministry of Agriculture 2012).

The mealybug species (Hemiptera: Pseudococcidae) are very injurious insect pests attacking these citrus orchards, cause serious damage, and affecting quantity and quality of the fruits and finally cause economic losses in the crop (Arif *et al*., 2009; Nagrare *et al*., 2009 ;Bailey *et al.*, 2010 ; Moustafa, 2012 ; El-kady, 2013).The citrus mealybug, *Planococcus citri (*Risso) (Homoptera: Pseudococcidae), is a polyphagous species that distributed over all zoogeographical regions (Williams and Watson, 1988). It is one of the most common pests in all greenhouses and nurseries, where it attacks a wide range of

ornamental, Fruit, and vegetable crops in several temperate and tropical regions (McKenzie, 1967; Blumberg *et al.*, 1995).

Ladybird beetles (Coccinellidae: Coleoptera) are considered as one of the most beneficial biological control agents. They are preying on mealybug, scale insects, aphids, and other soft bodied insects (Bozsik, 2006; Jalali *et al*., 2009). Among these *Rodolia cardinalis* (Mulsant), *Nephus includens* (Kirsch), and *Cryptolaemus montrouzieri* (Mulsant) are the most common predators attacking egg, nymphal and adult stages of mealybug. However, predators of mealybug are less effective biocontrol agents than parasitoids (DeBach, 1964). The only known exception is the control of the cottony-cushion scale, *Icerya purchasi* Maskell, by the vedalia beetle *R. cardinalis*. This famous success resulted in the widespread of *R. cardinalis* all over the world (Prasad, 1989). Following the successfully introduction of this predator to control *I. purchasi* in citrus orchards in California in the 1880s, *R. cardinalis* was imported in more than 60 countries and it has successfully established (Bennett *et al*., 1985; Caltagirone and Doutt, 1989). Specifically, *R. cardinalis* recorded 20 preys in its feeding range, and this information indicated that the feeding range for vedalia beetle is almost restricted to the Coccoidea (Pseudococcidae, Margarodidae, Diaspididae and Dactyliiopidae). Most biological and ecological studies on *R. cardinalis* were conducted on its main prey *I. purchasi*, however no study aimed to evaluate its behavioural response to other Coccoids, e.g., *P.citri*. Green lacewing, *Chrysoperla carnea* (Stephens) (Chrysopidae: Neuroptera), is an effective and widely distributed predator in several parts of the world (Afzal and Khan, 1978; Geetha and Swamiappan, 1998). The biological control by it has gained importance in pest management due to its widely geographical distribution,

highly relative frequency of occurrence, widely adaptability in field than other predators, highly tolerance to the wide ranges of ecological factors and easily rearing technique in the laboratory (Saminathan, *et al*., 1999 and Tauber *et al*., 2000). This species is one of the highly intensively studied specie of Chrysopidae. Although, it has received much attention from researchers as well as from farmers as a potential biological pest control agent (Gautam and Tesfay, 2002), little is known yet about its behavioural response and searching abilities in response to pseudococcids, e.g., *P. citri*.

Functional response has received much attention from researchers in the entomological and ecological literature since Holling, 1959 (Williams and Juliano, 1996; Gitonga *et al*., 2002). Functional response can improve understanding of predator–prey interactions, clarifying co-evolutionary relationships, and enhancing the predictability of biological control (Timms *et al*., 2008). The functional response is the change in number of prey consumed by an individual predator per time in relation to the change in initial prey density (Solomn, 1949) and numerical response is defined as the change in reproductive rates with changing prey density (Holling, 1959). The functional response is divided into three basic types expressed graphically by the relationship between initial density of prey and the corresponding consumed number by a predator at a specific time (Holling, 1959). The curves of functional response can be classified and differentiated by assessing the rate of attack and handling time (time spent between two successive meals that included subduing and eating the prey) coefficients. The attack rate measures the steepness of predation rates as prey density increased, and handling time theoretically estimates the threshold of predator's satiation (Holling, 1959). From a practical point of view, the

functional and numerical responses are usually used to provide insights about the suitability of predator as a biological control agent.

For the integrated pest management program requirements, the evaluation of the definite role of the natural enemies of these insect pests and knowledge of the population relationships of the host insect and its natural enemies needs more ecological and biological information. The role of predatory insects in controlling the mealybug species in different fruits orchards had been studied by several investigators (e.g., Ibrahim, 2005; Awadalla, 2013 ; Fahad, 2015)

Therefore, the present work is aimed to:

1) Studying the population density of the mealybug species and their associated predatory insects on different citrus trees.

2) Studying the effect of season within the year on population of mealybug species and their associated predators on varying citrus species.

3) Evaluating the correlation coefficients between the mealybug species and their associated predator species on varying citrus species.

4) Studying the effect of different citrus species on the biological aspects of *Icerya seychellarum* (Westwood).

5) Studying the behavioural responses of *C. carnea* (Chrysopidae: Neuroptera) and *R. cardinalis* (Coccinellidae: Coleoptera) to citrus mealybug, *P. citri* (Pseudaucoccidae: Hemiptera).

2

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1. Ecological studies:-

A survey was carried out in gardens in Cairo, Alexandria and Giza, in 1967-69 on the aphids and mealybugs present on various cultivated plants in Egypt by **Abul-Nasr *et al.*, (1975)**. The species found were *Icerya Purchasi* Maskell. and *Icerya aegyptiaca* Douglas on rose; *I. purchasi* and *Ferrisia virgata* (Ckll.) on chrysanthemum; and *I. purchasi* on violet.

In Cyprus, **Gerini (1977)** recorded the citrus mealybug *Planococcus citri* (Risso) on shaded parts of the branch near the location of the citrus fruits.

In Israel, **Berlinger *et al.*, (1979)** found that populations of ***P. citri*** and non-specific predator of the mealybug, *Chrysoperla carnea* (Steph.), was active only in spring; *Chilocorus* was whereas the only biological control agent presented in appreciable numbers in that citrus grove, as well as being abundant in the other groves. The high population level and long reproductive period of *Chilocorus bipustulatus* Linnaeus, suggested that this species could become an important biological control agent under favorable conditions.

Siddpapaji *et al.*, (1984) reported that the crawlers and settled forms of *I. aegyptiaca* (a new pest of mulberry in India) were preyed upon by *Scymnus* sp., while *I. purchasi* (which was also observed on mulberry in some places) was attacked by *Rodolia cardinalis*. *Scymnus* sp. prayed on the lower surface of the leaves close to the colonies of *I. aegyptiaca*, and in 1984 completely cleared the mulberry trees from scales.

In Taiwan **Chiu *et al.* (1985)** mentioned that the cottony-cushion scale, *I. purchasi*, entered Taiwan on *Acacia* trees imported from Australia.

The infestation of this scale on citrus was heavy in the early years following its establishment. During that period they recorded three native species of natural enemies. *P. citri* is a common citrus mealybugs attacking a wide range of fruit trees and ornamental plants. The coccinellid predator, *C. montrouzieri*, was introduced into Taiwan from New Zealand in 1909 by Shiraki. This predator readily became established in northern Taiwan and was considered to be a good predator because of its voracious appetite.

In Iran, **Khalaf (1987)** collected the margarodid *I. purchasi* from 12 host plants (mainly *citrus spp.*and pomegranate). This insect produced four generations a year. The life cycle lasted from 70 to 140 days. The coccinellid *R. cardinalis* proved as a very efficient predator of this insect and produced a generation every 19-22 days, unless prey was scarce or unfavorable climatic conditions.

In Egypt, **Assem *et al.*, (1991)** recorded the mealybug, *I. seychellarum* as one of the most economic insect pests attacking horticulture plants. The host plants attacked were 44 species at least belonging to 25 families, [persimmon was among in these species]. In most cases, the pest attacked severely the foliage. Accordingly, a large amount of sap is lost and a serious damage, which leads to defoliation and dryness is caused. Sometimes *I. seychellarum* causes little damage but a malaise may be appeared. Furthermore, this insect hinders the economic value of the host plant because of the bad appearance of its infestation (especially to the fruits and ornamental plants).

In Egypt, **Hamed and Hassanein (1991)** reported that the predators, *R. cardinalis* and *C. bipustulatus, Scymnus syriacus* Marseul, *Pharoscymnus varius* Kirsch, were found feeding on scale insects and mealybugs. They also pointed out that *Chrysopa* larvae are very common.

In Turkey, **Ozkan *et al.*, (1991)** mentioned that the citrus mealybug, *P. citri* is one of the most important citrus pests. It causes significant damage by feeding on all parts of citrus except the roots. It sometimes causes 30-60% fruit drop, which ranks it as a key pest in orchards where the natural balance of the pest predator complex has been damaged by over spraying of pesticides.

In India, the searching behavior of adults of the coccinellid *Nephus reunioni* was studied on six plants infested with *P. citri* and *Planococcus affinis* (Masckell) by **Copland *et al.*, (1993)**. The predator was more active on citrus and least active on Passiflora.

In the Loukos area in the north of Morocco, **Abdelkhalek *et al.*, (1998)** recorded *P. citri* on citrus orchards. A two-year study was undertaken on Maroc Late citrus cultivar to study the bioecology of *P. citri*. It was found that *P. citri* has 6 to 8 overlapping generations annually. High population levels occurred during June-December.

Abbas and Hebbeis (1998) found that four species of mealybugs infesting fruit trees and ornamentals in Shalala(the southern region of Oman). These were *P. longispinus, P. citri, I. aegyptiaca* and *I. purchasi*. The first and third species were the most common species and occurred almost all the year.

In Sharkia governorate, Egypt **Moustafa (1998)** recorded the mealybug which belongs to the family Margarodidae infested some fruits and medicinal plants.

Soares *et al.*, (1999) evaluate the population dynamics of *I. purchasi* and *R. cardinalis* on two citrus orchards in the North of Sao Miguel island (Rabo de Peixe) and Sao Miguel island (Azores) . For that purpose sixteen trees were sampled from May to November 1997 and from

April to October 1998. *I. purchasi* develops two annual generations, one at the end of spring and the other in autumn. *I. purchasi* developed two annual generations, one at the end of spring and the other in autumn. Young females are the most abundant stage during the winter. The larval stages of the predator appear mainly at the beginning of summer and adults start to appear in July reaching the peak of abundance at the end of the season. This maximum probably contributed to the decrease of *I. purchasi* density during the summer. During autumn, the population level of *Rodolia* beetle decreased coinciding with the second generation of *I. purchasi*. After November, no individuals were found on trees probably indicating the beginning of the hibernation period.

In Egypt, **Mangoud (2000)** mentioned that *I. seychellarum* has 2-3 population peaks/yearly on apple trees during late-June, late- October and mid-December. Distributional studies of the mealybug on apple tree showed that 61% of the mealybug was concentrated on old branches, 31.7% on new branches, 4.2% on old leaves and 2.2% on new leaves.

In Egypt**, Tawfik and Mohammad (2001)** studied the population fluctuation and seasonal abundance of *I. seychellarum* on *Morus alba* L. during 1997-1998 They found that *I. seychellarum* had two peaks of abundance.

El-Serafi *et* al. (2004) in Egypt, studied the population density of the most important insect pests infesting guava trees and their associated predatory insects. The main insects were *Coccus hesperidum* Linnaeus, *Pulvinaria psidii* Maskell, *Ceroplastes floridensis* Comstock, *Coccus elongates* Sandres, *Hemiberlesia lataniae* Signoret, *I. seychellarum*, *I. aegyptiaca.* Nine predatory insect species were recorded associated with these injurious insects. The most common predators were *R. cardinals* and

C. carnea. The temperature and relative humidity showed degrees of correlation varying from highly significant positive to significant negative with the population densities of the injurious insects and their predators.

In Egypt, **El-Sherbenie (2004)** mentioned that *I. aegyptiaca* had three peaks on guava orchards. The highest peak was recorded during mid. September in 2000 and 2001, while the other two peaks were recorded in the second week of May and the end of July during the two years of study. Whereas, *I. seychellarum* had only two peaks. The highest peak was found in the end of August and the second one was at the end of March during the two years of study. In addition, *R. cardinalis* had four peaks. The peaks were recorded in mid- March, mid-July, the second week of October and the first week of November during the two years, while *C. carnea* had three peaks during the second week of May, third week of July and the second week of October 2000. Meanwhile, in year 2001, the predator had also three peaks during July and the second week of October.

Mohamed and Goma'a (2004) recoded *I. seychellarum* infested Ficus trees In Egypt for the first time.

Abdel-Mageed (2005) found that *R. cardinalis* was main dominant insect predator of *I. seychellarum* on ficus trees and represented by 90.5 and 95.0% of the total collected predators during 2001/02 and 200/03, but *C. carnea* was rarely observed. *R. cardinalis* exhibited three periods of abundance yearly in December, May-July and September-October and the highest period of occurrence was on September-October. The predators: prey ratio was the highest (1:18 and 1.21) in May and in July during the two years. Furthermore, the predator activity showed significantly positive response to the increase of *I. seychellarum* density during the two years.

The predators exhibited highly significant positive and negative responses to the increase of temperature and relative humidity, respectively.

In Egypt**, Ibrahim (2005)** mentioned that the infestation by *I. seychellarum* to persimmon trees was initiated on the first week of May in 2002 and on the fourth week of May in 2003. The insect pest had two peaks in each season of study. *R. cardinalis* was the main predator associated with *I. seychellarum* and recorded three peaks in each season. Temperature had greatly effect on *I. seychellarum* population during the first season, while relative humidity had no significant impact on the pest population during the two years of study.

Abdel - Rahman *et al.*, (2006) mentioned that *I. seychellarum* heavily infested mango trees and completed its entire life cycle on this plant. However, mango cultivars were not equally susceptible to *I. seychellarum* infestation.

El-Said (2006) found that *I. seychellarum* had four annual peaks on mango trees. The effect of temperature on pest activity was significantly positive in 2003 and 2004 seasons. Whereas the effect of relative humidity was insignificant negative in both years of investigation. The combined effect of both weather factors on pest activity was highly significant during both years of investigation. The percentage of explained variance by both factors was 60% and 76% during 2003 and 2004.

Faust *et al.*, (2008) mentioned that two biological control agents were introduced from Australia, the vedalia ladybeetle, *R. cardinalis* and the parasitic fly, *Cryptochaetum iceryae* to control *I. purchasi* in California citrus industry in the 1880s.. The vedalia ladybeetle brought about the complete suppression of this scale insect by the end of 1889 (Doutt, 1958).

In Egypt **Bakry (2009)** found that *I. Seychellarum* had three generations in May, August and October on mango trees during the two years of investigation. The multiple regression analysis revealed that the three studied variables together (Maxi temp, Mini temp and % R.H.) were responsible about some reduction in the total population. The percentages of explained variance (E.V. %) were 95.9, 73.7 and 47.8% and 58.2, 54.2 and 12.6% for 1st, 2nd and 3rd generations, for the first and second year of investigation, respectively.

Rocca *et al.*, (2009) in Argentina, mentioned that, *I. purchasi* is a polyphagous scale pest of ornamentals and several other crops. It has two effective natural enemies that maintained its populations at low levels.

In Egypt, **Ramadan (2011)** found that the population density of *I. seychellarum* on ficus trees had six peaks during the first year of study (2008/09). These peaks were recorded in the first week of July, first week of August, first week of September, end of September, end of October and first week of January. In the second year of study (2009/10), *I. seychellarum* recorded four peaks, These peaks were found in the first week of July, third week of August, end of September and second week of February. The population density of *R. cardinalis* had six peaks during the first year of study. These peaks were recorded at the last week of May, third week of July, second week of October, second week of November, second week of December and first week of March in the 2008/2009. In the second year, *R. cardinals* recorded six peaks on the first week of June, first week of July, third week of August, end of September, first week of November and first week of December.

Mesbah *et al.*, (2012) in Egypt recorded *I. seychellarum* associated with *Dodonia viscose* Jacq in Montazah garden during two successive

years of study (2005/06 and 2006/07). The results showed that there was weak significant positive relationship between each of daily mean temperature, relative humidity and dew point and population density of *I. seychellarum*. Whereas the relationship was significantly negative with wind speed.

Moustafa (2012) in Egypt, found *I. seychellarum* on Demmyat with two annual peaks which recorded on June and November. He also recorded *R.cardinalis* associated with seychellarum mealybug, *I. seychellarum.*

Muniappan *et al.*, (2012) mentioned that *P. citri* had a wide host range including citrus, grapes, banana, coffee, fig, mango, cocoa, date, cassava, and passion fruit in Asia.

In Egypt, **Abdel-salam *et al.*, (2013a)** evaluated the attractiveness of the mealybug species and their predators on the different host plants. The obtained results revealed that *I. purchasi* was attracted to mandarin trees during the two years of study. Further *P. citri* was attracted to mandarin and guava trees and the latter one was more favorable host plant during the two successive years. Meanwhile, *I. aegyptiaca* was attracted to three host plants among them the ficus was the more favorable plant. On other hand, *I. seychellarum* highly attracted to guava followed by persimmon, ficus and mandarin trees during the first year and to persimmon followed by guava , ficus and mandarin trees during the second year of the study . *R. cardinalis* was highly attracted to ficus and guava trees, Whereas *N. includens* to guava and hibiscus plants.

In Egypt, **Awadalla (2013)** recorded the highest peak of abundance for *P. citri* on 15th of November 2010 and 15th of September 2011, for *I. seychellarum* on the beginning of September 2011 and on the beginning of

November 2011 and for *I. aegyptiaca* in the first week of November 2010 and 2011 during the two successive years of study, respectively. The maximum activity was recorded for *R. cardinalis* in the beginning of May 2011 and in the first week of June 2012, *C. carnea* in the beginning of November 2010 and in the beginning of June 2012 and for *N. includens* in the first week of November 2010 and in mid- June 2012 during the two years (2010/11 and 2011/12) respectively.

Ghanim *et al*,. (2013a) studied the population density of the common mealybug species attacking mandarin trees and their predatory insects .they found that, four mealybug species infesting mandarin trees, namely *P. citri* , *I. seychellarum*, *I. aegyptiaca* and *I. purchase*. The highest peak for *P. citri* in 15th of October 2010 and 15th of September 2012 for *I. seychellarum*, *I. aegyptiaca* and *I. purchasi* recorded in the 15th of September 2011 and 2012 during the two successive years of study. Respectively. The maximum activity of *R. cardinals* recorded in the beginning of October 2010 (31 indiv.) and in 15th of June 2012(55 indiv.). *C. carnea*.) recorded in 15th of June 2011(21 indiv) and in of September 2012(25 ndiv.) and *N. includens* in of September 2011(14 indiv.) and in 15 of June and 15th of September 2012(16 indiv.) during the two successive years, respectively. Results of statistical analysis of simple correlation coefficient indicated that the relationship between the mealybug species and their associated predators on mandarin trees showed a highly positive significant effect for *R. cardinalis*, *N includens* and *C. carnea* during the two years of study.

Mohamed (2013) in Egypt studied the population density of the common mealybug species attacking grapevine trees and their associated predators at Mansoura district, also to evaluate the effect of certain weather

factors on these insects. The obtained results showed that four mealybug species belonging to order: Homoptera were recorded. These species namely, *I. seychellarum; P. vitis* ;*Pseudococcus longispinus* and *Maconellicoccus hirsutus* Green. The results cleared that the dominant species was *I. seychellarum* during the two years of study as it formed 47.85% in 2009 and 39.63 % in 2010 of the total number of these insects respectively. The obtained results revealed that there were three peaks for *I. seychellarum* during the two years of study, the highest average numbers for *I. seychellarum* were recorded at the last week of October in the first year, while they were at the second week of November, in the second year of study.

EL-kady (2013) mentioned that, The citrus mealybug *P. citri* nymphs and adults had four peaks of abundance during the first season 2009/2010. While in the second season 2010/11 insect nymphs and adult had five peaks of abundance on different citrus trees. Six citrus species were screened during two seasons for susceptibility to citrus mealybug *P. citri* in Qalubia orchard. He added that clemantine mandarine and balady mandarine were the least infested species by the insect. while, sour orange and lemon were the heaviest attacked by the insect and navel orange and Persian agami were moderately infested by the insect. Volatile oils were analyzed in tested citrus species so that different levels of susceptibility in citrus species to *P. citri* infestation may be correlated to different kinds and percentage of components of volatile oils. Sour orange which was the heaviest infested was characterized by the highest rates of Champhor and Linalool, and Lemon which came the next after Sour orange showed highest rate of Carvon and d-limonene.

In Egypt **Fahad (2015)** studied the influence of different host plants on the attractiveness of *I. seychellarum* and its associated predator *R. cardinalis* during the first year, persimmon trees attractive the highest average number of *I. seychellarum* followed by loquat trees, ficus trees and mango trees while guava trees came in the last category. On the other hand, Persimmon trees also attracted the highest average number of the predator during the first year 2013/14. Meanwhile, loquat trees ranked the second place, while mango trees and guava trees came in the last category in attracting the predator *R. cardinalis*. During the second year, loquat trees attracted the highest average number of *I. seychellarum* followed by persimmon trees and guava trees came in the last category,while, Persimmon trees also attracted the highest average number of the predator during the second year 2014/15 Meanwhile, loquat trees ranked the second place, while mango trees and guava trees came in the last category in attracting the predator *R. cardinalis*. Statistical analysis showed a significantly difference between the different host plants for attractiveness the insect pest or its associated predator during the two years of the study .

Awadalla and Ghanim (2016) evaluated the population density of the main mealybug species attacking mango trees (*Mangifera indica* L.) and their associated predatory insects. Also the interaction between these insect pests and their associated predatory insects during two successive years 2013/14 and 2014/15. the highest peak of *I. aegyptiaca* was recorded at the first week of November 2013(67 indiv.) during the first year and at the fourth week of September 2015(59 indiv.) in the second year *I. seychellarum* recorded the highest peak at the third week of November 2013 during the first year and at the first week of November 2014 in the second year and represented by 496 and 516 indiv.

respectively. While, the highest peak of *P. citri* was found at the third week of July 2014(156 indiv.) and at the fourth week of September 2015(281 indiv) during the two successive years, respectively. Moreover the obtained results showed that *M. hirsutus* had the highest peak at the third week of July 2014(156 indiv.) during the first year and at the second week of August 2015 (227 indiv.) in the second year. the highest peak of *R. cardinalis* was at the first week of November 2013 and represented by 84 and 93 indiv, for the two success years 2013/14 and 2014/15, respectively . *C. carnea* had the highest peak at the second week of August 2014(37 indiv.) in the first year and at the end of the second year(43 indiv.) While the highest peak of *N. includens* was found at the second week of August 2014(22 indiv.) and at the second week of September 2015(29 indiv.) for the two successive years, respective. The highest average number of the main predatory insects were recorded in autumn and summer seasons and were coincided with the highest average number of the mealybug species during the two successive years 2013/14 and 2014/15. A highly positive significant effect were recorded between the highest abundant of the mealybu species as *I. seychellarum* and *P. citri* and the highest abundant as *R. cardinalis* and *C. carnea* during the two successive years.

2.2. Biological studies:-

2.2.1. On *Icerya seychellarum* (Westwood):-

In Egypt **Aly (1980)** studied the biology of *I. seychellarum* on sprouting potato and palm tree. The duration of the total nymphal instars of the insert when reared on sprouting potato was 61.33 ± 2.64 days. The duration of generation was 83.54 ± 2.15 days at mean temperature of 26.86

°C and 51.5% R.H. On palm tree, the duration of the total nymphal instar was 103 days ± 2.83, the duration of a generation was 83.54 ± 2.15 days at mean temperature of 17.8 °C and 56.5% R.H.

Saad (1980) in Egypt, mentioned that no parasitoids were observed on different stages of *I. seychellarum*. The predator, *R. cardinalis* was found attacking this pest.

Valuli and Kosal (1992) determined the life history of *I .seychellarum* on ornamental plants in the laboratory, and found that the life span ranged 70-90 days.

Ibrahim (2005) in Egypt, studied the biology of *I. seychellarum* reared on persimmon. The duration of first, second, and third lasted 18.7±2.32, 20.00 ± 1.26 and 19.3 ± 2.3 days, respectively at 28.6 °C, while it were 18.25 ± 1.19, 19.75 ± 0.96 and 22.25 ± 0.66 days at 22.54°C. The average of total developmental period of the nymphal stage recorded 58.00± 2.93 at 28.6 °C and 60.25 ± 1.78 at 22.54 °C. The pre-oviposition period was 15.8 ± 2.44 days at 28.6 °C and 15.12 ± 1.89 at 22.54 °C. Meanwhile, the mean of oviposition period was 21.00 ± 1.542 and 36.5 ± 2.91 days at 28.6°C and 22.54°C, respectively. The post-oviposition period lasted 10.9±2.58 and 13.00 ± 2.87 days at 28.6 °C and 22.54 °C, respectively. The longevity was 51.12 ± 5.44 and 64.75 ± 3.63 days at 28.6 °C and 22.54 °C, respectively. Fecundity of female was 68.2 ± 4.26 and 51.5 ± 5.58 eggs at 28.6 °C and 22.54 °C, respectively.

Abdel-Rahman *et al.* (2006) found that *I. seychellarum* can complete its life cycle on mango plants. However, they observed that mango cultivars are not equally susceptible to *I. seychellarum* infestation. The leaf components of secondary metabolites were screened using

solvent/solvent extraction technique. The results suggested that peymene, camphene, and limonene play an important role in resistance of Alphonso mango to *I .seychellarum* infestation.

Abdel Aleem (2008) in Egypt studied the biology of the mealybug *I. seychellarum* under field and laboratory conditions. The insect passed through four generations/year. Males are not existed so parthenogensis is the only way of reproduction. The average of eggs laid per female was 46.7± 2.7. Females fed on mango fruit laid more eggs than those fed on branches or leaves. Eggs incubated at 35°C and 90% R.H. did not hatch. Eggs incubated at 35°C with 70% R.H. hatched earlier than those at 15.0±1.0 °C with 90% R.H. with average duration 5.2 ± 0.2 and 18.2 ± 1.2 days, respectively. The nymphal stage duration was 25.2 ± 1.8 days during summer and 42.8+1.8 days during winter at 33.0 ± 1.0 with 50% R.H. and 15.0 ± 1.0°C with 60% R.H, respectively. In Spring and Autumn this duration was 38.4 ± 2.1and 33.4 ± 2.4 days at 21.0 ± 1.0°C with 55% R.H. and 27.0 ± 1.0°C with 70% R.H. respectively. The shortest pre-oviposition, oviposition and post-oviposition periods were 8.6 ± 0.3, 7.6 ± 1.2 and 9.6±0.2 days, respectively during Summer at 33.0 ± 1.0°C with 50% R.H.

Sayed (2008) in Egypt, recorded that the highest percentages of the total nymphal counts in relation to the total population counts for *I. Seychellarum* could be observed in the first year in early March (95.2%), mid-July (96.8%) and early-November (92.1%). In the second year at mid-March (95.3%), early-August (92.1%) and early-November (95%). In the third year, at early-March (95.2%), mid-July (96.8%) and early-November (92.7%), indicating that this insect may have three overlapping generations on mango trees. Also, he stated that the four tested factors (maximum temperature, mean temperature, minimum temperature and mean relative

humidity) simultaneously were responsible for about 32.8-65% of this insect activity.

Awadalla (2015a) in Egypt, mentioned that the chemical analysis of *I. Seychellarum* significantly differented on crude protein, lipids and total carbohydrates when the insect reared on different host plants. *I. Seychellarum* when reared on ornamental palm had the highest crude protein (2.53%) , lipids (12.05%) and total carbohydrates (32.81%) while the lowest crude protein recorded on mango and pomegranate .

Awadalla *et al*. (2015) studied the influence of different host plants on some biological characteristics of *I. seychellarum* . under fluctuated temperature degrees of 28±1˚c ; 20±1˚c and 60±5% R.H. The total developmental stages were the shortest when *I. seychellarum* reared on ornamental palm and represented by 40.1 ± 0.71 and 54.9 ± 1.61 days under fluctuated temperature of 28 ± 1 ˚c and 20 ± 1 ˚c respectively. The survival rates during the nymphal stage of *I. seychellarum* was the highest on ornamental palm followed by persimmon and the lowest on mango and guava. Based on the survival rate as an index of suitability of different host plants, the suitability in decreasing order was: on ornamental palm, persimmon, ficus, loquat, guava, mango under fluctuated temperature of 28±1 ˚C and 20 ± 1 ˚C. The longest oviposition period, the adult longevity and the highest fecundity of adult females were reared on ornamental palm (21.6 ± 0.41, 52.7 ± 0.50 days and 63.1 ± 0.71 eggs/female) respectively, under fluctuated temperature of 28 ± 1 ˚C. On the other hand, the longest oviposition period, the adult longevity and the highest fecundity of adult females when reared on ornamental palm were (30.8 ± 0.91, 71.8 ± 0.29 days and 51.7 ± 0.38 eggs/female) respectively, under fluctuated temperature of 20 ± 1 ˚C.

2.2.2 On *R. caradinalis* and *C. carnea* :-

Matsuka and Watanabe (1981) in Japan**,** indicated that adult females of vedalia beetles which fed on adults of *Icerya* scales in a Petri dish at 25ºC produce an average of 365 eggs during their adult life span of 29.4 days, including 3.7 days of pre-oviposition. The average developmental period (egg to adult) was 19.7 days. The 4th instar larva was the most voracious larval stage and consumed about 80% of the prey eaten during whole larval period. When a piece of absorbent cotton was inserted into a Petri dish the beetles used it as an oviposition substrate and deposited 25% more eggs than in its absence. Elimination of the male after oviposition resulted in a greater increase in total egg production and in a decrease in *Icerya* consumption.

In Japan **Matsuka *et al.*, (1982)** used *R. cardinalis*, in controlling *I. purchasi* on orange, which reared on artificial. On lyophilized drone honeybee brood fortified with sucrose (DPS), females survived longer (76.3 days) but laid fewer eggs (106.3) than others fed on live *I. purchasi* (38.6 days and 489.2 eggs). On sucrose or a chemically defined diet, they also survived longer but laid only about 20 eggs. The beetles produced more eggs when *I. purchasi* was combined with DPS or other artificial diets. Beetles fed on *I. purchasi* for one day and DPS for two days oviposited at 80% of the control level and beetles fed on *I. purchasi* for one day and sucrose for two days oviposited at 120 % of their eggs in comparison of the control. Control treatments were fed only on *I. purchasi.* This technique makes it possible to breed the beetles under controlled conditions with a small number of natural prey scales.

Hamed and Saad (1989) in Egypt, studied the effect of *I. aegyptiaca and I. seychellarum* on the biological aspects of *R. cardinalis*.

The kind of prey had an effect on egg color and hatchability rate but no effect appeared in respect of incubation period. The average total number of eggs laid by female of *R. cardinalis* through its life span was significantly affected by the prey consumed by these females. The longevity of females and males was comparatively shorter in association with *I. seychellarum*.

in Egypt **Ragab (1995)** showed the adaptation of *R. cardinalis* when feeding on *I. aegyptiaca* as compared with feeding on *I. purchasi*. Choice of prey type was found to have a marked effect on egg coloration but appears to have no effect on hatching success or incubation period. The development of *R. cardinalis* larvae when reared in culture on *I. aegyptiaca* was significantly faster than when fed on *I. purchasi*. The fecundity of *R. cardinalis* females was not affected by the prey consumed as adults, and although the longevity of males and females was shorter in associated with *I. purchasi*, This difference was not significant. The results indicated that *R. cardinalis* is well adapted to *I. aegyptiaca* in Egypt

Salisbury and Booth (2004) in UK**,** indicated that *R. cardinalis*, a cosmopolitan species native to Australia, *R. cardinalis* was found on *Hedera helix* and *Acacia dealbata* infested with its prey, recently established on *I. purchasi*. The continued presence of *R. cardinalis* could be based on a great extent on the survival of *I. purchasi.*

Abdel-Mageed (2005) studied the influence of host plant species on *R. cardilnalis* searching behavior. She found that, *R. cardinalis* female exhibited high preferability to ficus leaves extract, followed by guava and kaki extracts. Also, *R. cardinalis* female exhibited the highest K value of mortality on ficus followed by guava and kaki plants, while *I. seychellarum*

on other plants not attacked by the predator females during the experimental period.

Ibrahim (2005) in Egypt**,** evaluated the effect of different constant temperature on the biological characters of *R. cardinalis*. He found that, the optimum temperature for mass rearing of this predator was 25ºC because the number of eggs, hatchability percentage and female longevity were the highest in comparison with the other tested degrees. He added that, the temperature threshold for egg stage, first, second, third, fourth larval instars and pupal stage were 10.67, 9.23, 9.60, 9.84, 11 and 10.74ºC, respectively.

Grafton *et al.* (2005) in the USA**,** studied the effect of temperature on the development of the vedalia beetle, *R. cardinalis*, which reared on *I. purchasi* under controlled laboratory conditions. Adult exposed to temperature of 25, 28, 31, 34, and 37°C for 72 h showed 95-100% survival, however eggs production was significantly reduced at 34 and 37°C. Eggs maintained at 34°C showed reduced hatch and survival of larvae, and eggs held at 37°C failed to hatch. There was no egg hatchability at 10°C. The developmental time from egg to adult emergence decreased from 97 to 18 days for temperatures from 14 to 25°C. The lower developmental temperature threshold of *R. cardinalis* was estimated to be 10.8°C and degree-day accumulation was calculated as 279 for development from egg to adult eclosion.

Ghanim *et al.* (2006) in Egypt**,** studied the effect of mealybug species as preys on the developmental time, feeding capacity and fecundity of vedalia beetle, *R. cardinalis* under laboratory conditions. The obtained results showed that the averages of the duration period of the predator larvae were 13.34 ± 1.26; 15.28 ± 1.78 and 12.23 ± 1.95 days when reared on *P. citri*, *I. seychellarum* and *I. purchasi*, respectively. The averages of

the total consumption during the larval stage were 76.98 ± 5.96, 53.22±3.85, and 91.14 ± 5.91 of the third nymphal instar individuals from the three tested mealybug species respectively. The longevity period of the predator adult female was 40.45 ± 2.98, 45.62 ± 2.40, and 36.56 ± 2.65 days when fed on *P. citri*, *I. seychellarum,* and *I. purchasi*, consecutively. The predator female consumed during its life span an average of 418.82 ± 6.89, 305.54±3.79, and 311.92 ± 6.75 of third nymphal instar individuals when reared on the three tested mealybug species successively. The average total number of eggs laid by female of *R. cardinalis* through its life span was significantly affected by the prey consumed by female. The statical analysis showed that, there were highly significant differences in the biological characteristics of *R. cardinalis* larvae and adult when reared on *P. citri*, *I. seychellarum,* and *I. purchasi,* consecutively.

Khan and Zaki (2008), studied the functional response and numerical response of third instar larvae of *C. carnea*(Stephens) feeding on the Euonymus aphid. *Aphis fabae* solanella Theobald. which is a key pest of *Euonymus japonicus* L in Kashmir were investigated. The Type II functional response curve exhibited a curvilinear rise to plateau as the aphid densities increased and the curve predicted by Holling's disk equation did not differ significantly from the observed functional response curve. The attack rate and the handling time predicted by disk equation were 0.54 and 2.17, respectively. The attack rate(a) increased with the increase of prey(aphid) density. The numerical response curve had a linear rise to a plateau at fixed aphid density with varying density of *C. carnea*.

Abd El-Gawad *et al.*, (2010) mentioned that, A functional response study of the predator green lacewings, *C. carnea* larvae to various densities of potato tuber moth, *Phthorimaea operculella* Zeller (Lepidoptera:

Gelechiidae) eggs was conducted under laboratory conditions of 27±1°C, 65 ±5% RH and 14:10 h (L: D). Based on Holling's disk equation, the first and third larval instars showed searching rates (á) of 1.03 and 0.894, respectively. These were greater than the second larval instar (i.e. 0.695). Handling time (T_h)) per prey decreased as predator aged being 0.0009 day for the third larval instar. This value was shorter than at each of the first and second larval instars (i.e. 0.0163 and 0.00148 day, respectively). The greatest theoretical maximum number of potato tuber moth eggs to be consumed was estimated for the third larval instar as 1111.11 eggs/day followed by second and first larval instars as 675.68 and 61.35 eggs/day, respectively.

Awadalla (2010), in Egypt mentioned that, The total developmental times of the immature stages for *R. cardinalis* were 62.30, 41.10, 26.85, 18.85 and 12.7 days with significant differences when reared on *I. purchasi* at 16, 20, 24, 28 and 32ºC, respectively. While, there were 60.80, 38.30, 24.80, 16.75 and 11.95 days with significant differences when reared on *I. aegyptiaca* at the same temperatures. On the other hand, there were 63.6, 41.95, 29.10, 21.6 and 14.55 days when reared the predator on *I. seychellarum* with significant differences under the same temperatures, respectively. The survival percentage of *R. cardinalis* immature stages were the highest rates when the predator reared on constant temperature of 24ºC followed by 28, 20, 16 and 32ºC on the third nymphal instars of the three mealybug species. The survival percentage of *R. cardinalis* immature stages were the highest rates when the predator reared on *I. aegyptiaca* followed by *I. purchasi* and *I. seychellarum*. There were significant differences in pre-oviposition, oviposition and inter-oviposition periods as well as adult female longevity when reared at five tested temperatures.

Male longevity of *R. cardinalis* was significantly shorter at 32ºC than at 28, 24, 20 and 16ºC when the predator reared on the three mealybug species. Fecundity rate were significantly higher at 28ºC than at 24, 32, 20 and 16ºC when fed on three tested preys.

Rashid *et al.*, (2012) recorded that, The feeding potential of *C. carnea* larvae and adults of *C. montrouzieri* feeding on different nymphal instars of cotton mealybug, *Phenacoccus solenopsis* was investigated in ambient laboratory conditions at Agricultural Research Institute, Dera Ismail Khan, Pakistan. Both predators were found very active and successfully consumed all the nymphal instars of *P. solenopsis*. The daily predation rate of *C. carnea* larvae increased slowly during the first two larval instars and reached to its peak in the third larval instar. First instar nymphs of *P. solenopsis* were the most preferred food of different larval instars of *C. carnea*. Third instar larvae of *C. carnea* were the most voracious feeder and consumed significantly high number of first, second and third instars nymphs of mealybug as compared to first and second instar larvae of the predator. Adult *C. montrouzieri* consumed significantly more first instar nymphs of mealybug than second and third instar nymphs. These results indicate that *C. carnea* and *C. montrouzieri* have great potential for the biological control of *P. solenopsis*.

Abdel-salam *et al.*, (2013b) studied the influence of different constant temperature degrees on the biological characters and predaceous efficiency of the predator *R. cardinalis*, The larval stage of the predator *R. cardinalis* when reared on the third nymphal instar of *I. aegyptiaca* under three constant temperature 20±1 , 24±1 and 28±1º c lasted an average of 20.7±0.34, 11.8±0,34 and 7.3±0.49 days, respectively, The average of the total consumption for larval stage when reared on *I. aegyptiaca* at 20,24

and 28ºC reached 28.80±2.18; 60.50±2.48 and 53,45±3.27 individuals/ larva. Meanwhile, results showed that, the highest total consumption for larva during its four larval instars when reared at 24º c followed by 28º c with highly significant differences. The highest total consumption for adult female was recorded during the oviposition period especially, under 24º c (289.0±10.53 individuals/ female) and resulting, the number of deposited eggs/female was the highest (354.30±19.90 egg/female), it could be concluded that the temperature degree of 24º c was the best for mass rearing of *R. cardinalis* because the female layed the highest eggs on this degree.

Ghanim *et al.*, (2013b) studied the influence of different mealybug species as preys on the biological aspects of *R. cardinalis* , the larval stage of the predator *R. cardinalis* when reared at 24±1˚c and fed on the third nymphal instars of *I. purchasi, I. aegyptiaca* and *I. seychellarum* averaged with 14.5±0.60, 11.8±0.34 and 16.6±0.55 days, respectively. The average of the total consumption for the total larval instars at 24±1˚c and fed on *I. purchasi, I. aegyptiaca* and *I. seychellarum* as preys reached 68.90±4.01, 60.50±2.18 and 42.65±1.77 individuals/ predator larva. Meanwhile, results indicated that, the highest total consumption for the predator larvae during the larval stages when fed on *I. purchasi* followed by *I. aegyptiaca* and *I. seychellarum* with significant differences. The adult longevity for female and male when reared at 24±1˚c and fed on the third nymphal instar of *I. purchasi, I. aegyptiaca* and *I. seychellarum* lasted an average of (40.5±2.25 and 26.8±1.72), (46.4±2.12 and 29.0±2.09) and (32.5±2.60 and 20.8±1.8 days), respectively. The highest total consumption for adult female recorded during the ovipostion period especially, when reared on *I. aegyptiaca* (289.0110.53 individuals/ female) and resulting, the number

of deposited eggs female was the highest(354.3 eggs/ female), it could be concluded that the best mealybug species for rearing *R. cardinals* was *I. aegyptiaca* because the female layed 354.30 eggs/female.

Hamad *et al.*, (2013) studied the functional response of second and third larval instars of, *C. carnea*, against different nymphal instars of Dubas bug *Ommatissus libycus* De Berg. was studied. The larval instars of the predator exhibited Type II functional responses against the prey. Based on disk equation the attack rate (*a*) of the second larval instars of the predator were estimated to 1.03± 0.043 , 0.94± 0.015 , 0.88± 0.009 and 0.77 ± 0.02 and the handling time ((T_h)) were 0.0031, 0.0039, 0.0083, and 0.008 day for second , third , fourth and fifth nymphal instars respectively. of the third instar larvae of the predator, the attack rate against these nymphal instars were 1.11± 0.01, 1.04 ± 0.29 , 0.97± 0.017 and 0.89 with handling time 0.0019, 0.0028, 0.0064, and 0.0067 day respectively. The theoretical maximum predation(T/T_h) of the second larval instars were 322, 256, 120 and114 nymphs for second , third ,fourth and fifth nymphal instar respectively; while they were 526, 357, 156, and 149 for the third larval instar . according to this study this predator have a good predation potential in preying on nymph of Dubas bug especially the small nymphs (second and third).

In Pakistan, **Batool *et al.*, (2014)** studied the Effect of Prey Density on Biology and Functional Response of *C. carnea* recorded that, the prey density had a significant effect on positive consumption rate, development and fecundity of *C. carnea*. In general maximum consumption with shortest developmental time, maximum fecundity and longest adult longevity were observed as prey density increased. In all treatments, predatory potential was high when the prey density was raised. Daily

predation rate of *C. carnea* increased slowly during the first two instars and reached to its peak in the third larval instar. Although, *C. carnea* completed its development at all prey densities, the increase in prey densities reduced developmental time and mortality. Lacewing larvae provided with an overabundance of *S. cerealella* eggs developed faster than the larvae provided with fewer eggs. Lacewing fed during larval stage with 20 eggs/day showed lowest fecundity with the increase in prey density. A smaller intrinsic rate of increase was due to the fact that the population fed at a low prey density had prolonged developmental time, higher mortality rate in immature stages as well as a low daily rate of progeny.

Awadalla (2015 a), studied the effect of prey quality on the biological characteristics of the predator *R. cardinalis* under laboratory conditions . She found that, the survival rate for immature stages of the predator was the highest when *I. seychellarum* as prey fed on ornamental palm and the lowest survival rate was recorded on pomegranate as a host plant for *I. seychellarum* . Based on the survival rate for predator as an index of prey suitability, the quality of host plant for prey-predator trophic interaction in decreasing order was as follows : ornamental palm , persimmon , ficus, mango and pomegranate . there were significant difference among females of *R. cardinalis* in total number of eggs produced after feeding on *I. seychellarum* harbored different host plants.

Awadalla (2015 b), studied the influence of different stages of *I. seychellarum* on the developmental stages , adult longevity , fecundity and predatory potential of vedalia beetle *R. cardinalis* under laboratory conditions and found that, the total development periods of *R. cardinalis* fed on gravid females of *I. seychellarum* were the shortest periods . Also, the highest survival rate recorded when the predator fed on the gravid

females, the longest oviposition period as well as the adult longevity for male and female were the longest when *R. cardinalis* fed on gravid females . According to no choice test or choice test, the different larval instars of *R. cardinalis* consumed the highest number of the second nymphal instar followed by the third nymphal instar of the prey . The total consumption during the larval stage of *R. cardinalis* was 74.9±2.94 indiv/larva and the adult female and male consumed 128.3±4.91 and 68.8±4.16 indiv. from all stages of *I. seychellarum* as prey, respectively .

Saljoqi *et al.*, (2015) studied the Functional response study of C. Montrouzieri fed on Cotton mealy bug, *Phenacoccus Solenopsis* Tinsley under Laboratory Conditions. The prey densities used for the 4th in star and adult male and female were kept uniform i.e. 30, 45, 60, 75 and 90 individuals. Results showed that increasing in the prey density the consumed prey number increased up to certain limit in the 4th instar stage as well as in the adult male and female of *C. Montrouzieri*. The recorded highest consumed prey number were 76, 75 and 71 for the highest prey densities of 90 in adult female, male and the 4th instar stage of *C. Montrouzieri*, respectively. The average potential regarding the consumptive rate adult female was found higher followed by adult male and 4th instar stage of *C.Montrouzieri*. Also results showed almost lower searching time, handling time and resting time in the 4th larval instar stage followed by the adult male and female of *C. Montrouzieri.*

3

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1 Ecological studies :-

The present work was carried out in the experimental farm belonging to the Faculty of Agriculture, Mansoura University, Mansoura, Egypt to study the population abundance of the citrus mealybug *Planococcus citri* (Risso), The cottony cushion scale *Icerya purchasi* Maskell, the Egyptian mealybug *Icerya aegyptiaca* (Douglas) and the Seychelles fluted scale *Icerya seychellarum* (Westwood) on different citrus plants as Mandarin, Lemon, Common balady, Washington navel and Succari (sweet) orange trees. Furthermore, the seasonal activity of the main associated predators with each mealybug species during the two successive years (2014/15 and 2015/16) was evaluated. All agricultural practices were applied except insecticide application during the two years of investigation.

3.1.1 Sampling technique:-

Five trees of the same age and size from each citrus host plant were selected as replicates. Samples were collected biweekly during the two successive years from the beginning of April 2014 till 25th of March 2015 in the first year and from April 2015 till January 2016 in the second year. Each sample consisted of 100 leaves were randomly collected from each host plant (20 leaves from each tree form the four directions and the middle of each tree). The collected leaves from each host plant were taken to the laboratory in polyethylene bags for further investigation of the different mealybug species attacking various citrus host plants and their population abundance. Further, the

seasonal activity of the associated predatory insects during the two years was assessed. Moreover, the total number and percentage of the different mealybug species during the two years 2014/15 and 2015/16 were recorded. Also, the seasonal average number of different mealybug species was estimated.

3.1.2. Statistical approach

One-way ANOVA was used to analyze the data followed by Duncan's Multiple Range Test to separate the means (CoStat, 2004).

3.2 Biological studies:-

3.2.1. Effect of host plants on the biological aspects of *Icerya seychellarum:-*

3.2.1.1. Rearing of *Icerya seychellarum (Westwood)* :-

The experiments were conducted in the laboratory of Economic Entomology Department, Faculty of Agriculture, Mansoura University. These trials were conducted to evaluate the influence of different host plants on some biological characteristics of *I. seychellarum* under room temperature of 22.4 ± 3.1°C (Range 16 : 28) , 60± 5 R.H. % and a photoperiod of 16 : 8 h. L:D.

Highly infested leaves from different host plants were selected in the field and used in the laboratory to infested some of healthy seedlings of different citrus host plants (Mandarian, Lemon, Balady orange, Navel orange and Succari (sweet) orange). These seedlings were transplanted in pots under room conditions. For estimating the incubation period, the ovisacs were carefully isolated from these seedlings and kept in petri-dishes (9 cm diameter) under the room fluctuated temperatures.

The newly hatched crawlers genitally were transferred to each host plant seedling, To study the duration of the nymphal instars under these conditions. Twenty crawlers were reared on each host plant. Observations were daily conducted to recognize the moults until development completed. Furthermore, adult longevity and fecundity for *I. seychellarum* were recorded on each citrus host plant at the fluctuated temperatures. Daily average temperature and relative humidity was recorded twice a day in the laboratory during the whole experiments.

3.2.1.2. Rearing of Vedalia beetle *Rodalia cardinalis* (Mulsant) :-

To have a culture from Vedalia beetle, *R. cardinalis* (Mulsant), a large number of the predator was collected in the pupal stage from the infested host plants with different mealybug species in Eppendorf tubes and kept in the laboratory until adult emerged.

Once, adults were emerged , a group of ten beetles were confined together in petri- dishes (9 cm diameter) and kept in an incubator at 28 ±1 ˚C , 60 ± 5% R.H., and a photoperiod of 16:8h (L:D) until adults become 10 days old to ensure mating. During this period, an adequate numbers of first instars of *I. seychellarum* were brushed daily in each dish for feeding.

Once, mating finished, each female was isolated in petri- dish (5.5 cm diameter) and provided daily with an infested leaf for feeding and oviposition. These leaves harbored the predator eggs were maintained in petri- dishes until eggs hatched , The newly emerged larvae were isolated in new petri- dishes (5.5 cm diameter) and fed on frozen moth eggs of *Ephestia Kuhiella* Zeller (Lepidoptera: Pyralidae) which obtained from a commercial lab (Beneficial

Insectary, Cairo University, Egypt), until pupation. The emerged adults were isolated again and the previously mentioned procedure was followed until adult females laid eggs. All rearing trails were conducted at 28±1 ˚C and 60±5% R.H., and a photoperiod of 16:8h (L:D) .

3.2.2. Behavioural responses of *Chrysoperla carnea* and *Rodolia cardinalis* to Citrus mealybug, *Planococcus citri*.

3.2.2.1. preparation of the study:

A behavioral study of *R. cardinalis* was started from ca. 100 pupae collected from ficus trees in Mansoura region, Mansoura, Egypt in August, 2015, transferred to the laboratory, isolated in Petri-dishes (5.5 cm in diam.), and then kept in an incubator set to a temperature of 25.0±1.0°C and a 16:8 L:D photoperiod until adult emergence. Once adult emerged, they fed an *ad libitum* diet of the *Ephestia* eggs and water, and then held in an incubator under the same previously physical conditions for 5 days. Mating was conducted by brought every ten adults in a petri-dish (9.0 cm in diam.) and monitored until mating started. Each couple was isolated in Petri-dish with *ad libitum* second-instar *P. citri* for 24 h to ensure mating, and then both sexes were isolated and monitored. Females were observed daily for egg laying.

A trial of *C. carnea* was established from 100 newly emerged adults (1 day old) received from biological control lab (Beneficial Insectary, Cairo University, Egypt), in August 2015. The lacewing adults were placed in two plastic containers (each 20 cm diam., 40 cm ht., and 8 cm diam. of neck). Neck of these containers was covered with black mesh screen held in place with a rubber band. The stock colony were held in an incubator set to 25.0 ± 1.0℃, 60

± 10 % RH, and 16:8 (L:D) photoperiod. Adults in the containers were provisioned every 48 h with an artificial diet composed of honey and brewer's yeast smeared on a two pieces of sponge and water on another piece of sponge, both refreshed every 48 h. Eggs laid on the mesh or/and the walls of the container were removed every 24 h by clipping their stalks with scissors. These were then isolated in Petri dishes (5.5 cm diam) to prevent cannibalism by hatching neonates. Larvae were fed every 48 h with *ad libitum* diet of *Ephestia* eggs and water on a piece of sponge until required instars for the current study were obtained.

3.2.2.2. Functional and numerical responses of *R. cardinalis*:

Eight-days post emergence females (n = 30) and males (n = 30) of *R. cardinalis* were collected to evaluate their functional responses to citrus mealybug, *P. citri*. Mated females and males (8 days- old) were prevented for 24 h from feeding before using in the trials to equalize the hunger and oviposition levels. To assess functional responses, standardized adult females (9 days-old) and males (9 days-old) were confined with 10, 20, 30, 40, 50 and 60 second-third-instars of *P. citri* on citrus leaves in Petri-dish (5.5 cm diam.) for 24 h. at 25.0±1.0 °C and of 16 : 8 (L : D) photoperiod. Each prey density replicated five times. Mealybug eaten by both sexes of *R. cardinalis* during the experiment were not replaced during the experiment. 24 h latter, the total number of mealybug eaten (N_a) and eggs produced at each density of prey were recorded and all females from the various prey-predator densities were isolated in Petri-dishes for another 24 h without food to estimate the number of stored eggs in their ovarioles which developed during that period depend on females' previous meal. The efficiency of conversion of ingested food (ECIF) into eggs was

estimated as 100 (number of produced eggs per number of prey eaten /number of eggs per100 prey), for each density of prey (Omkar and Pervez 2004). The daily number of eggs produced per female *R. cardinalis* and the daily ECIF values at each prey density versus different prey densities were fitted by performed linear and curve linear regressions (GraphPad 3 software).

3.2.2.3. Functional response of *C. carnea*:

Newly moulted second (1 day-old) and third (1 day-old) instars of *C. carnea* were collected from the stock colony to assess their behavioural response to citrus mealybug, *P. citri.* To assess functional responses, each larval individual of both instars were provided with 10, 20, 30, 40, 50, and 60 second-third-instar nymphs of *P. citri* on citrus leaves in Petri-dish (5.5 cm diam.) for 24 h. at 25.0 ± 1.0 °C and a photoperiod of 16:8 (L:D). Each prey density replicated five times. Mealybug consumed by both sexes of *R. cardinalis* during the trial were not replaced during the experiment.

3.2.2.4. Analytical approach:

The analytical protocol designed by Juliano (2001) was applied to evaluate the functional response of the predator to its prey densities. Firstly, the type of response (I, II, or III) was classified using a polynomial (logistic) regression of the proportion of prey eaten (N_a/N_0) versus the initial number of prey provided (N_0) as follows:

$$\frac{N_a}{N_0} = \frac{\exp\left(P_0 + P_1 N_0 + P_2 N_0^2 + P_3 N_0^3\right)}{1+\exp\left(P_0 + P_1 N_0 + P_2 N_0^2 + P_3 N_0^3\right)} \qquad (1)$$

where: N_a is the number of prey eaten, N_0 is the initial density of prey, and the parameters P_0, P_1, P_2, and P_3 are the constant, linear, quadratic, and cubic, parameters, respectively. Maximum likelihood estimates of P_0 to P_3 coefficients were obtained by fitting the data with the polynomial regression (NLIN procedure in SAS software) (SAS Institute, 2000).

For type II of functional response, the curve of N_a/N_0 vs. N_0 had a negative exponential shape, while it was dome-shape for type III. In some cases, these curves may both fit by higher order (quadric) polynomial expressions, but in other cases, the polynomial regression equation could be reduced by deleting the quadric coefficient until all remaining coefficients become significant (Juliano, 2001). If the linear coefficient (Eq. 1) was not significantly different from 0, a type I response was detected, whereas a significant negative value indicated a type II response, and a significant positive and negative values for linear and quadratic coefficients, respectively, refer to a type III response (Juliano, 2001).

Secondly, the non-linear least squares regression (NLIN procedure in SAS) was applied to estimate the parameters of attach rate, a, and handling time, T_h [T_h, and either a (for type II) or b, c, and d (for type III)]. Data were applied to "random-predator" model (Eq. 2) (Rogers, 1972), that is regarded as more suitable because it considers density of prey to be influenced by prey consumption, as well as because the experiment was conducted without prey replacement during the trial.

$$N_a = N_0 \{1\text{-exp } [a(T_h N_a - T)]\} \quad (2)$$

where: N_a is the number of prey eaten, T is the time of experiment (24 h), P is the predator numbers, N_0 is the density of prey, a is the rate of attack (or searching efficiency, and T_h is the handling time. In this trial, $T = P = 1$, because

preys were confined to one predator for one day. The parameters *a* and T_h were obtained depend on the number of prey consumed as dependent variable.

In model of type III response, attack rate (a) in equation 3 was placed in equation 2 as a function of prey density (Hassell, 1978). In the simplest generalized form, attack rate, in equation 3, is a function of initial prey density:

$$a = \frac{d + bN_0}{c + bN_0} \qquad (3)$$

The simplest form obtains when *a* is a function of initial density of prey, as follows:

$$Na = N_0\{1 - \exp [d + bN_0)(T_h N_a - T)(1 + cN_0)]\} \qquad (4)$$

Based on handling time, the maximum rate of predation (T / T_h) by one individual of *R. cardinalis* during a day was obtained.

4

RESULTS and DISCUSSION

4. Results and Discussion

4.1. Ecological studies:-

4.1.1. Mealybug species:-

4.1.1.1. The citrus mealybug *Planococcus citri* (Risso) :-

Data represented in Fig.(1) showed the total number and percentage of the citrus mealybug *P. citri* on different citrus host plants during the two successive years 2014/15 and 2015/16 at Mansoura district . It can be noticed that Common balady orange attracted the highest number of *P. citri* during the first year 2014/15 which represented by 2591 indiv. (40.08 %) followed by mandarin 1142 indiv.(17.67%) and lemon 1085 indiv. (16.78%), while, Navel orange and Succari orange came in the last category and represented by 930 indiv. (14.39 %) and 716 indiv.(11.08 %), respectively.

During the second year, results arranged in Fig.(1) showed that Common balady orange attracted the highest number of *P. citri* during the second year 2015/16 which represented by 3197 indiv. (33.68%) followed by lemon 1991 indiv.(20.98%) and mandarin 1607 indiv. (16.93%), while, Navel orange and Succari orange came in the last category and represented by 1462 indiv.(15.40 %) and 1234 indiv.(13.00%), respectively.

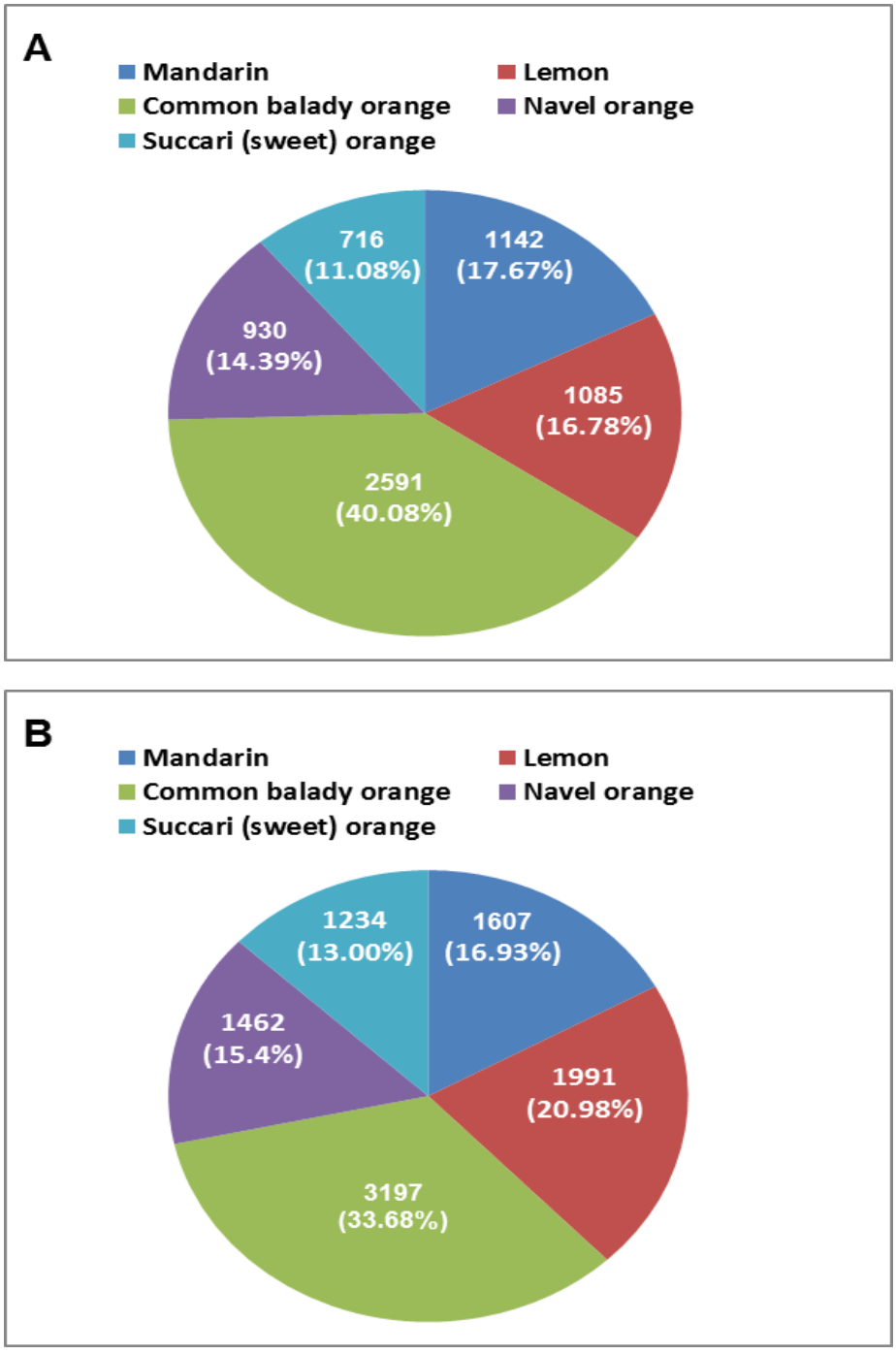


Fig.(1): Total number and percentage of the citrus mealybug *P. citri* on different citrus trees during two successive years 2014/15(A) and 2015/16(B) at Mansoura district.

The obtained results in Fig. (2) presented the population abundance of *P. citri* on different citrus host plants during the first year 2014/15. The highest peak of *P. citri* recorded on mandarin and lemon in 11th of June 2014 and represented by 84 and 62 indiv. /100 leaves, respectively. While, the highest peak of *P. citri* on common balady orange and navel orange was recorded at 17 th of September 2014 which represented by 206 and 63 indiv./100 leaves, respectively. Meanwhile, the highest peak of *P. citri* on succari orange was recorded at the beginning of October 2014 and represented by 50 indiv. /100 leaves.

Data arranged in Fig. (3) showed that *P. citri* recorded two peaks on mandarin and lemon trees during the second year 2015/16, the first peak at 15th of July which represented by (135 indiv/100.), (150indiv/100.), respectively, and the second one at the 7 th of October 2015 (122indiv./100) , (142 indiv. /100), respectively. while , the highest peak of *P. citri* on common balady orange , navel orange and succari orange was recorded at the 9 th of September 2015 which represented by 252 , 135 and 102 indiv. /100 leaves, respectively.

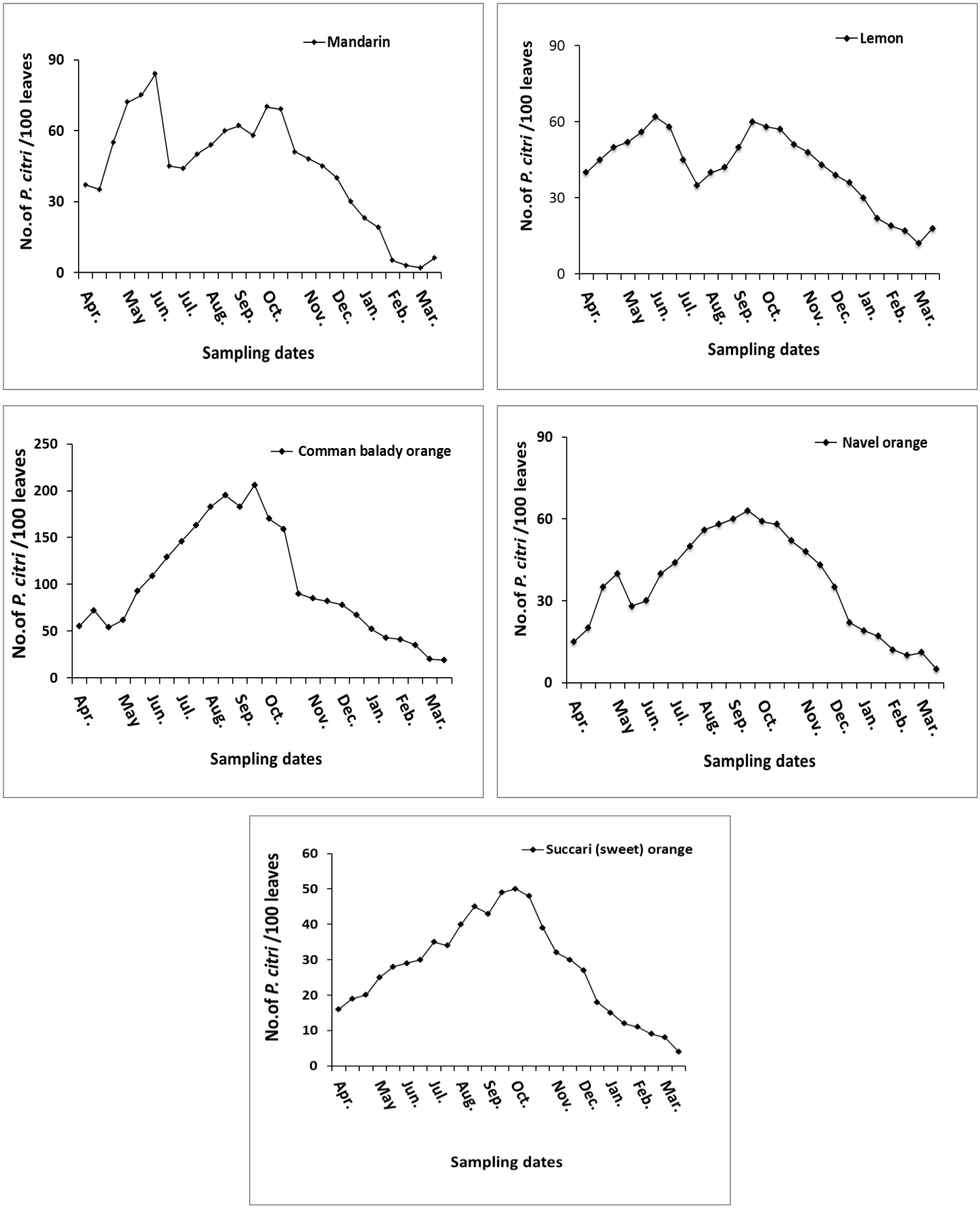


Fig.(2): The population abundance of *P. citri* on different citrus trees during the first year (2014/15) at Mansoura district.

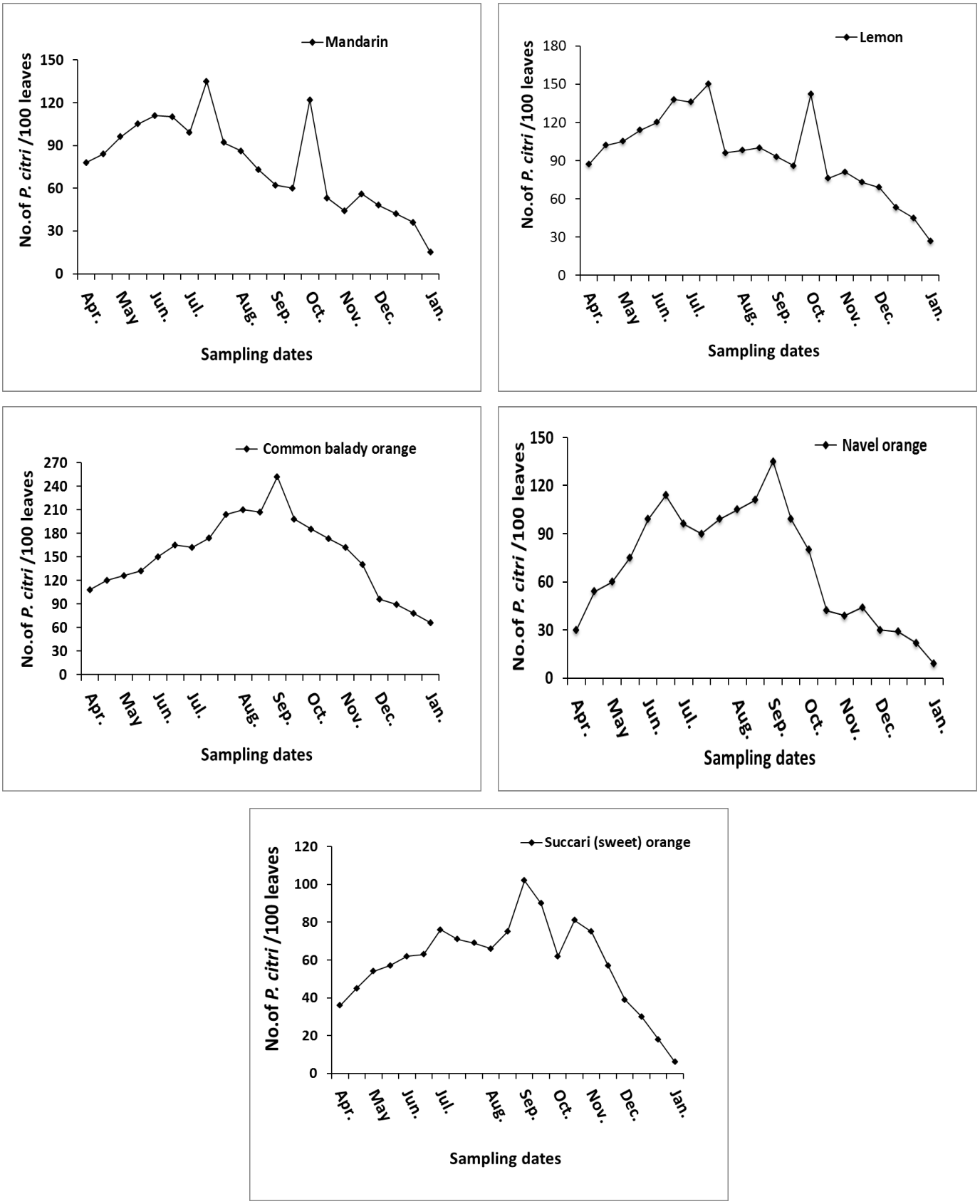


Fig.(3): The population abundance of *P. citri* on different citrus trees during the second year (2015/16) at Mansoura district.

Data illustrated in Table (1) showed the seasonal average number of citrus mealybug *P. citri* on different citrus host plants during the frist year 2014/15 at Mansoura district. It can be noticed that the highest average number was recorded during summer on common balady orange wich represented by 171.3±18.2 indiv. /100 leaves and the lowest average number was observed during winter on succari orange and represented by 11.0±1.8 indiv. /100 leaves. Statistical analysis showed a highly significant difference according to the average number of *P. citri* between the different citrus host plants during the four seasons.

As a conclusion, the highest annualy average number was recorded on common balady orange (99.2±11.4) fllowed by mandarin (44.8±4.5), lemon (42.3±2.8), navel orange (36.0±3.6) and succari orange (27.7±2.7) with significantly differences between the citrus host plants.

Data arranged in Table (2) reported the seasonal average number of citrus mealybug *P. citri* on different citrus host plants during the second year 2015/16 at Mansoura district. It can be noticed that the highest average number recorded during summer on common balady orange wich represented by 201.5±12.8 indiv. /100 leaves and the lowest average number was observed during winter on succari orange and represented by 18±6.9 indiv. /100 leaves. Statistical analysis showed a highly significant difference according to the average number of *P. citri* between the different citrus host plants during the four seasons. As a conclusion, the highest annualy average number was recorded on common balady orange (142.9±10.6) fllowed by lemon (88.2±7.0), mandarin (70.8±6.8), navel orange (63.4±7.9) and succari orange (53.6±5.1) with significantly differences between the citrus host plants.

Table (1): Seasonal average number of the citrus mealybug *p. citri* on different citrus trees during each season of the first year 2014/15 at Mansoura district.

Seasons	Host Plants				
	Mandarin	Lemon	Common balady orange	Navel orange	Succari orange
Spring	59.0±8.1 ab	50.8±3.2 b	74.2±9.1 a	28±3.8 c	22.8±2.2c
Summer	53.9±2.4 b	47.1±3.5 b	171.3±18.2 a	52.9±3.2 b	39.4±2.6 b
Autumn	53.8±5.2 b	49.3±3.1 b	111.7±17.7 a	49.3±3.8 b	37.7±3.9 b
Winter	12.6±4.3 b	22.0±3.1ab	39.6±6.5 a	13.7±2.2 b	11.0±1.8 b
mean±SE	44.8±4.5ab	42.3±2.8ab	99.2±11.4 a	36.0±3.6 b	27.7±2.7 b

Means followed by the same letters within each season are not significantly different at 0.05 level of probability (Duncan's Multiple Range Test).

Table (2): Seasonal average number of the citrus mealybug *p. citri* on different citrus trees during each season of the second year 2015/16 at Mansoura district.

Seasons	Host Plants				
	Mandarin	Lemon	Common balady orange	Navel orange	Succari orange
Spring	97.3±5.6 b	111±7.1ab	133.5±8.5 a	72±12.6 c	52.8±4.3 c
Summer	91.2±10.3bc	112.2±9.9 b	201.5±12.8 a	106±6.5 b	76.5±5.3 c
Autumn	63.8±11.8 b	87.8±11.1 b	159.5±14.9 a	55.6±11.1b	67.3±7.5 b
Winter	31±8.1 b	41.6±7.6 b	77.6±6.6 a	20±5.8 b	18±6.9 b
mean±SE	70.8±6.8 b	88.2±7.0 b	142.9±10.6 a	63.4±7.9 b	53.6±5.1 c

Means followed by the same letters within each season are not significantly different at 0.05 level of probability (Duncan's Multiple Range Test).

The results are in agreement with those of Abdelkhalek *et al.*, (1998) found that the high population of *P. citri* on citrus orchards during June-December in Marocco. Abdel-salam *et al.*, (2013a) mentioned that *P. citri* attracted to guava and mandarin as favorable host plants. Awadalla (2013) found that *P. citri* recorded the highest peak of abundance on guava trees in November and September during two successive years 2010/11 and 2011/12 in Egypt. Ghanim *et al.*, (2013a) suggested that the highest peak of abundance for *P. citri* on mandarin recorded in October and September during two successive years 2010/11 and 2011/12 in Egypt. EL-kady (2013) mentioned that *P. citri* nymphs or adults had 4-5 peaks of abundance on different citrus trees during two successive season 2009/10 and 2010/11 in Egypt. He added that Sore orange and lemon was the heaviest citrus attacked by *p. citri*.

4.1.1.2. The cottony cushion scale *Icerya purchasi* Maskell :-

Data represented in Fig. (4) showed the total number and percentage of the cottony cushion scale *I. purchasi* on different citrus host plants during two successive years 2014/15 and 2015/16 at Mansoura district. It can be noticed that Common balady orange attracted the highest number of *I. purchasi* during the first year 2014/15 wich represented by 1457 indiv. (34.67 %) followed by mandarin 799 indiv. (19.01 %) and lemon 713 indiv. (16.97 %), while, Succari and Navel orange came in the last category and represented by 644 indiv. (15.33 %) and 589 indiv. (14.02%), respectively.

During the second year, results arranged in Fig. (4) showed that Common balady orange attracted the highest number of *I. purchasi* during the second year 2015/16 wich represented by 707 indiv. (32.11 %) followed by mandarin 420 indiv. (19.07 %) and lemon 376 indiv. (17.08%), while, Navel orange and Succari came in the last category and represented by 355 indiv. (16.12 %) and 344 indiv. (15.62 %), respectively.

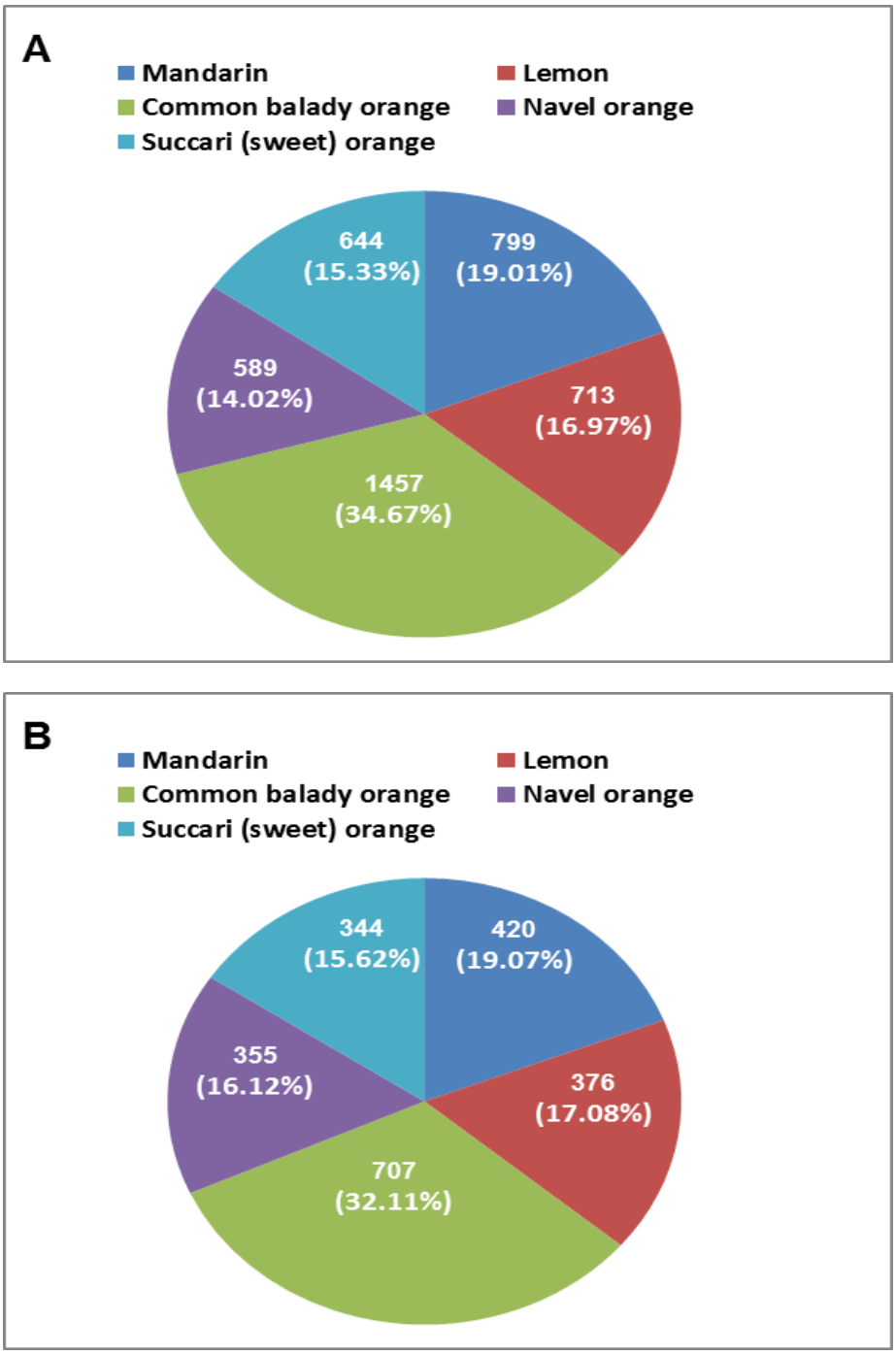
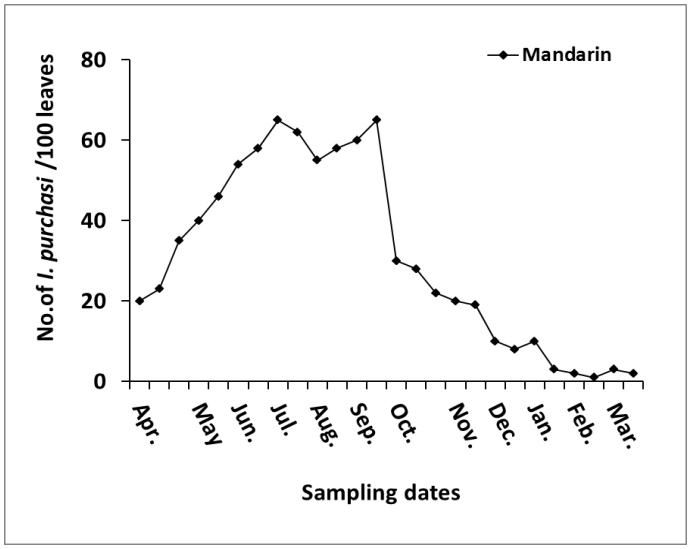
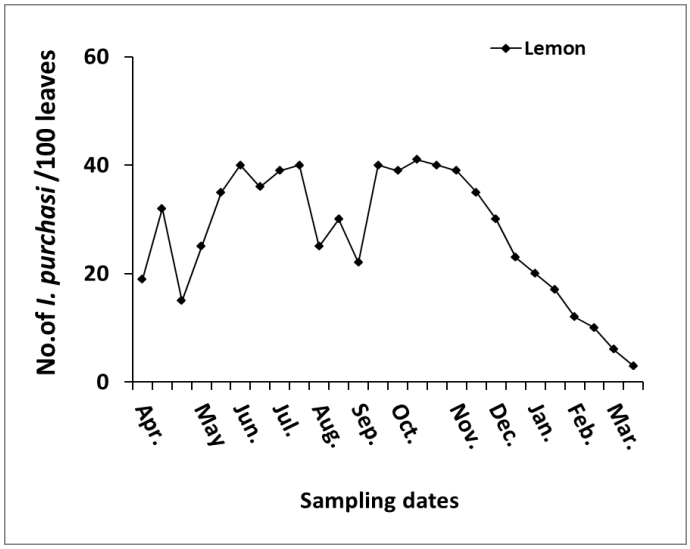


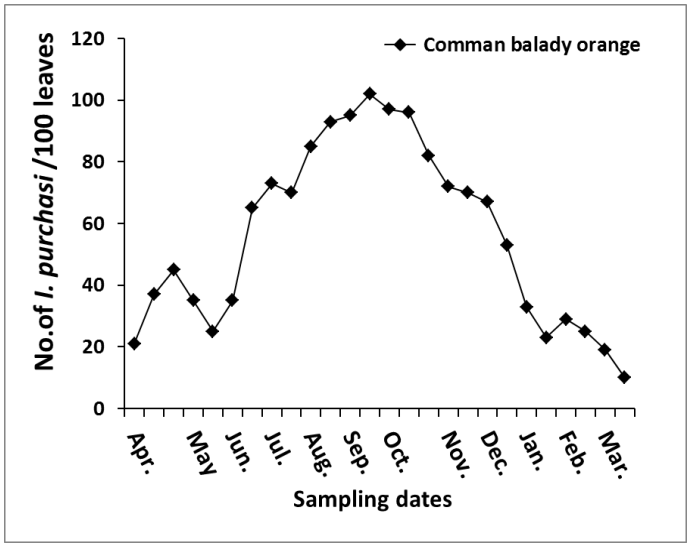
Fig.(4): Total number and percentage of the cottony cushion scale *I. purchasi* on different citrus trees during two successive years 2014/15(A) and 2015/16(B) at Mansoura district.

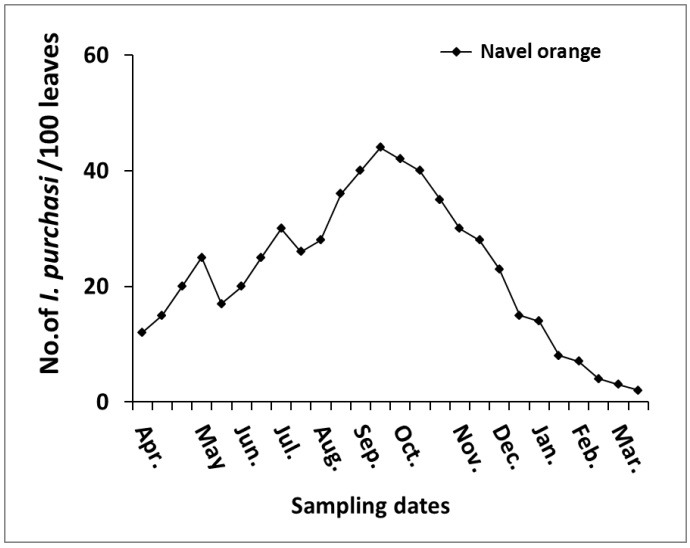
The obtained results in Fig. (5) showed the population abundance of *I. purchasi* on different citrus host plants during the first year 2014/15. The highest peak of *I. purchasi* found on mandarin and common balady orange and navel orange were recorded on 17th of September 2014 and represented by 65; 102 and 44 indiv. /100 leaves, respectively. While, the highest peak of *I. purchasi* on lemon was observed on 15th of October 2014 and represented by 41 indiv. /100 leaves. Meanwhile, the highest peak of *I. purchasi* on succari orange occurred at the beginning of October 2014 and represented by 46 indiv. /100 leaves.

Data arranged in Fig. (6) showed the population abundance of *I. purchasi* on different citrus host plants during the second year 2015/16. It can be noticed that, the highest peak of *I. purchasi* on mandarin and common balady orange and navel orange were recorded on 9th of September 2015 and represented by 35; 54 and 26 indiv. /100 leaves, respectively. While, the highest peak of *I. purchasi* occurred on lemon was observed on 7th of October 2015 and represented by 27 indiv. /100 leaves. Meanwhile, the highest peak of *I. purchasi* on succari orange occurred at 23th of September 2015 and represented by 25 indiv. /100 leaves.









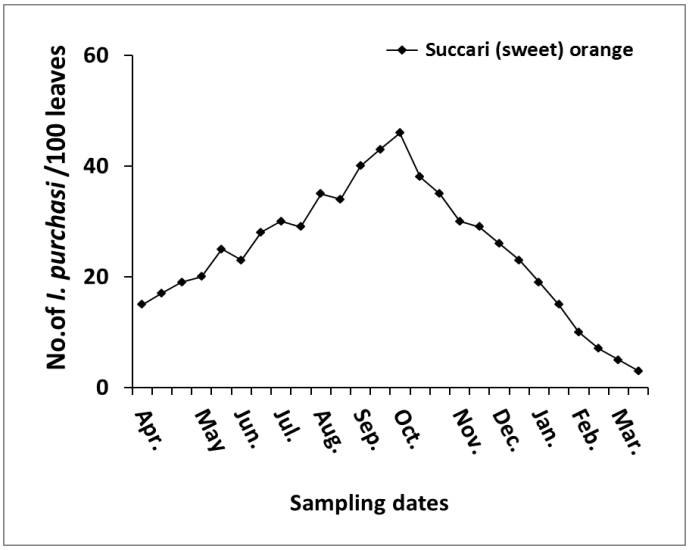


Fig.(5): The population abundance of *I. purchasi* on different citrus trees during the first year (2014/15) at Mansoura district.

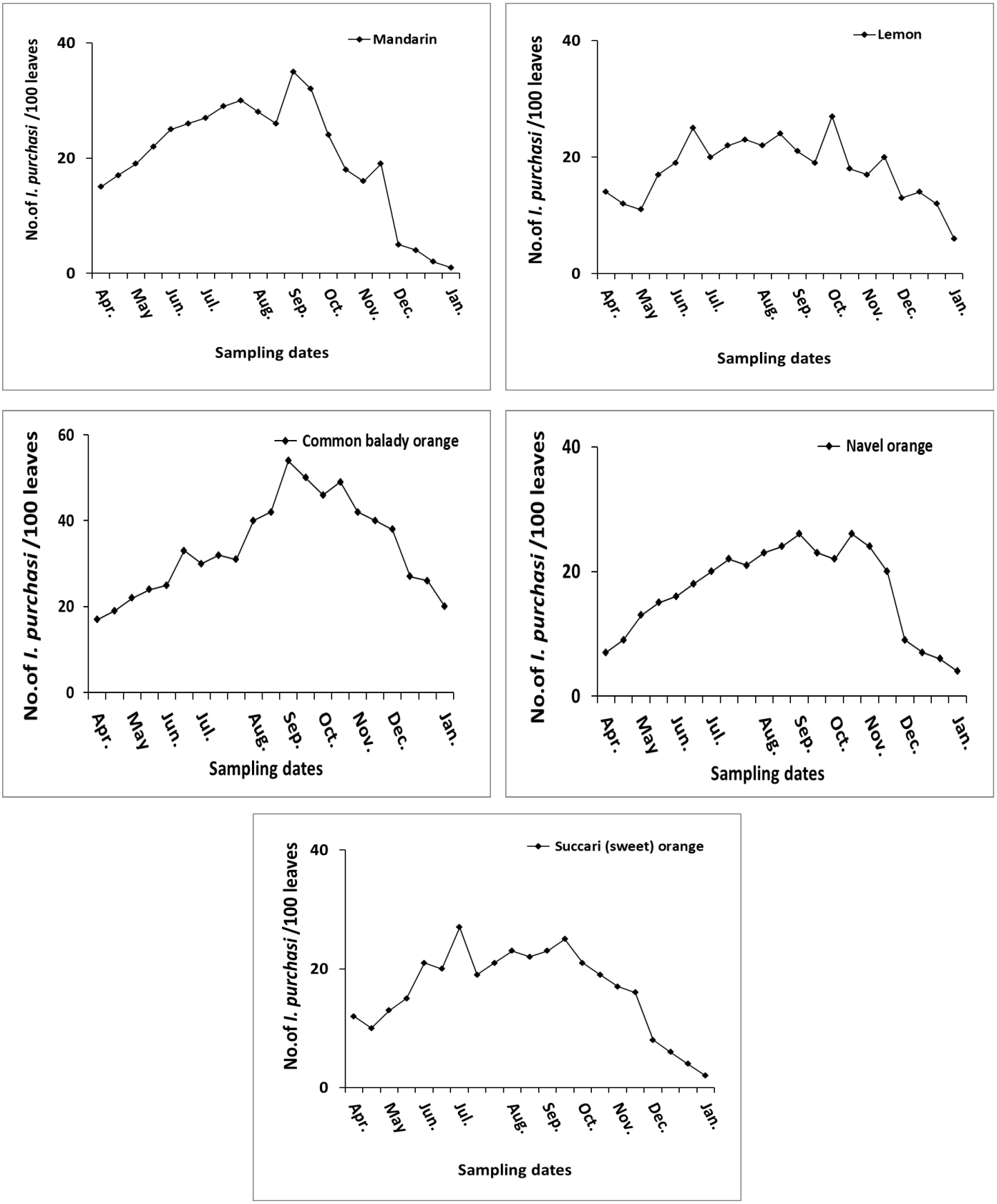


Fig.(6): The population abundance of *I. purchasi* on different citrus trees during the second year (2015/16) at Mansoura district.

Data illustrated in Table (3) showed the seasonal average number of the cottony cushion scale *I. purchasi* on different citrus host plants during the first year 2014/15 at Mansoura district. It can be noticed that the highest average number was recorded during summer on common balady orange and represented by 83.0±5.2 indiv./100 leaves and the lowest average number was recorded during winter on mandarin and represented by 4.1±1.3 indiv./100 leaves. Statistical analysis showed a highly significant difference according to the average number of *I. purchasi* between the different citrus host plants during the four seasons.

As a conclusion, the highest annualy average number was recorded on common balady orange (56.1±5.7) followed by mandarin (30.6±4.5) , lemon (27.8±2.3), succari orange (24.9±2.3) and navel orange (22.9±2.5) with significantly difference betwen the different citrus host plants.

Data arranged in Table (4) showed the seasonal average number of cottony cushion scale *I. purchasi* on different citrus host plants during the second year 2015/16 at Mansoura district. It can be noticed that the highest average number recorded during Autumn on common balady orange and represented by 44.1±2.0 indiv./100 leaves and the lowest average number was recorded during winter on mandarin and represented by 2.3±0.8 indiv./100 leaves. Statistical analysis showed ahighly significant differences according to the average number of *I. purchasi* between the different citrus host plants during the four seasons.

As a conclusion, the highest annualy average number was recorded on common balady orange (32.4±2.3) followed by mandarin (17.7±2.1), lemon (16.9±1.1), navel orange (15.5±1.5) and succari orange (14.8±1.5) with significant differences betwen the different citrus host plants.

Table (3): Seasonal average number of the cottony cushion scale *I.purchasi* on different citrus trees during each season of the first year 2014/15 at Mansoura district.

Seasons	Host Plants				
	Mandarin	Lemon	Common balady orange	Navel orange	Succari (sweet) orange
Spring	36.3±5.4 a	27.7±4.0 ab	33±3.5 a	18.2±1.9 b	19.8±1.5 b
Summer	60.4±1.4 b	33.1±2.8 c	83±5.2 a	32.7±2.8 c	34.1±2.2 c
Autumn	21.5±2.9 c	37.3±1.7 b	81±5.6 a	33±3.0 b	34±2.9 b
Winter	4.1±1.3 b	13±2.8 b	27.4±5.1 a	7.6±2.0 b	11.7±2.8 b
mean±SE	30.6±4.5 b	27.8±2.3 b	56.1±5.7 a	22.9±2.5 b	24.9±2.3 b

Means followed by the same letters within each season are not significantly different at 0.05 level of probability (Duncan's Multiple Range Test).

Table (4): Seasonal average number of the cottony cushion scale *I.purchasi* on different citrus trees during each season of the second year 2015/16 at Mansoura district.

Seasons	Host Plants				
	Mandarin	Lemon	Common balady orange	Navel orange	Succari (sweet) orange
Spring	20.6±1.8ab	16.3±2.1 bc	23.3±2.2 a	13±1.7 c	15.2±1.8 bc
Summer	29.1±1.3 b	22±0.6 c	38.1±3.7 a	22.6±0.8 c	22.5±1.0 c
Autumn	19±3.6 b	19±1.8 b	44.1±2.0 a	20.6±2.4 b	17.6±2.3 b
Winter	2.3±0.8 c	10.6±2.4 b	24.3±2.1 a	5.6±0.8 bc	4±1.1 c
mean±SE	17.7±2.1ab	16.9±1.1 bc	32.4±2.3 a	15.5±1.5 bc	14.8±1.5 bc

Means followed by the same letters within each season are not significantly different at 0.05 level of probability (Duncan's Multiple Range Test

The results are in agreement with those of Soares *et al.,* (1999)**.**They mentioned that *I. purchasi* develops two annual generations, one at the end of spring and the other in autumn and associated predatory *R. cardinalis* young females are the most abundant stage during the winter. The larval stages of the predator appear mainly at the beginning of summer and adults start to appear in July on citrus in Sao Miguel Island**.** Abdel-salam *et al.,* (2013a) mentioned that *I. purchasi* attracted to mandarin trees as a host plant during the two years of study in Egypt. Ghanim *et al.,* (2013a) recorded that the highest peak for *I. purchasi* on mandarin was in September during the two successive years in Egypt.

4.1.1.3. The Egyptian mealybug *Icerya aegyptiaca* (Douglas):-

Data represented in Fig. (7) showed the total number and percentage of the Egyptian mealybug *I. aegyptiaca* on different citrus host plants during the two successive years 2014/15 and 2015/16 at Mansoura district. It can be noticed that Common balady orange attracted the highest number of *I. aegyptiaca* during the first year 2014/15 wich represented by 778 indiv. (32.54 %) followed by mandarin 543 indiv.(22.71%) then Succari orange 392 indiv. (16.39 %), while, Navel orange and lemon came in the last category and represented by 376 indiv.(15.73 %) and 302 indiv. (12.63 %), respectively.

During the second year, results arranged in Fig. (7) showed that Common balady orange attracted the highest number of *I. aegyptiaca* during the second year 2015/16 wich represented by 1049 indiv. (28.19%) followed by mandarin 930 indiv. (24.99%) then Succari orange 616 indiv. (16.55%), while, Navel orange and lemon came in the last category and represented by 612 indiv. (16.45%) and 514 indiv. (13.81%), respectively.

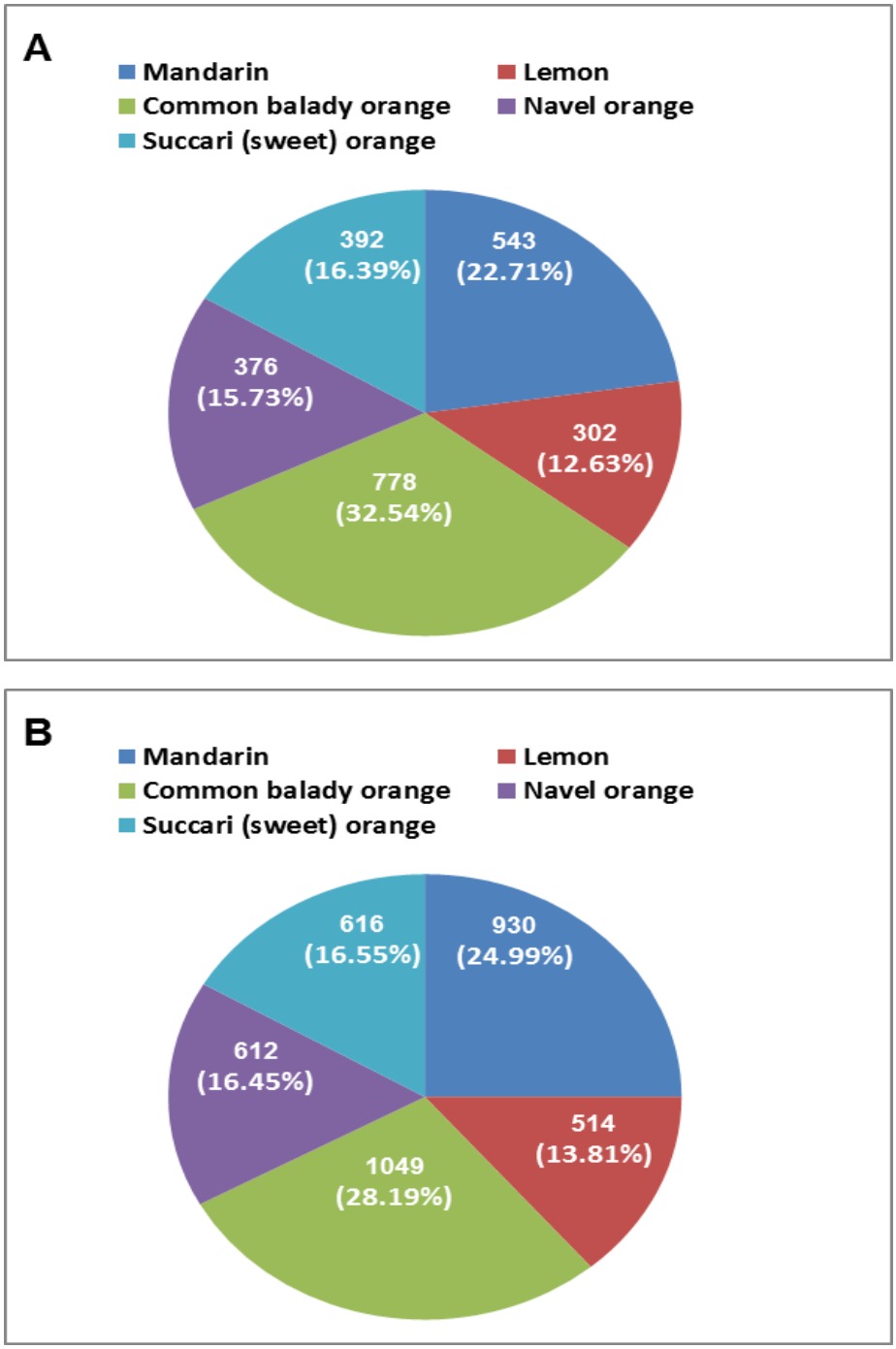


Fig.(7): Total number and percentage of the Egyptian mealybug *I.aegyptiaca* on different citrus trees during two successive years 2014/15(A) and 2015/16(B) at Mansoura district.

The obtained results in Fig. (8) showed the population abundance of *I. aegyptiaca* on different citrus host plants during the first year 2014/15. The highest peak of *I. aegyptiaca* on mandarin and navel orange recorded at the beginning of October 2014 and represented by 42 and 29 indiv. /100 leaves, respectively. While, the highest peak of *I. aegyptiaca* on lemon and succari orange were recorded at the 3rd of September 2014 and represented by 32 and 33 indiv. /100 leaves, respectively. Meanwhile, the highest peak of *I. aegyptiaca* on common balady orange was observed on 17th of September 2014 and represented by 58 indiv. /100 leaves.

Data arranged in Fig. (9) showed the population abundance of *I. aegyptiaca* on different citrus host plants during the second year 2015/16. It can be noticed that the highest peak of *I. aegyptiaca* on mandarin, navel orange and common balady orange recorded at 23th of September 2015 and represented by 78, 57 and 79 indiv. /100 leaves, respectively. while, the highest peak of *I. aegyptiaca* on lemon and succari orange were recorded at 7th of October 2015 and represented by 57 and 55 indiv. /100 leaves, respectively.

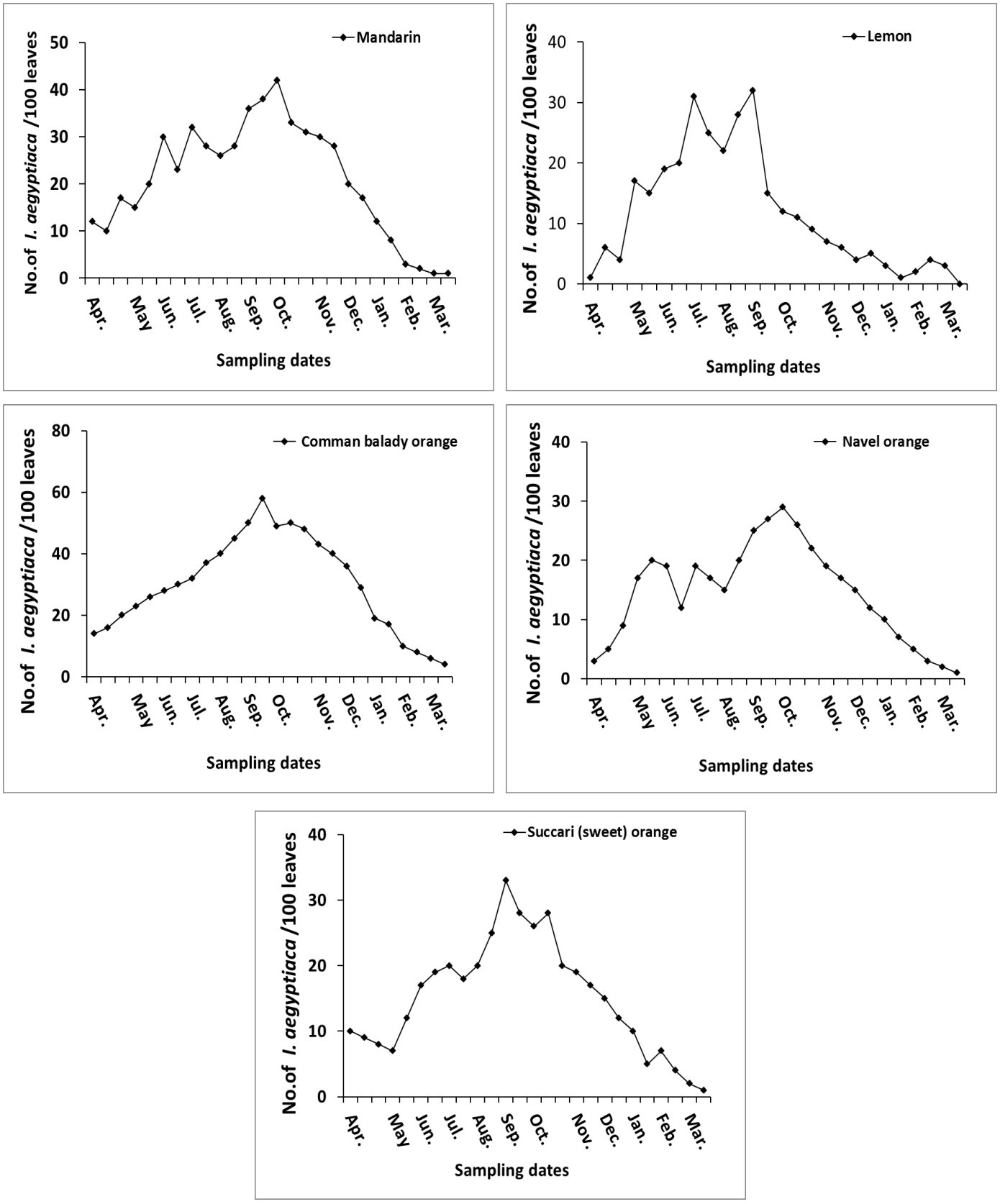


Fig.(8): The population abundance of *I. aegyptiaca* on different citrus trees during the first year (2014/15) at Mansoura district.

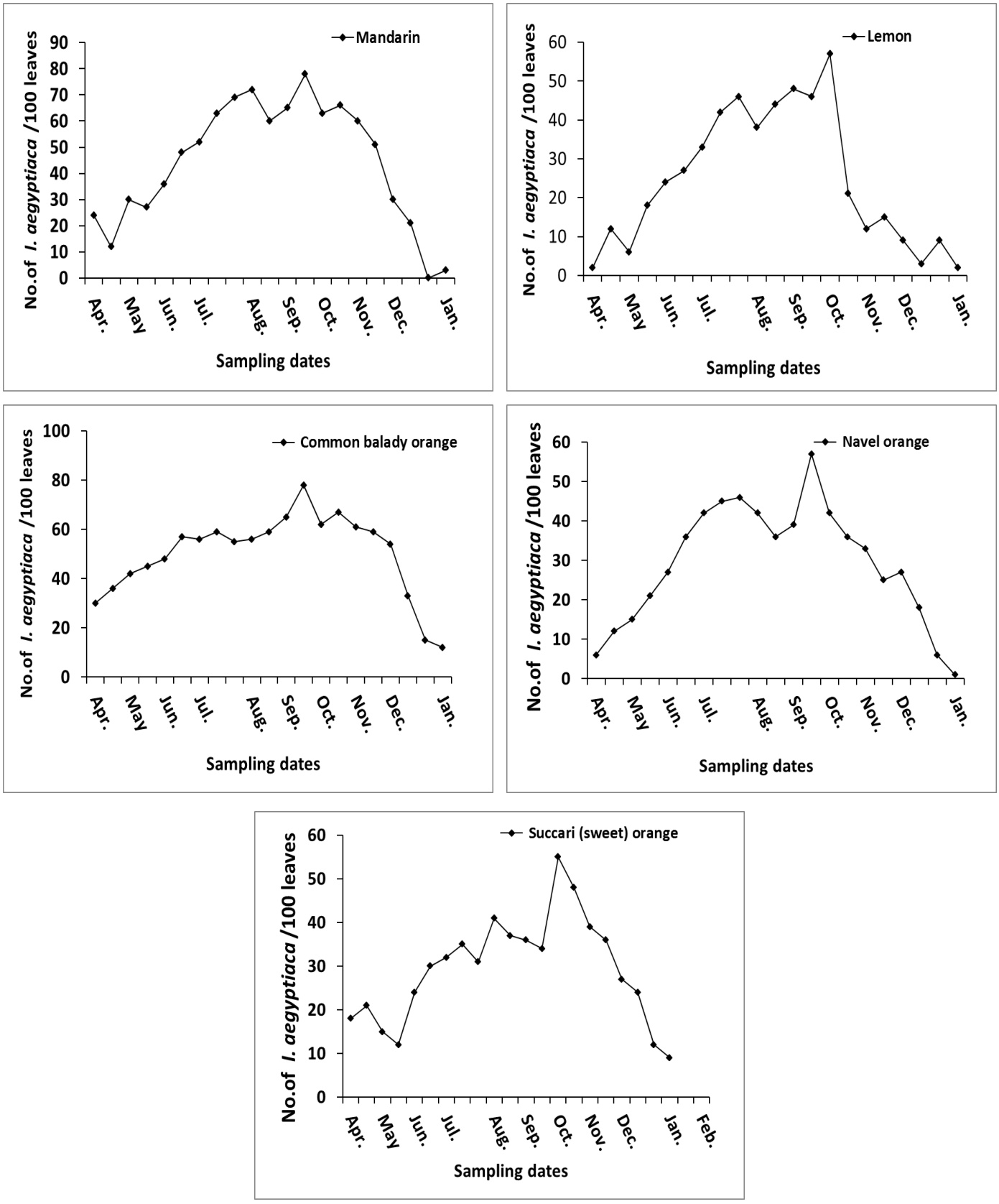


Fig.(9): The population abundance of *I. aegyptiaca* on different citrus trees during the Second year (2015/16) at Mansoura district.

Data illustrated in Table (5) showed the seasonal average number of the Egyptian mealybug *I. aegyptiaca* on different citrus host plants during the first year 2014/15 at Mansoura district. It can be noticed that the highest average number was recorded during autumn on common balady orange wich represented by 44.3±2.3 indiv./100 leaves and the lowest average number was observed during winter on lemon and represented by 2.6±0.7 indiv./100 leaves. Statistical analysis showed ahighly significant differences according to the average number of *I. aegyptiaca* between the different citrus host plants during the four seasons.

As a conclusion, the highest annualy average number was recorded on common balady orange (30.1±3.0) fllowed by mandarin (21.1±2.4), succari orange (15.2±1.7), navel orange (14.6±1.6) and lemon (11.5±1.9) with significant differences betwen the different citrus host plants.

Data arranged in Table (6) illustrated the seasonal average number of citrus mealybug *I. aegyptiaca* on different citrus host plants during the second year 2015/16 at Mansoura district. It can be noticed that the highest average number recorded during autumn on common balady orange wich represented by 63.5±3.3 indiv./100 leaves and the lowest average number was observed during winter on lemon and represented by 4.6±2.1 indiv./100 leaves. Statistical analysis showed a highly significant differences according to the average number of *I. aegyptiaca* between the different citrus host plants during the four seasons.

As a conclusion, the highest annualy average number was recorded on common balady orange (46.2±3.6) fllowed by mandarin (41.5±5.5), succari orange (27.5±2.6), navel orange (26.5±3.2) and lemon (21.9±3.2) with significant differences betwen the different citrus host plants.

Table(5): Seasonal average number of the Egyptian mealybug *I. aegyptiaca* on different citrus trees during each season of the first year 2014/15 at Mansoura district.

Seasons	Host Plants				
	Mandarin	Lemon	Common balady orange	Navel orange	Succari (sweet) orange
Spring	17.3±2.9 ab	10.3±3.1 b	21.2±2.3 a	12.2±3.0 b	10.5±1.5 b
Summer	30.1±2.1 b	24.7±2.3 bc	41.7±3.8 a	19.3±2.0 c	22.9±1.8 bc
Autumn	30.7±2.8 b	8.2±1.3 d	44.3±2.3 a	21.3±2.2 c	21.3±2.4 c
Winter	6.3±2.4 b	2.6±0.7 b	13.3±3.4 a	5.7±1.6 b	5.9±1.5 b
mean±SE	21.1±2.4ab	11.5±1.9bc	30.1±3.0 a	14.6±1.6 b	15.2±1.7 bc

Means followed by the same letters within each season are not significantly different at 0.05 level of probability (Duncan's Multiple Range Test).

Table(6): Seasonal average number of the Egyptian mealybug *I. aegyptiaca* on different citrus trees during each season of the second year 2015/16 at Mansoura district.

Seasons	Host Plants				
	Mandarin	Lemon	Common balady orange	Navel orange	Succari (sweet) orange
Spring	29.5±4.9b	14.8±4.1 c	43±3.8 a	19.5±4.4bc	20±2.6 bc
Summer	63.5±2.8a	41.8±2.2 b	58.3±1.4 a	41.6±1.5 b	35.3±1.4 c
Autumn	58±6.6 a	26.6±8.1 b	63.5±3.3 a	36.6±4.7 b	39.8±4.1 b
Winter	8±6.5 a	4.6±2.1 a	20±6.5 a	8.3±5.0 a	15±4.8 a
mean±SE	41.5±5.5a	21.9±3.8bc	46.2±3.6 a	26.5±3.2bc	27.5±2.6 bc

Means followed by the same letters within each season are not significantly different at 0.05 level of probability (Duncan's Multiple Range Test).

The results are in agreement with those of El-Sherbenie (2004) who recorded that *I. aegyptiaca* had three peaks. The highest peak on guava in September**,** May and July. during the two years .in Egypt. Abdel-salam *et al*, (2013a) suggested that *I. aegyptiaca* attractive to three host plants mandarin, guava and the favorable host plant was the ficus trees during the two successive years of study in Egypt. Awadalla (2013) recorded that the highest peak for *I. aegyptiaca* in November during two successive years of study in Egypt. Ghanim *et al.,* (2013a) recorded that the highest peak for *I. aegyptiaca* in September during the two successivestud years of y on mandarin trees in Egypt**.**

4.1.1.4. The Seychelles fluted scale *Icerya seychellarum* (Westwood):-

Data represented in Fig. (10) showed the total number and percentage of the Seychelles fluted scale *I. seychellarum* on different citrus host plants during the two successive years 2014/15 and 2015/16 at Mansoura district . It can be noticed that Common balady orange attracted the highest number of *I. seychellarum* during the first year 2014/15 wich represented by 3956 indiv. (30.82%) followed by lemon 2424 indiv. (18.89%) and Navel orange 2269 indiv. (17.68%), while Succari orange and mandarin came in the last category and represented by 2110 indiv. (16.44 %) and 2076 indiv. (16.17%), respectively.

During the second year, results arranged in Fig. (10) showed that Common balady orange attracted the highest number of *I. seychellarum* during the first year 2015/16 wich represented by 4309 indiv. (24.62%) followed by lemon 3695 indiv.(21.11%) and Navel orange 3515 indiv. (20.08%), while Succari orange and mandarin came in the last category and represented by3021 indiv.(17.26%) and 2962 indiv. (16.92%), respectively.

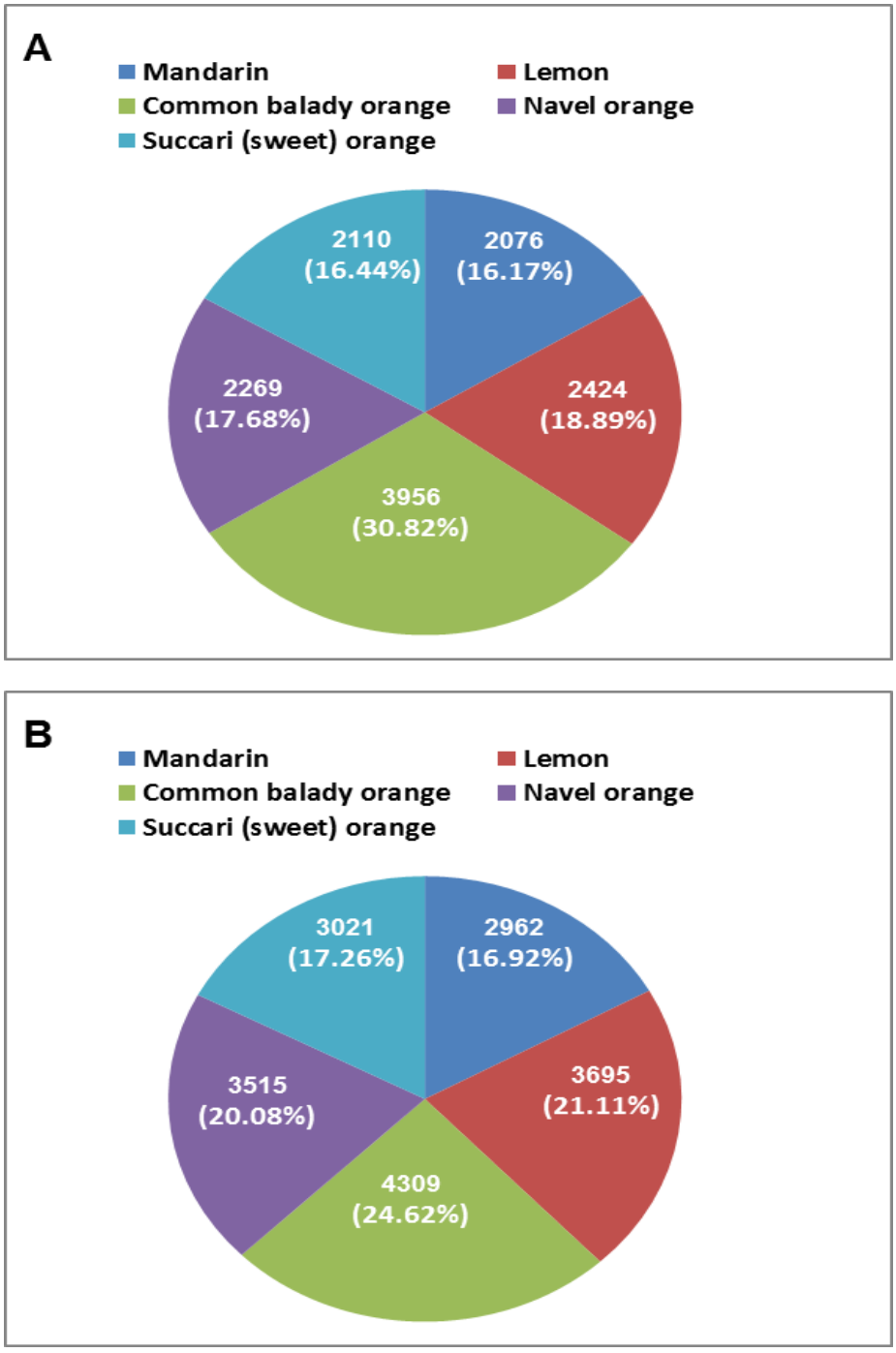
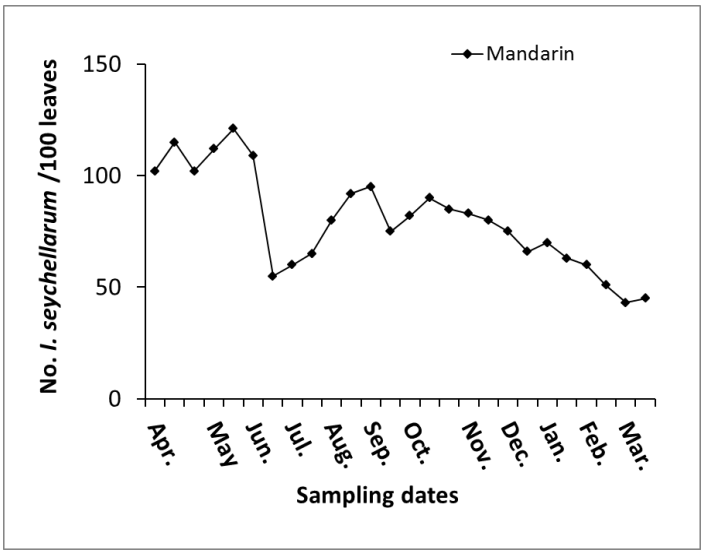
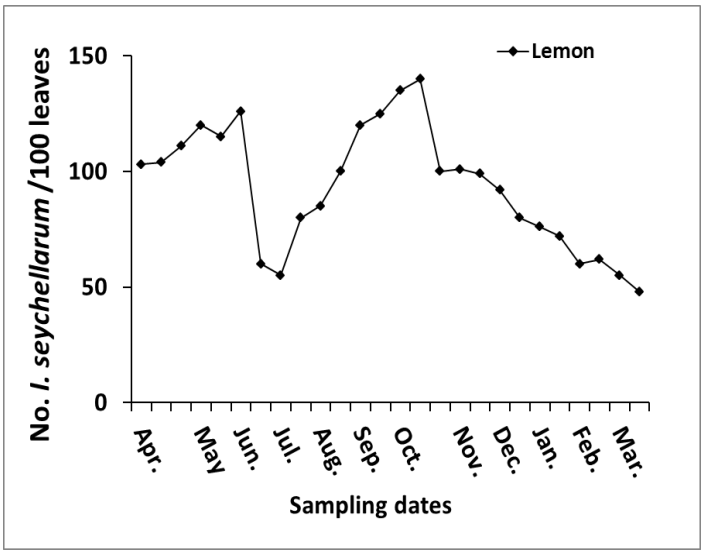


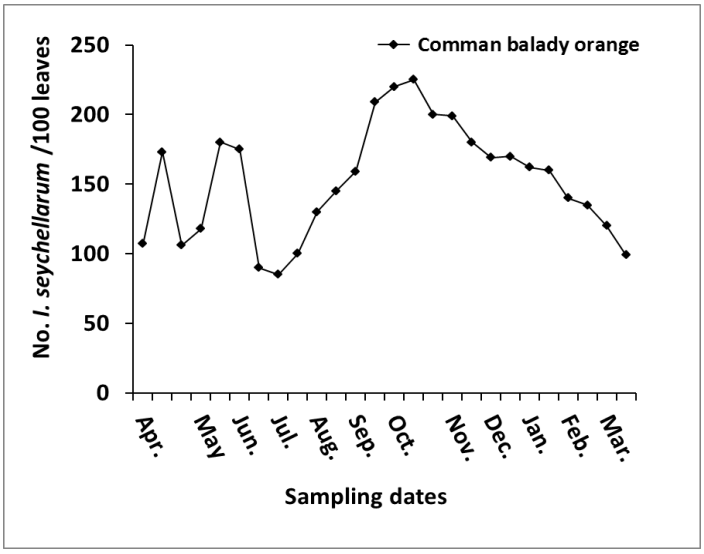
Fig.(10): Total number and percentage of the Seychelles fluted scale *I. seychellarum* on different citrus trees during two successive years 2014/15(A) and 2015/16(B) at Mansoura district.

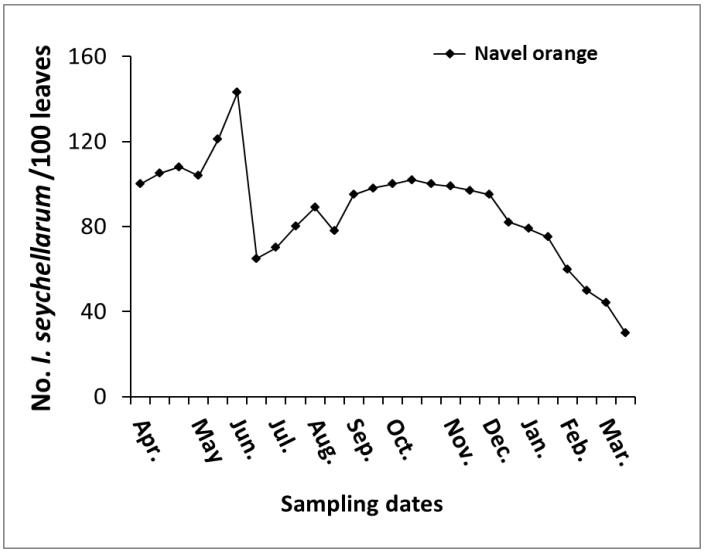
The obtained results in Fig. (11) showed the population abundance of *I. seychellarum* on different citrus host plants during the first year 2014/15. The highest peak of *I. seychellarum* on mandarin and succari orange was recorded at the last week of May 2014 and represented by 121 and 123 indiv. /100 leaves, respectively, while the highest peak of *I. seychellarum* on lemon and navel orange occurred on the 11th of June 2014 and represented by 126 and 143 indiv. /100 leaves. respectively. Meanwhile, the highest peak of *I. seychellarum* on common balady orange recorded at 15th of October 2014 and represented by 225 indiv. /100 leaves.

Data arranged in Fig. (12) showed the population abundance of *I. seychellarum* on different citrus host plants during the second year 2015/16. It can be noticed that the highest peak of *I. seychellarum* mandarin and succari orange was recorded at the begining of July 2015 and represented by 210 and 186 indiv. /100 leaves, respectively, while the highest peak of *I. seychellarum* on lemon and navel orange occurred on the 17th of June 2015 and represented by 216 and 207 indiv. /100 leaves. respectively. Meanwhile, the highest peak of *I. seychellarum* on common balady orange recorded at 9th of September 2015 and represented by 300 indiv. /100 leaves.









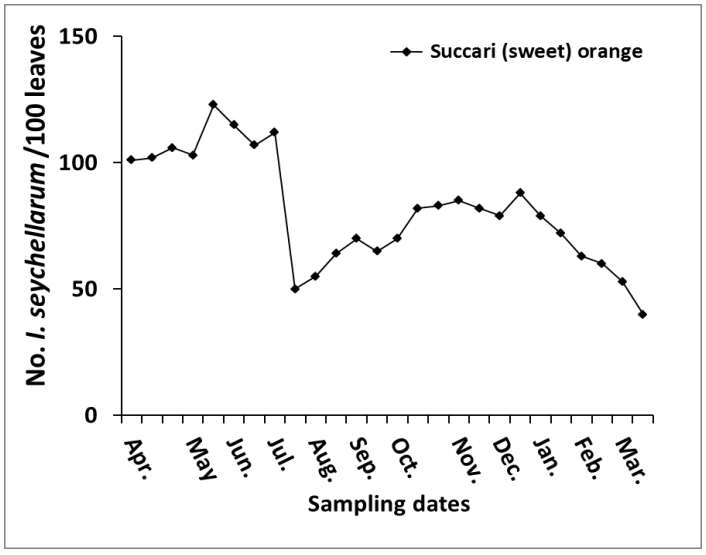


Fig.(11): The population abundance of *I. seychellarum* on different citrus trees during the first year (2014/15) at Mansoura district.

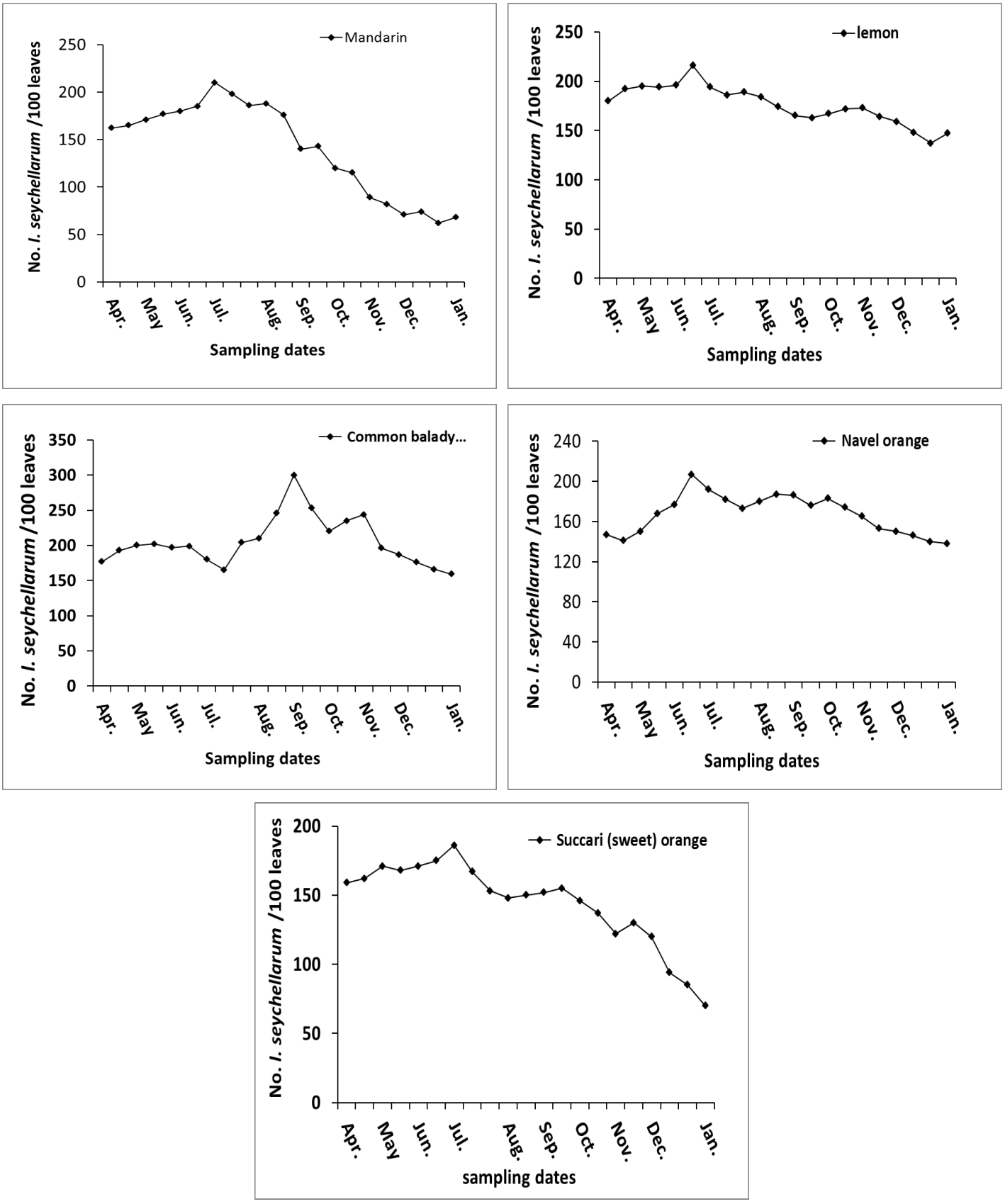


Fig.(12): The population abundance of *I. seychellarum* on different citrus trees during the second year (2015/16) at Mansoura district.

Data illustrated in Table (7) showed the seasonal average number of the Seychelles fluted scale *I. seychellarum* on different citrus host plants during the first year 2014/15 at Mansoura district. It can be noticed that the highest average number was recorded during autumn on common balady orange and represented by 198.8±8.9 indiv./100 leaves and the lowest one was recorded during winter on mandarin and represented by 56.9±4.0 indiv./100 leaves. Statistical analysis showed a highly significant difference according to the average number of *I. seychellarum* between the different citrus host plants during the four seasons.

As a conclusion, the highest annualy average number was recorded on common balady orange (153.5±8.1) fllowed by lemon (94.6±5.3), navel orange (88.5±4.8), Succari orange (82.1±4.4) and mandarin (81.1±4.3) with significant differences betwen the different citrus host plants.

Data arranged in Table (8) showed the seasonal average number of citrus mealybug *I. seychellarum* on different citrus host plants during the second year 2015/16 at Mansoura district. It can be noticed that the highest average number recorded during autumn on common balady orange and represented by 222.5±10.8 indiv./100 leaves and the lowest one was recorded during winter on mandarin and represented by 68±3.4 indiv./100 leaves. Statistical analysis showed a highly significant differences according to the average number of *I. seychellarum* between the different citrus host plants during the four seasons.

As a conclusion, the highest annualy average number was recorded on common balady orange (200±4.2) fllowed by lemon (171.9±7.5), navel orange (164.1±4.2), Succari orange (136.2±6.7) and mandarin (131.9±10.7) with significant differences betwen the different citrus host plants.

Table (7): Seasonal average number of the Seychelles fluted scale *I.seychellarum* on different citrus trees during each season of the first year 2014/15 at Mansoura district.

seasons	Host Plants				
	Mandarin	Lemon	Common balady orange	Navel orange	Succari (sweet) orange
Spring	110.2±3.1 b	113.2±3.7 b	143.2±14.8 a	113.5±6.6 b	108±3.3 b
Summer	74.6±5.9 b	89.3±10.3 b	131.1±16.8 a	82.1±4.7 b	75.1±9.6 b
Autumn	82.5±2.1 cd	111.2±8.5 b	198.8±8.9 a	98.3±1.0 bc	80.2±2.2 d
Winter	56.9±4.0 b	64.7±4.4 b	140.9±9.6 a	60±7.4 b	65±6.1 b
mean±SE	81.1±4.3 cd	94.6±5.3 b	153.5±8.1 a	88.5±4.8 bc	82.1±4.4 d

Means followed by the same letters within each season are not significantly different at 0.05 level of probability (Duncan's Multiple Range Test).

Table (8): Seasonal average number of the Seychelles fluted scale *I.seychellarum* on different citrus trees during each season of the second year 2015/16 at Mansoura district.

seasons	Host Plants				
	Mandarin	Lemon	Common balady orange	Navel orange	Succari (sweet) orange
Spring	173.3±3.6 b	195.5±4.7 a	194.6±3.7 a	165±10.0 b	167.6±2.4 b
Summer	183±9.8 b	182±4.3 b	217±20.0 a	183.3±.6 b	159.3±5.9 b
Autumn	103.3±11.0d	166.3±2.2 b	222.5±10.8 a	166.8±5.4 b	135±5.6 c
Winter	68±3.4 d	144±3.5 b	167±4.9 a	141.3±2.4 b	83±7.0 c
mean±SE	131.9±10.7b	171.9±7.5b	200.4±4.2 a	164.1±4.2 b	136.2±6.7 bc

Means followed by the same letters within each season are not significantly different at 0.05 level of probability (Duncan's Multiple Range Test).

The results are in agreement with those of Mangoud (2000) who recorded that *I. seychellarum* has 2-3 population peaks/year on apple trees in June, October and December in Egypt. El-Sherbenie (2004) recorded that *I. seychellarum* had two peaks. The highest peak was found in the August and March during the two years of study. on guava in Egypt. Ibrahim (2005) mentioned that, the infestation by *I. seychellarum* to persimmon trees initiated on May in 2002 and 2003. The insect pest had two peaks in each season of study. *R. cardinalis* was the main predator associated with *I. seychellarum* and recorded three peaks of each season in Egypt. Bakry (2009) Found that *I. Seychellarum* had three generations in May, August and October on mango trees during the two years of investigation in Egypt. Moustafa (2012) in Egypt recorded that seychellarum mealybug, *I. seychellarum* infested citurs trees in Demmyat and has two annual peaks one in June and the other in November. Also *R.cardinalis* associated with seychellarum mealybug, *I. seychellarum.* Abdel-salam *et al.,* (2013a) suggested that *I. seychellarum* recorded the highest attractiveness on guava trees followed by persimmon, ficus and mandarin during the first year and on persimmon trees followed by guava , ficus and in the last category mandarin trees during the second year of the study in Egypt. Awadalla (2013) recorded the highest peak for *I. seychellarum* in September and November 2011 in Egypt.Ghanim *et al.*, (2013a) suggested that the highest peak for *I. seychellarum* recorded in September 2011 and 2012 during the two successive years of study.

4.1.2. Predatory inseacts:-

4.1.2.1. On mandarin:-

Data illustrated in Fig. (13) showed the seasonal activity of the main predatory insects associated with the mealybug species on mandarin during the first year 2014/15 at Mansoura district. *Rodolia cardinalis, Chrysoperla carnea* and *Nephus includens* recorded the highest peaks on mandarin in the beginning of October 2014 and represented by 72, 56 and 38 indivi. / 100 leaves. respectively.

Data arranged in Fig. (14) evaluated the seasonal activity of the main predatory insects associated with the mealybug species on mandarin during the second year 2015/16 at Mansoura district. *R. cardinalis, C. carnea* and *N. includens* recorded the highest peaks on mandarin at 9th of September 2015 and represented by 92, 64 and 39 indivi. / 100 leaves. respectively.

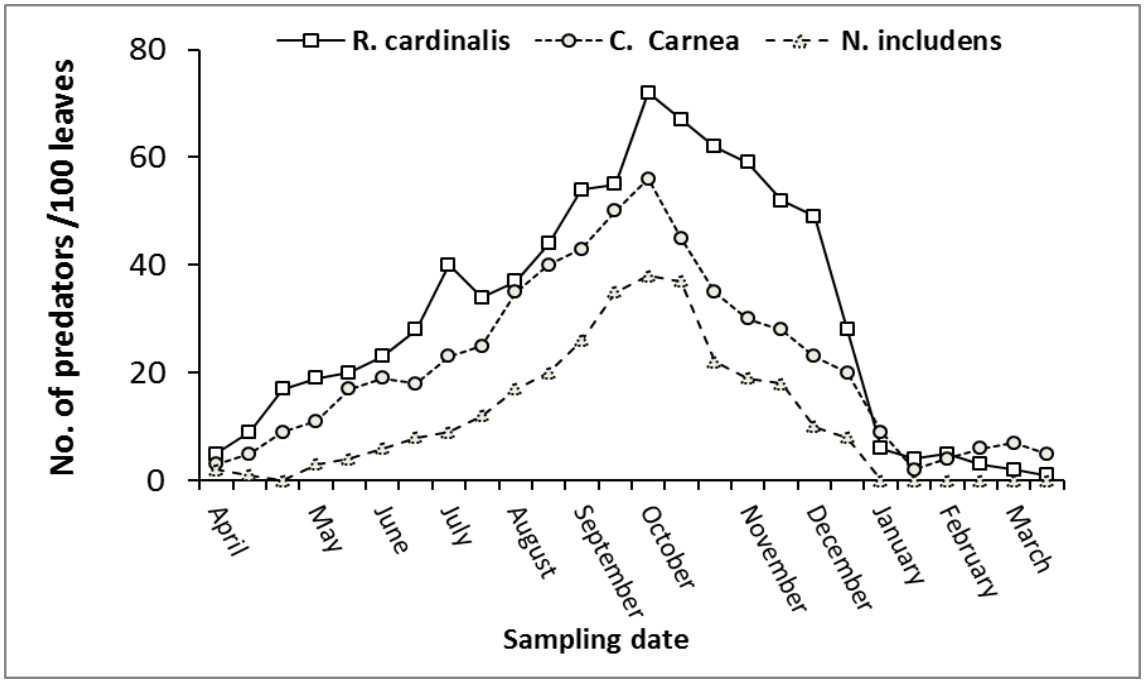


Fig.(13): Seasonal activity of the main predatory insects associated with the mealybug species on mandarin during the first year (2014/15) at Mansoura district.

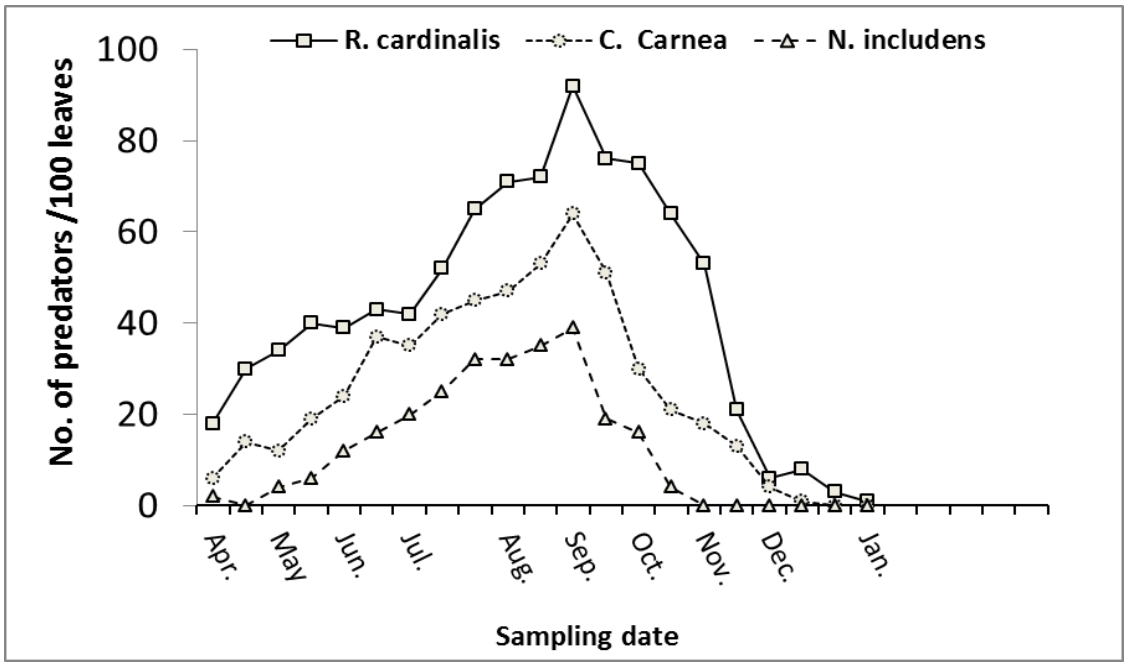


Fig.(14): Seasonal activity of the main predatory insects associated with the mealybug species on mandarin during the second year (2015/16) at Mansoura district.

Results of the statistical analysis of simple correlation coefficient arranged in Table (9) indicated that the relationship between *P. citri* and *I. aegyptiaca* and their associated predators on mandarin trees during the first year 2014/15 showed a highly positive significant effect. On the other hand, the relationship between *I. purchasi* and *R. cardinalis* or *N. includens* showed a positively significant effect, while, the relationship between *I. seychellarum* and the three predatory insects showed insignificantly positive effects during the first year 2014/15.

During the second year 2015/16, results of the statistical analysis of simple correlation coefficients illustrated in Table (9) revealed that, the relationship between *P. citri*, *I. purchasi* and *I. seychellarum* and their associated predators on mandarin trees during the second year 2015/16 showed a highly positive significant effect while, the relationship between *P. citri* and the three predatory insects showed insignificantly positive effects during the second year 2015/16.

Table (9): Simple correlation coefficients between number of mealybug species and their associated predatory insects on mandarin trees during two years (2014/15 and 2015/16) at Mansoura district.

Mealybug species	Predatory insects					
	First year 2014/15			Second year 2015/16		
	R. cardinalis	*C. carnea*	*N. includens*	*R. cardinalis*	*C. carnea*	*N. includens*
P. citri	0.631^{**}	0.632^{**}	0.566^{**}	0.398^{ns}	0.428^{ns}	0.417^{ns}
I. purchase	0.422^{*}	0.529^{**}	0.407^{*}	0.864^{**}	0.912^{**}	0.805^{**}
I. aegyptiaca	0.908^{**}	0.900^{**}	0.853^{**}	0.871^{**}	0.817^{**}	0.697^{**}
I. seychellarum	0.185^{ns}	0.153^{ns}	0.132^{ns}	0.494^{*}	0.614^{**}	`0.608^{**}

Correlation is significant at the 0.01 level. **
Correlation is significant at the 0.05 level.*
ns: Correlation is insignificant .

4.1.2.2. On Lemon :-

Data illustrated in Fig. (15) recorded the seasonal activity of the main predatory insects associated with the mealybug species on Lemon during the first year 2014/15 at Mansoura district. Vedalia beetle *R. cardinalis* recorded the highest peak on lemon trees at the third week of September, *C. carne* at the first week of September *and N.includens* at the first week of Augest 2014 and represented by 60, 45 and 25 indivi./100 leaves. respectively.

Data arranged in Fig. (16) evaluated the seasonal activity of the main predatory insects associated with the mealybug species on lemon during the second year 2015/16 at Mansoura district. *R. cardinalis* recorded the highest peaks on lemon at the 9th of September and represented by 74 indivi./100 leaves , *C. carnea* and *N. includens*. recorded at the 12th of Augest and represented by 54 , 30 indivi./100 leaves,respectively.

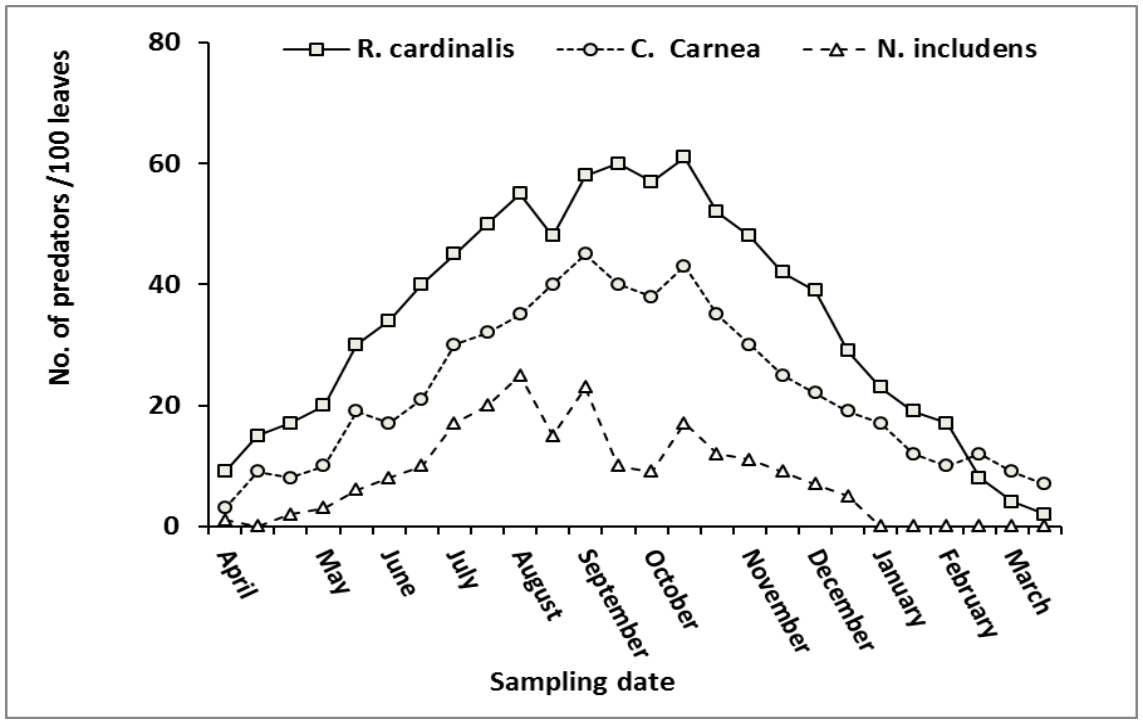
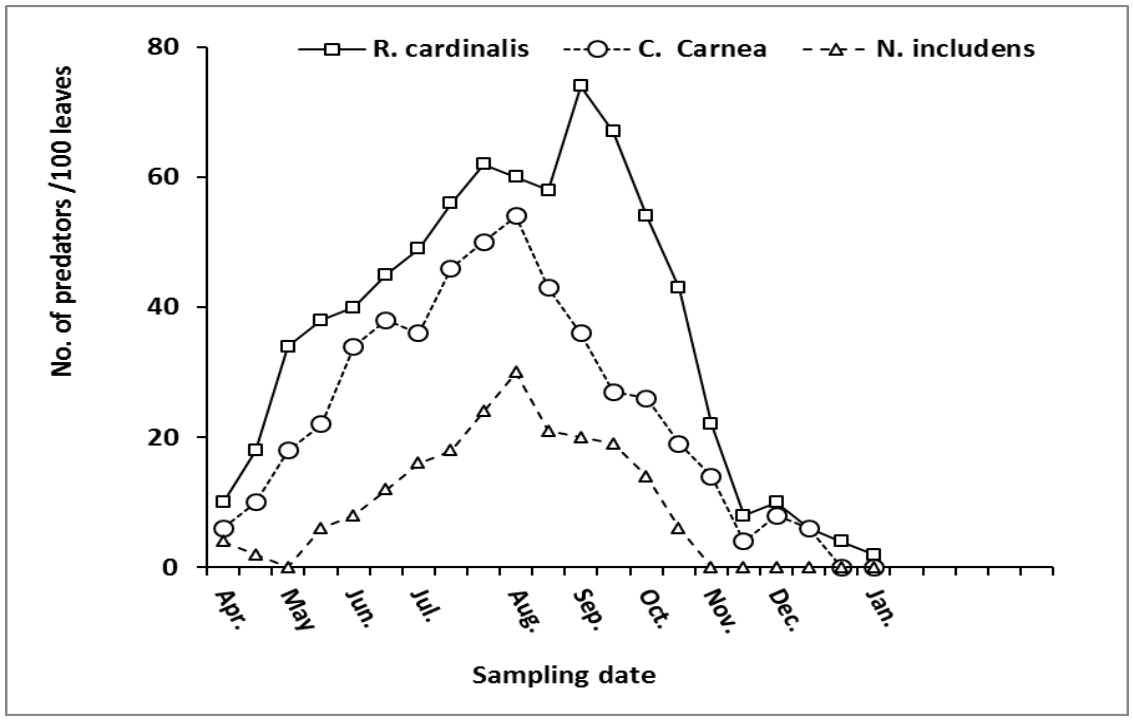


Fig.(15): Seasonal activity of the main predatory insects associated with the mealybug species on Lemon during the first year(2014/15) at Mansoura district.



Fig(16): Seasonal activity of the main predatory insects associated with the mealybug species on Lemon during the second year (2015/16) at Mansoura district.

Results of the statistical analysis of simple correlation coefficients arranged in Table (10) indicated that the relationship between the different mealybug species and their associated predators on lemon trees during the first year 2014/15 showed a highly positive significant effects or positive significant effects except *I. seychellarum* and *N. includens* which showed a positive insignificant effect.

During the second year 2015/16, results of the statistical analysis of simple correlation coefficients illustrated in Table (10) revealed that the relationship between the different mealybug species and their associated predators on lemon trees during the second year 2015/16 showed a highly positive significant effects or positive significant effects except *I. seychellarum* their associated predators which showed a positive insignificant or highly positive significant effect.

Table (10): Simple correlation coefficients between number of mealybug species and their associated predatory insects on lemon trees during two years (2014/15 and 2015/16) at Mansoura district.

Mealybug species	Predatory insects					
	First year 2014/15			Second year 2015/16		
	R. cardinalis	*C. carnea*	*N. includens*	*R. cardinalis*	*C. carnea*	*N. includens*
P. citri	0.652**	0.502**	0.451*	0.628**	0.677**	0.493*
I. purchase	0.785**	0.643**	0.569**	0.752**	0.768**	0.735**
I. aegyptiaca	0.642**	0.651**	0.809**	0.908**	0.804**	0.875**
I. seychellarum	0.505**	0.432*	0.275 ns	0.423 ns	0.571**	0.311 ns

Correlation is significant at the 0.01 level. **

Correlation is significant at the 0.05 level.*

ns: Correlation is insignificant .

4.1.2.3. On Common balady orange :-

Data in Fig. (17) illustrated the seasonal activity of the main predatory insects associated with the mealybug species on Common balady orange during the first year 2014/15 at Mansoura district. Vedalia beetle *R. cardinalis* and *N. includens* were recorded the highest peaks on Common balady orange trees at the third week of September**,** and represented by 199 and 61 indivi. / 100 leaves, while *C. carnea* reached the highest peak at the third week of October 2014 and represented by 82 indivi. / 100 leaves.

Data arranged in Fig. (18) evaluated the seasonal activity of the main predatory insects associated with the mealybug species on Common balady orange during the second year 2015/16 at Mansoura district. *R. cardinalis* and *N. includens* were recorded the highest peaks on Common balady orange trees in 9th of September and represented by 122 and 30 indivi. / 100**,** while *C. carnea* reached the highest peak at 23th of September and represented by 75 indivi. / 100 leaves.

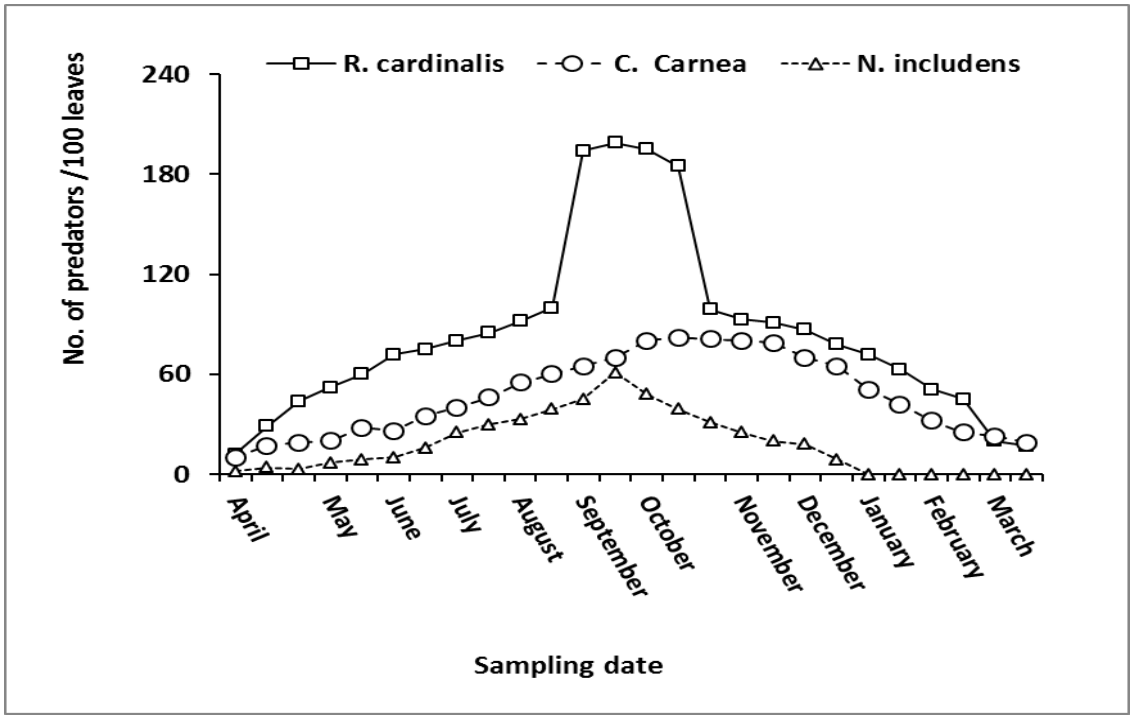


Fig.(17): Seasonal activity of the main predatory insects associated with the mealybug species on Common balady orange during the first year (2014/15) at Mansoura district.

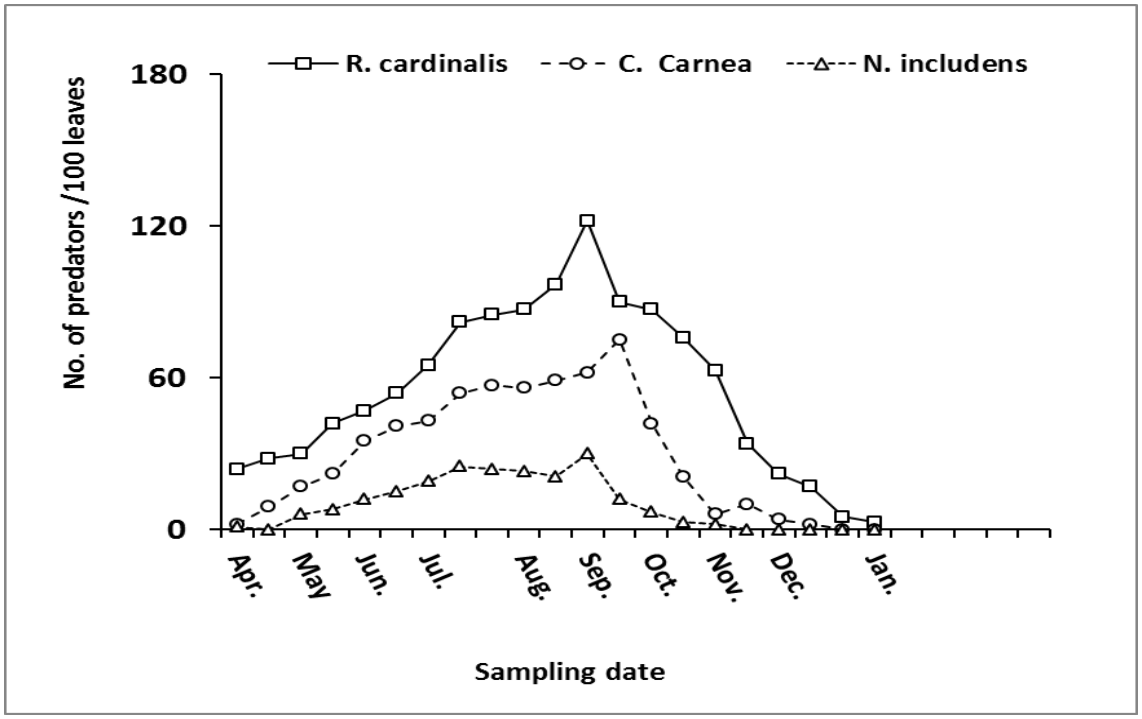


Fig.(18): Seasonal activity of the main predatory insects associated with the mealybug species on Common balady orange during the second year (2015/16) at Mansoura district.

Results of the statistical analysis of simple correlation coefficients arranged in Table (11) indicated that, the relationship between the different mealybug species and their associated predators on Common balady orange trees during the first year 2014/15 showed a highly positive significant effect, except *I. seychellarum* and *N. includens* which showed positive significant effect.

During the second year 2015/16, results of the statistical analysis of simple correlation coefficients illustrated in Table (11) revealed that the relationship between the different mealybug species and their associated predators on Common balady orange trees during the second year 2015/16 showed a highly positive significant effects, except *I. seychellarum*, *I. purchase* and *N. includens* which showed positive insignificant effect.

Table (11): Simple correlation coefficients between number of mealybug species and their associated predatory insects on Common balady orange trees during two years (2014/15 and 2015/16) at Mansoura district.

Mealybug species	Predatory insects					
	First year 2014/15			Second year 2015/16		
	R. cardinalis	*C. carnea*	*N. includens*	*R. cardinalis*	*C. carnea*	*N. includens*
P. citri	0.788**	0.529**	0.913**	0.980**	0.882**	0.820**
I. purchase	0.862**	0.810**	0.943**	0.757**	0.552**	0.370 ns
I. aegyptiaca	0.877**	0.836**	0.936**	0.815**	0.699**	0.505*
I. seychellarum	0.626**	0.692**	0.455*	0.762 **	0.542*	0.410 ns

Correlation is significant at the 0.01 level. **

Correlation is significant at the 0.05 level.*

ns: Correlation is insignificant .

4.1.2.4. On Navel orange :-

Data in Fig. (19) illustrated the seasonal activity of the main predatory insects associated with the mealybug species on Navel orange during the first year 2014/15 at Mansoura district. Vedalia beetle *R. cardinalis* and *C. carne* were recorded the highest peaks on Navel orange trees at the third week of September which represented by 42 and 39 indivi./ 100 leaves. respectively,while, *N. includens* recorded the highest peak of abundance at the last week of August 2014 and represented by 21 indivi. /100 leaves.

Data arranged in Fig. (20) evaluated the seasonal activity of the main predatory insects associated with the mealybug species on Navel orange during the second year 2015/16 at Mansoura district. *R. cardinalis* and *C. carne* were recorded the highest peaks on Navel orange trees at 9th of September which represented by 50 and 41 indivi. / 100 leaves. respectively .While, *N. includens* recorded the highest peak of abundance at 26th of August 2015 and represented by 25 indivi. / 100 leaves.

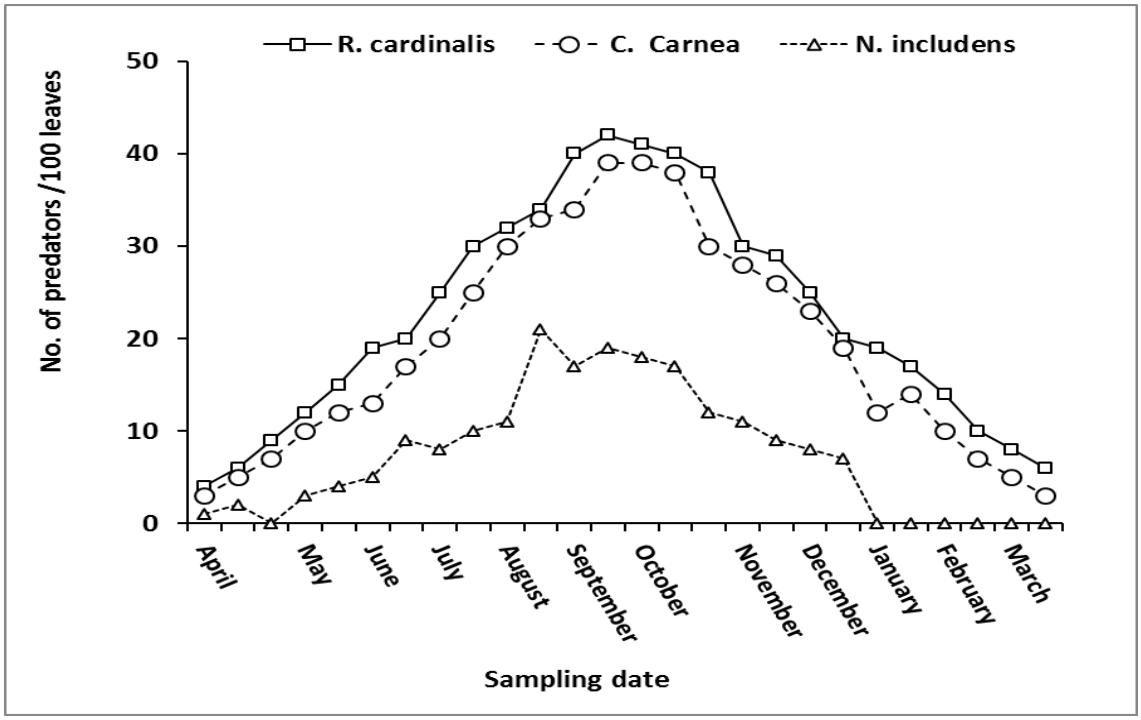


Fig.(19): Seasonal activity of the main predatory insect associated with the mealybug species on Navel orange during the first year (2014/15)at Mansoura district.

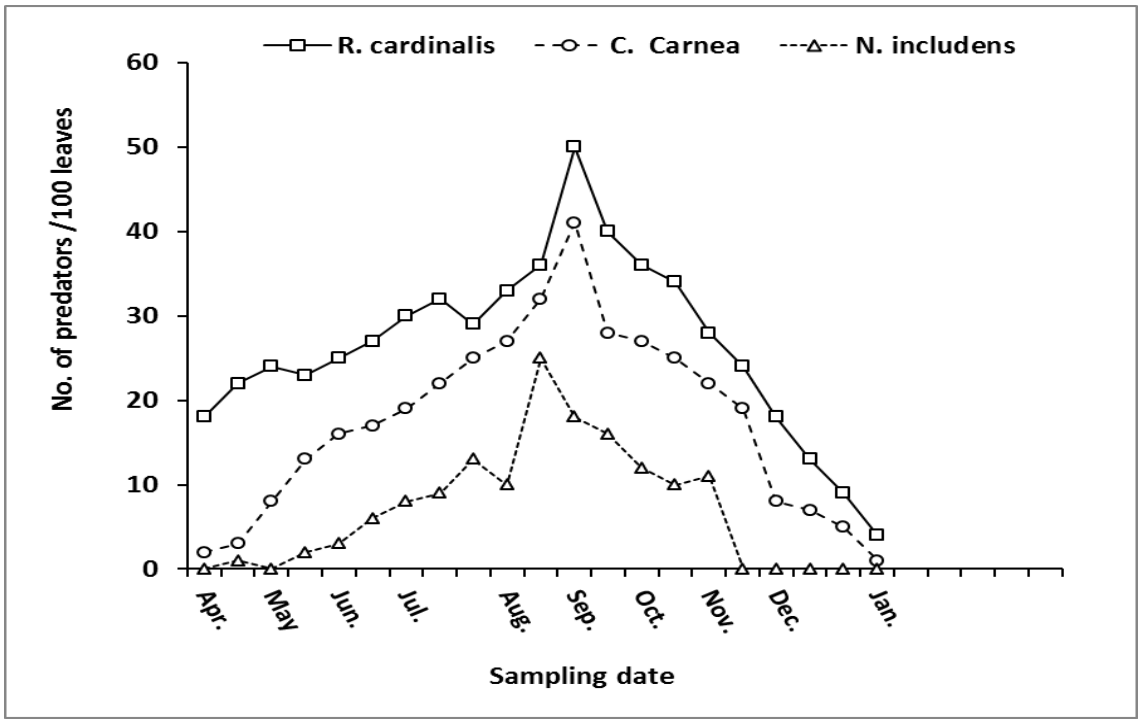


Fig.(20): Seasonal activity of the main predatory insect associated with the mealybug species on Navel orange during the second year (2015/16) at Mansoura district.

Statistical analysis of simple correlation coefficients arranged in Table (12) indicated that the relationship between *P. citri*, *I. purchasi* and *I. aegyptiaca* and their associated predators on Navel orange trees during the first year 2014/15 showed a highly positive significant effect, while, the relationship between *I. seychellarum* and its associated predators showed a positively insignificant effect during the first year 2014/15.

During the second year 2015/16, results of the statistical analysis of simple correlation coefficients illustrated in Table (12) revealed that the relationship between the different mealybug species and their associated predators on Navel orange trees during the second year 2015/16 showed a highly positive significant effect**.**

Table (12): Simple correlation coefficients between number of mealybug species and their associated predatory insects on Navel orange trees during two years (2014/15 and 2015/16) at Mansoura district.

Mealybug species	Predatory insects					
	First year 2014/15			Second year 2015/16		
	R. cardinalis	*C. carnea*	*N. includens*	*R. cardinalis*	*C. carnea*	*N. includens*
P. citri	0.896**	0.905**	0.916**	0.805**	0.763**	0.698**
I. purchase	0.895**	0.905**	0.923**	0.903**	0.937**	0.805**
I. aegyptiaca	0.883**	0.875**	0.860**	0.827**	0.844**	0.751**
I. seychellarum	0.272 ns	0.278 ns	0.277 ns	0.753**	0.761**	0.688**

Correlation is significant at the 0.01 level. **

Correlation is significant at the 0.05 level.*

ns: Correlation is insignificant .

4.1.2.5. On Succari (sweet) orange :-

Data in Fig. (21) illustrated the seasonal activity of the main predatory insects associated with the mealybug species on succari orange during the first year 2014/15 at Mansoura district. Vedalia beetle *R. cardinalis* and *N. includens* were recorded the highest peaks on succari orange trees at the third week of September which represented by 55 and 19 indivi. / 100 leaves.On the other hand, *C. carnea* recrded the highest peak of abundance at the beginning of October 2014 and represented by 48 indivi. / 100 leaves.

Data arranged in Fig. (22) evaluated the seasonal activity of the main predatory insects associated with the mealybug species on succari orange during the second year 2015/16 at Mansoura district. *R. cardinalis, C. carnea* and *N. includens* recorded the highest peaks on succari orange at 9^{th} of September 2015 and represented by 71, 54 and 22 indivi. / 100 leaves. respectively.

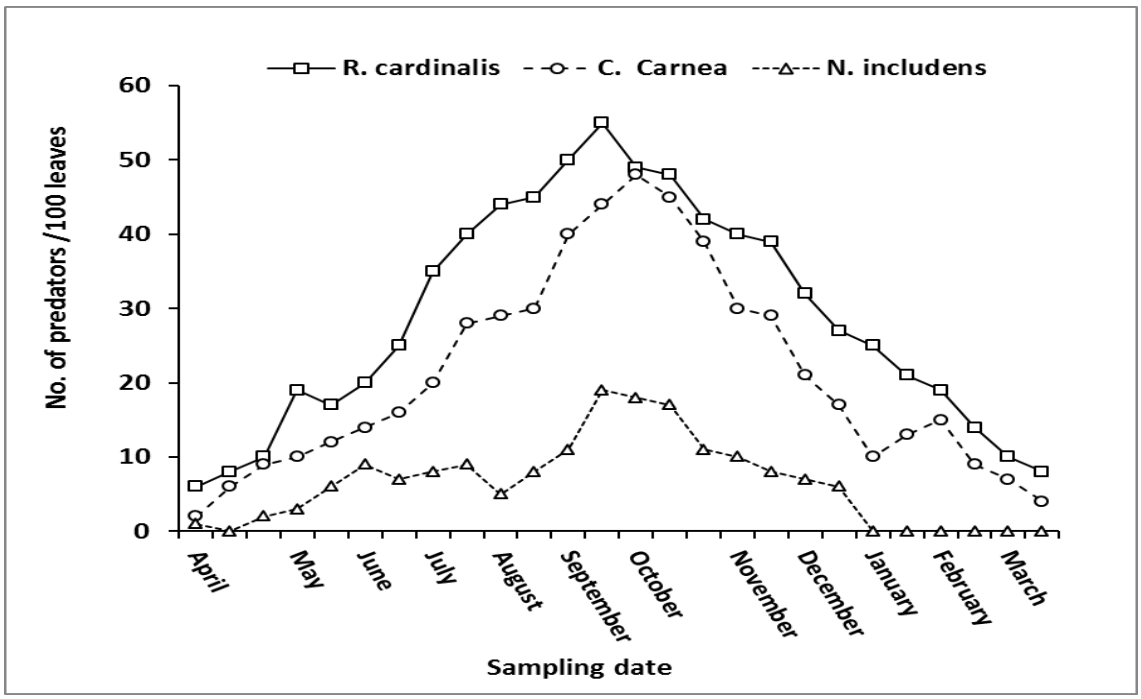
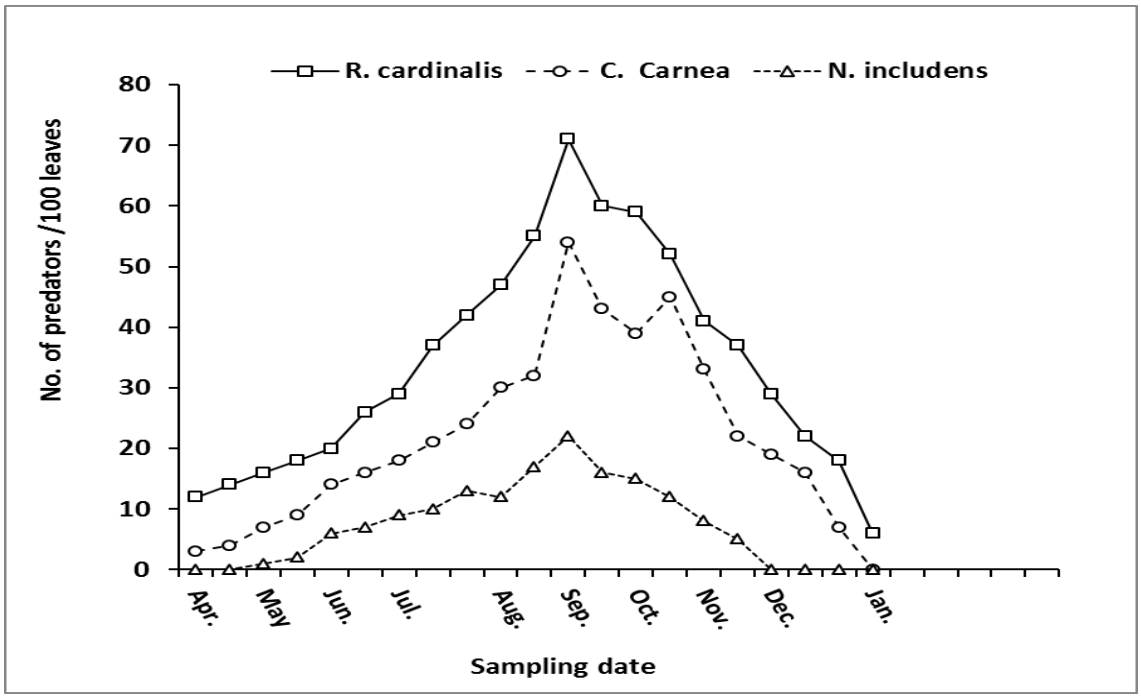


Fig.(21): Seasonal activity of the main predatory insects associated with the mealybug species on Succari (sweet) orange during the first year (2014/15) at Mansoura district.



Fig(22): Seasonal activity of the main predatory insects associated with the mealybug species on Succari (sweet) orange during the second year (2015/16) at Mansoura district.

Statistical analysis of simple correlation coefficients arranged in Table (13) indicated that , the relationship between the *P. citri*, *I. purchase* , *I. aegyptiaca* and their associated predators on succari orange during the first year 2014/15 showed a highly positive significant effects, on the other hand, *I. seychellarum* and its associated predators showed a negative or positive insignificant effect.

During the second year 2015/16, results of the statistical analysis of simple correlation coefficients illustrated in Table (13) revealed that the relationship between the *P. citri*, *I. purchase*, *I. aegyptiaca* and their associated predators on succari orange during the second year 2015/16 showed a highly positive significant effects, on the other hand, *I. seychellarum* and its associated predators showed a positive insignificant effect.

Table (13): Simple correlation coefficients between number of mealybug species and their associated predatory insects on succari orange trees during two years (2014/15 and 2015/16) at Mansoura district.

Mealybug species	Predatory insects					
	First year 2014/15			Second year 2015/16		
	R. cardinalis	*C. carnea*	*N. includens*	*R. cardinalis*	*C. carnea*	*N. includens*
P. citri	0.887**	0.890**	0.897**	0.802**	0.808**	0.850**
I. purchase	0.908**	0.900**	0.891**	0.697**	0.660**	0.818**
I. aegyptiaca	0.903**	0.899**	0.893**	0.837**	0.833**	0.751**
I. seychellarum	-0.253 ns	-0.242ns	0.015 ns	0.175 ns	0.129 ns	0.335 ns

Correlation is significant at the 0.01 level. **

Correlation is significant at the 0.05 level.*

ns: Correlation is insignificant .

The obtained results are in agreement with those of Berlinger *et al.*, (1979) who found that ***P. citri*** and its predator *C. carnea* was active in spring on citrus grove in Israel**.** Copland *et al.*, (1993) suggested that *Nephus reunion* was most active on citrus with *P. citri* in India. Khalaf (1987) recorded that the predator *R. cardinalis* proved to thea very efficient predator of *I. purchasi* and produced a generation every 19-22 days, unless prey was scarce or climatic conditions are not favourable in Iran. Ghanim *et al.*, (2013a) suggested that the maximum activity of the predatory insects *R. Cardinals* was during October and June, while, the *C. carnea* recorded during June and September and *N. includens* in September and June. Results of statistical analysis of simple correlation coefficients between the mealybug species and their associated predator on mandarin trees showed a highly positive significant effect for *R. cardinalis*, *N includens* and *C. carnea* during the two years of study in Egypt. El-Sherbenie (2004) recorded that, *R. cardinalis* had four peaks were recorded in March, July, October and November during the two years, while *C. carnea* had three peaks in May, July and October 2000. Meanwhile, in year 2001, the predators had also three peaks in July and the second week of October.in Egypt. Abdel-Mageed (2005) mentioned that, *R. cardinalis* was recorded as the main dominant insect predator on *I. seychellarum* on ficus trees but *C. carnea* was observed rearlier. *R. cardinalis* exhibited three peaks of abundance yearly in December, May-July and September-October and the highest peak of occurrence was on September-October. Awadalla (2013) mentioned that activity of *R. cardinalis* recorded in May 2011 and in June 2012, *C. carnea* recorded in November 2010 and in June 2012 and *N. includens* in November 2010 and in June 2012 during the two successive years 2010/11 and 2011/12 in Egypt.

4.2. Biological studies :-

4.2.1. Effect of different citrus species as host plants on the biological aspects of the Seychelles fluted scale *Icerya seychellarum* (Westwood).

4.2.1.1. Developmental stages:-

Data presented in Table (14) indicated that the incubation periods took the same time in all tested citrus host plants (10.5± 0.4 days) under insectary conditions of 22.4±3.1°C and 60±5% R.H. with insignificant differences.

Table (14) : Duration of the developmental stages of the Seychelles fluted scale *I. seychellarum* under fluctuated daily temperature 22.4 ±3.1°C (Range 16 : 28) and 60 ± 5 % R.H. on different citrus host plants.

Citrus host plants	Incubation period	1st instar	2nd instar	3rd instar	Total nymphal stage	Total developmental period
Mandarin	10.5±0.4 a	10.8±0.4 a	13.7±0.3 a	15.6±0.6 a	40.1±1.1 a	50.6±1.6 a
Lemon	10.5±0.4 a	10.2±0.3 b	13.5±0.2 a	14.6±0.5 b	38.3±0.8 b	48.8±1.3 b
Common balady orange	10.5±0.4 a	10.3±0.3 b	13.4±0.2 a	14.5±0.5 b	38.2±0.8 b	48.7±1.3 b
Navel orange	10.5±0.4 a	10.4±0.3 ab	13.5±0.2 a	14.8±0.5 ab	38.7±0.9 b	49.2±1.4 ab
Succari(sweet) orange	10.5±0.4 a	10.5±0.4 ab	13.6±0.3 a	14.9±0.6 ab	39±1.0 ab	49.5±1.5 ab

Means followed by the same letter in a column are not significantly different at 0.05 level of probability (Duncan's Multiple Range Test).

Data illustrated in Table (14) showed that the shortest nymphal instars for *I. seychellarum* when reared on common balady orange are represented by 10.3 ± 0.3 , 13.4 ± 0.2 and 14.5 ± 0.5 days for the 1st , 2nd and 3rd nymphal instars , respectively . While, the longest nymphal instars when *I. seychellarum* reared on mandarin and represented by 10.8 ± 0.4 , 13.7 ± 0.3 and 15.6 ± 0.6 days for the three nymphal instars , respectively .

Statistical analysis indicated that, there were a significant differences according to different citrus host plants for the three nymphal instars of *I. seychellarum*.

As a conclusion, the total developmental stages were the shortest when *I. seychellarum* reared on common balady orange followed by lemon and navel orange when represented by 48.7 ± 1.3, 48.8 ± 1.3 and 49.2±1.4 days with insignificant differences, respectively. On the other hand, the longest developmental periods were recorded on succari (sweet) orange and mandarin when represented by 49.5±1.5 and 50.6 ± 1.6 days, respectively.

The obtained data in Table (15) and Fig.(23) showed that the survival percentage of the three nymphal instars were the highest on common balady orange and represented by 89, 95.5 and 96.5 % , respectively. *I. seychellarum* when reared on lemon, the survival percentage came in the second category and represented by 86, 94.2 and 95.1 %, respectively.

Table (15) : Survival percentage for the three nymphal of the Seychelles fluted scale *I. seychellarum* on different citrus host plants under daily fluctuated temperature of 22.4 ± 3.1°C (Range 16 : 28) and 60 ± 5 % R.H.

Citrus host plants	1st instar	2nd instar	3rd Instar	Nymphal stage
Mandarin	65	90.8	94.9	56 %
Lemon	86	94.2	95.1	77 %
Common balady orange	89	95.5	96.5	82 %
Navel orange	78	92.3	94.4	68 %
Succari(sweet) orange	67	92.5	91.9	57 %

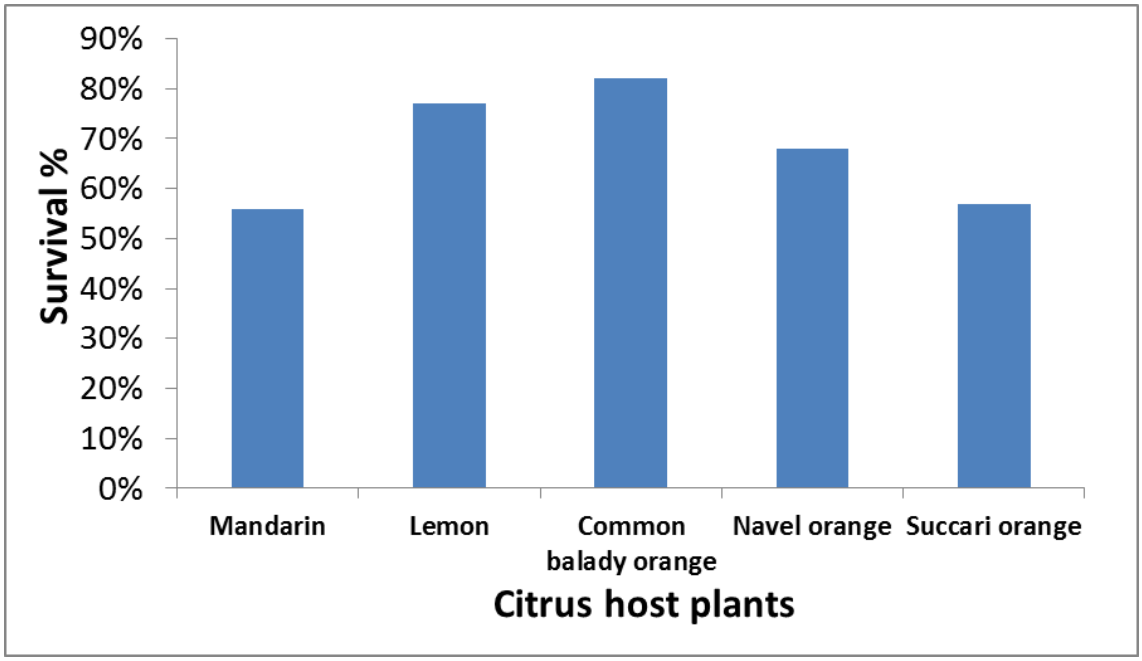


Fig (23) . Survival percentage for nymphal stage of the Seychelles fluted scale *I. seychellarum* on different citrus host plants under daily fluctuated temperature degree degree 22.4 ± 3.1°c (Range 16 : 28) and 60 ± 5 % R.H.

As a conclusion , the survival rates during the nymphal stage of *I. seychellarum* was the highest on common balady orange followed by lemon , navel orange and the lowest on succari(sweet) orange and mandarin . Based on the survival rate as an index of suitability of different citrus host plants , the suitability arranged in decreasing order was : on common balady orange (82.0 %) , lemon (77.0%) , navel orange (68.0%) , succari (sweet) orange (57.0%) , mandarin (56.0%) Fig.(23).

4.2.1.2. Adult stage:-

Data arranged in table (16) showed the ovipostional periods of *I. seychellarum* when reared an different host plants under insectary conditions of 22.4 ± 3.1°c and 60 ± 5 % R.H. . Pre-oviposition period was the shortest on lemon and common balady orange followed by succari (sweet) orange, navel orange and mandarin with insignificant differences. On the other hand, the longest oviposition period was on common balady orange (23.5 ± 1.1 days) and the shortest on mandarin (20.1 ± 0.9 days) with significant differences.

Table (16) : Ovipositional periods , adult longevity and fecundity of the Seychelles fluted scale *I. seychellarum* under fluctuated daily temperature 22.4 ± 3.1°C (Range 16 : 28) and 60 ± 5 % R.H. on different citrus host plants.

Citrus host plants	Pre – oviposition	Ovi – position	Inter – oviposition	Adult longevity	Fecundity (No. of egg laying)
Mandarin	19.1±0.8 a	20.1±0.9 b	12.2±0.2 b	51.4±1.7 b	42.4±2.1 b
Lemon	18.7±0.7 a	22.8±1.2 a	16.5±0.6 ab	58±2.1 ab	52.1±3.3 a
Common balady orange	18.7±0.7 a	23.5±1.1 a	17.2±0.6 a	59.4±2.3 a	56.2±4.1 a
Navel orange	19.2±0.7 a	22.4±1.1ab	15.9±0.4 ab	57.5±1.9 ab	44.4±1.7 ab
Succari(sweet) orange	18.9±0.7 a	22.7±1.2 a	15.7±0.4ab	57.3±1.9ab	50.4±3.1 a

Means followed by the same letter in a column are not significantly different at 0.05 level of probability (Duncan's Multiple Range Test).

In respect to adult longevity was the longest on lemon and common balady orange followed by navel orange and succari(sweet) orange, while, the shortest adult longevity was recorded on mandarin with significant differences . Moreover, the fecundity was the highest on common balady orange and lemon.

As a conclusion, the longest oviposition period, the longest adult longevity and the highest fecundity was when the adult females were reared on common balady orange (23.5 ± 1.1 , 59.4 ± 2.3 days and 56.2 ± 4.1 eggs/female) followed by lemon (22.8 ± 1.2 , 58±2.1 days and 52.1 ± 3.3 eggs/female) and the navel orange (22.4 ± 1.1 , 57.5± 1.9 days and 44.4±1.7eggs/female) , respectively . Meanwhile , the shortest oviposition period , the shortest adult longevity and the lowest fecundity were noticed when the adult females were reared on Succari(sweet) orange (22.7±1.2, 57.3±1.9days , and 50.4±3.1 eggs/ female) followed by mandarin and represented by 20.1±0.9 , 51.4 ± 1.7 days and 42.4 ± 2.1 eggs/female , respectively .

These results are in agreement with those of Valuli (1992), they found that, *I. seychellarum* on ornamental plants in the laboratory, the life span ranged between 70 and 90 days. Ibrahim (2005) who found that, *I. seychellarum* reared on persimmon trees, the adult longevity was 51.12±5.44 at 28.6 ˚C, while fecundity of female was 68.2 ± 4.26 eggs/female at 28.6˚c Abdel-Rahman *et al.*, (2006) mentioned that, *I. seychellarum* can complete its life cycle on mango trees. Awadalla *et al.*, (2015) studied the influence of different host plants on the biological characteristics of the seychellarum mealybug *I. seychellarum* and they found that ornamental palm and persimmon trees were the suitable host plants for rearing the insect, survival rates during nymphal stage, adult longevity and fecundity.

4.2.2. Behavioural responses of *C. carnea* and *R. cardinalis*) to Citrus mealybug *P. citri*.

4.2.2.1. Functional and numerical responses of *R. cardinalis*:-

The consumption of prey by adult female and male of *R. cardinalis* increased with increasing prey density of *P. citri*, reaching the maximum killing at 40 preys for both sexes. Female consumed more preys and killed more proportions than the male did with increasing prey density (Fig. 24). Logistic regression analysis showed that the slopes of the functional response curves for male of the predator not significantly differed from zero regardless of prey density ($P_1 > 0.05$), which obviously refers to type I response (Table 17). The curve for the proportion consumed by female of *R. cardinalis* showed a waving form that appeared to be a combination of decelerating (as in type II) at low prey densities, followed by accelerating (as in type III) at medium prey densities, and then followed by decelerating (as in type II) at high prey densities (*Fig. 24b*). However, the parameters of

polynomial regression analysis, that distinguishes type II (when it is negative) from type III (when it is positive), indicated a type II ($P_1 < 0.001$) (Table 17).

The Type I and II functional response coefficients showed that the female had significantly higher attack rates (a = 0.0197h^{-1}) and lower handling times (T_h = 0.3194h) than the male did (a = 0.0126 h^{-1} and T_h=1.0148h) (Table 19). Theoretically, the maximum number of *P. citri* (second and third instars) that could be consumed by a single individual of predator during 24 h (T/T_h) was 75.14 and 23.65 s or third instars of *P. citri* by female and male of predator, respectively.

Although, the number of laid eggs by female *R. cardinalis* increased with increasing prey density till prey density of 30, The efficiency of conversion of ingested food (ECIF) into for female predator decreased with increasing prey density specifically after prey density of 20 (Fig. 25 a and b). The efficiency of conversion of food into eggs (ECIF) curve by female increased at lower prey density, whereas it decreased on higher density of *P. citri*. The maximum oviposition for female predator was 9.80±2.48eggs/per day at prey density of 30s and third instars of *P. citri* and a minimum of 3.4 ± 0.49 at the lowest density of prey (10). Consumption data converted into eggs (ECIF) per female during 24 h at varying prey density of *P. citri* were fit using nonlinear (non-parametric) polynomial regression (r^2 = 0.65).

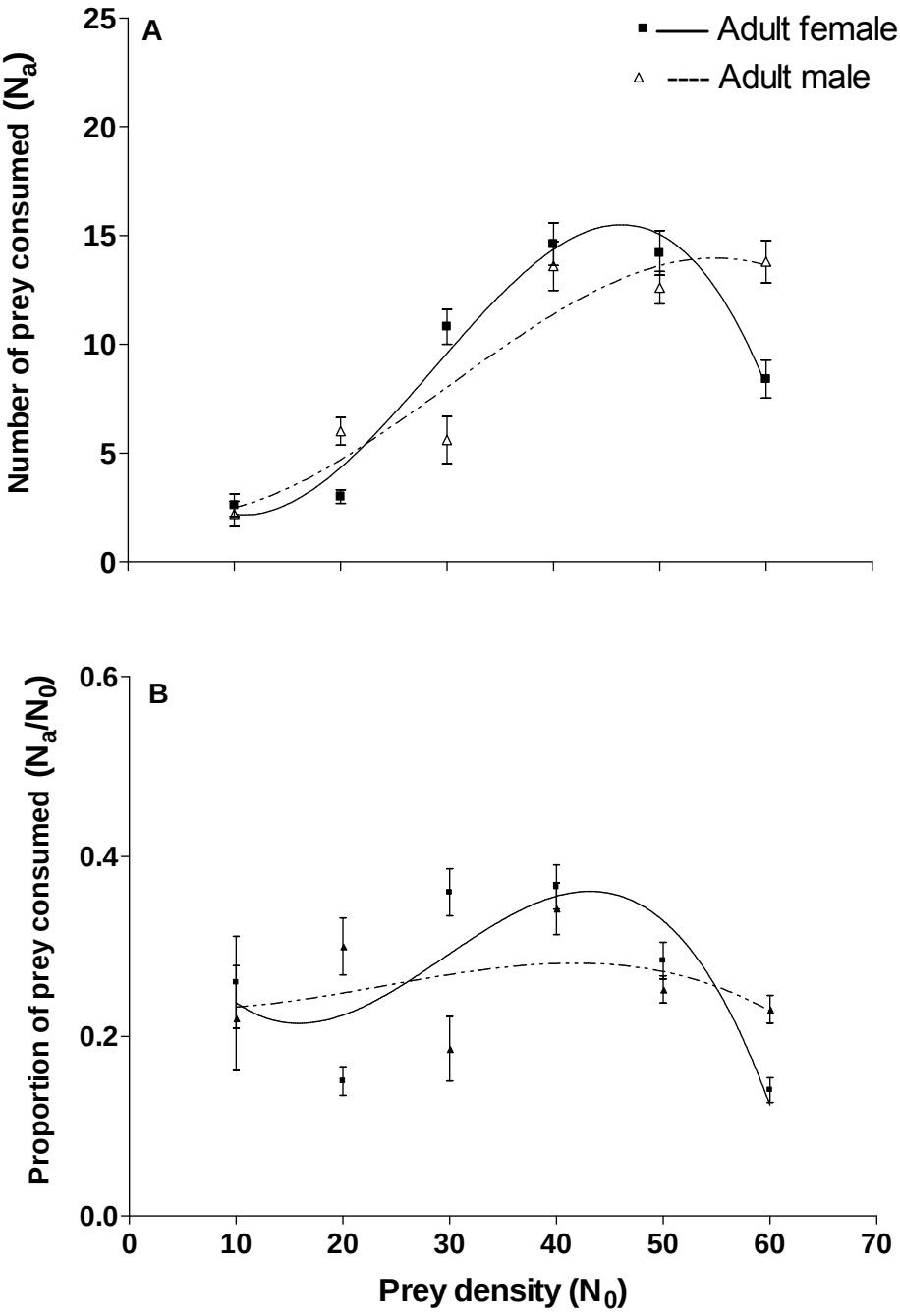


Fig. 24: Mean (±SE) number (A) and proportion (B) of *P. citri* consumed by a single predator in response to initial prey density (N_0). The solid and dashed lines represent the best-fit type III and I functional response curves for female and male of *R. cardinalis* by the logistic regression models (second and third orders, respectively) at 25 ± 1.0 °C and 16 L:8 D photoperiod for 24 h, an experimental period.

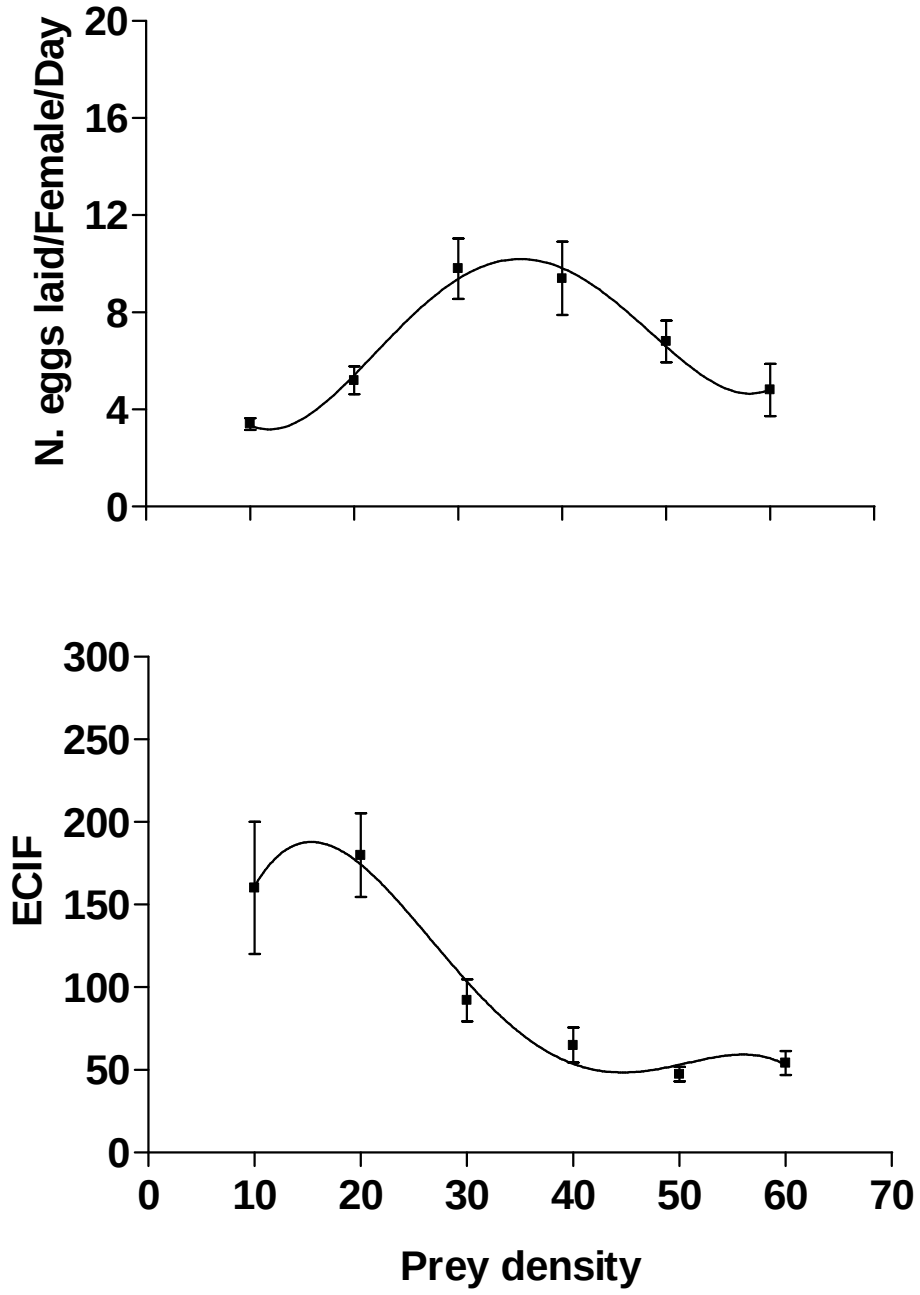


Fig. 25. Relationship between the average numbers (±SE) of eggs laid per female *R. cardinalis* per day and initial densities of *P. citri* at 25 ± 1.0 °C and 16 L:8 D photoperiod for 24 h. This relation was best fit with fourth order of nonlinear polynomial regression ($y = 13.97 – 2.185\times^{1} + 0.1413\times^{2} - 0.00312\times^{3}+0.0000221\times^{4}$, $r^2 = 0.75$). As well, this relation between the efficiency of conversion of ingested food into eggs (ECIF) and densities of *P. citri* was best fit with fourth order of nonlinear

polynomial regression ($y = -118.3 + 49.25\times^1 - 2.594\times^2 + 0.0496\times^3 - 0.000321\times^4$, $r^2 = 0.65$).

Table 17: Estimates of maximum likelihood from polynomial (logistic) regression of the proportion of third instar *P. citri* consumed by female and male of *R. cardinalis* as a function of initial prey density at 25 ± 1.0 °C and 16 L:8 D for 24 h.

Predator sex	**Parameter**	**Estimate**	**SE**	**Chi-Square (χ^2)**	***P*-value**
Female	Intercept (P_0)	-2.933	0.5325	30.34	< 0.001
	Linear (P_1)	0.1303	0.0285	20.86	< 0.001
	Quadratic (P_2)	-0.00183	0.000358	26.28	< 0.001
Male	Intercept (P_0)	-0.9353	0.9314	1.01	0.3153
	Linear (P_1)	-0.0347	0.0915	0.14	0.7044
	Quadratic (P_2)	0.00161	0.00268	0.36	0.5479
	Cubic (P_3)	-0.0002	0.000024	0.61	0.4366

* A significant positive estimate for P_1 and a significant negative estimate for the parameter P_3 indicates that the slope of the functional response curve is accelerating, thus a type III functional response confirmed, whereas A non-significant estimate for the parameter P_1 indicates that the slope of the functional response curve is constant, thus a type I functional response.

Ladybirds (Coleoptera: Coccinellidae) have a great economic impact in agro-ecosystems due to their successful employment in biocontrol programs. They have received an increasing attention over the time due to some of their abilities such as: ability to feed on wide range of preys, to rear very easily, and to have a rapid numeric response (e.g., Hodek and Honěk, 1996).

Coccinellids are one of the most important groups of predatory insects, that have immense biocontrol potential (Omkar and Pervez 2003a) with all three types of functional responses reported for the group (Hodek and Honek 1996). Attempts to evaluate the searching efficiency of *Rodolia* led to the opinion that older concepts of searching efficiency were biologically unrealistic and misleading because they were only concerned with the process of attacking prey at a patch and they ignored the process of a predator's immigration to an emigration from a prey patch. The new concept of searching efficiency evaluated a predator's response to both between and within patches (Prasad, 1985). The concept was dependent on a distinction between patches of prey that were visited (but no prey were eaten and no eggs were laid) and those that were attended (in which prey were eaten and eggs were laid). Ecologists almost find difficulties in discriminating functional response type when the curve lies between type II and III responses. Hence, a correct analysis that can right determine the functional response is highly required (Trexler et al. 1988). A logistic regression model was therefore used to determine the correctness of the curve shapes specifically when the data set of type II response shows inclination towards type III response. This can lead to drawing misleading inferences (as one exhibits negative-density dependence while the other one exhibits positive-density dependence). The functional response of a natural enemy offers a good conceptual framework for understanding the action of agents in inundative releases (Waage and Greathead, 1988). Many studies have been devoted to the foraging behaviour of insect predators (e.g., Nakamuta, 1982; Ettiffouri and Ferran, 1993), but foraging differences between the sexes have received little attention. Thus, we tested differences in the foraging responses of *R. cardinalis* sexes, to different densities of *P. citri* as prey. The logistic regression analysis showed that there was significant effect of predator's sex on the type of response for *R.*

cardinalis. Male and female predator exhibited a type I and III responses, respectively. For a type I response, there should be a stability in the proportion of consumed preys regardless of the prey density increased or decreased, so that the linear term of polynomial regression should be not significantly different from zero. For type III, the significant positive value for the linear term and the negative value for quadratic term in this study confirmed the type III response which obtained for females of this predator on *P. citri.* Usually, a Type III response does not exhibit positive density dependence throughout the range, as only a portion, *i.e.* at the initial level, shows a sigmoidal increase; later on, it also exhibits negative density dependence due to satiation. A type II functional response with a decelerating predation rate has the potential to destabilize prey- predator population dynamics due to an inverse density- dependent mortality of the prey (Hassell 1978). In contrast, the type III functional response, which incorporates density-dependent prey mortality, may stabilize the dynamics (Murdoch and Oaten 1975).

In the current study, female of *R. cardinalis* exhibited a type III functional response to second-third instars of its prey, *P. citri* with attach rate of $0.0197h^{-1}$ and handling time of 0.3194h higher than those of male. The handling time (T_h) is a good indicator of the predation rate (Athan and Guldal, 2009). According to Nordlund and Morisson (1990), the handling time affects the type of functional response, suggesting that the shorter the handling time, the faster the curve reaches the asymptote. Furthermore, handling time can influence other components, such as attack rate and searching efficiency (Beddington *et al.,* 1976). The T_h value for females was lower than for males in this study. Therefore, the maximum theoretical predation rate (T/T_h) of females was greater than for males. The values of attack estimated by both Holling model for females were also greater than for males. The greater number of prey consumed by females may be due to

the larger size of females, and also the additional energy requirement to produce eggs (Hodek and Honek 1996; Omkar and James 2004). The functional responses of female of adult *Cryptolaemus montrouzieri* to different densities of second and third instars and female adults of *P. citri* were type II, III and II respectively. The rates of searching efficiency of female ladybirds on second and third instars and female adults of prey were estimated 0.047, 0.013 and 0.097 and the rates of handling time were obtained 0.177, 0.843 and 2.974, respectively (Abdollahi et al., 2010). Prasad (1985) found that in a small searching arena (270 x 410 x 120 mm), *R. cardinalis* killed more prey, laid more eggs and spent more time at patches of higher prey densities. Further, it killed prey and laid eggs in higher proportion of patches of higher prey densities.

The shape of the reproductive response was similar to that of functional response showing that both responses are interlinked and function simultaneously (Omkar and Pervez 2004, Bayoumy and Michaud, 2012; Bayoumy et al., 2015). The prey density-dependent fecundity was also sigmoidal in *Cheilomenes lunata* Fabricus (Ofuya and Akingbohungbe 1988) and curvilinear in *Menochilus sexmaculata* (Agarwala and Bardhanroy 1997).

The trend of ECIF in this study indicated that the conversion rate of prey biomass was higher at lower densities, as it decreased at higher prey densities. In other words, if we consider the structure of the model, the No. of eggs laid at different prey density has a decelerating rate. So, number of eggs laid at low prey density multiplied by 100 is relatively higher than those at higher prey density. Therefore, we can see a decelerating trend as prey density increases. Similarly, Bayoumy and Michaud (2012) reported that the ECI of *Nephus includens* (Kirsch) (Coccinellidae, Coleoptera) decreased with increasing prey density. The decreased ECIF at higher prey densities may due to the good-fed females laying higher number of eggs

and investing much in maintenance and metabolic costs (Omkar and Pervez 2004).

4.2.2.2. Functional response of *Chrysoperla carnea:-*

The third instar predator consumed more prey and killed more proportions of *P. citri* than those killed by second instar of *C. carnea* with increasing prey density. The accelerated decline in proportion of mealybug killed by second instar was good fit the characterization of a type II functional response. Logistic regression outputs showed that the slopes of the functional response curve for second instar of the predator was declining ($P_1 < 0.05$), which refers to type II response (Table 18), whereas the proportion of mealybug killed by third instar of *C. carnea* increased with increasing prey density, justifying the decision to use nonlinear curve fitting (Fig. 26a and b). The significant positive linear and negative quadratic coefficients suggested a type III response (Table 18). Therefore, equation 3 was set in equation 2 and the two data sets were fit to a type III functional response. Outputs of nonlinear least square regression indicated that coefficients *c* and *d* were not significantly different from 0; therefore, they were deleted from the equation and the resulted equation was applied (Juliano 2001).

The type II and III functional response coefficients for second and third instars of *C. carnea* showed that there were significantly higher attack rates and lower handling times ($a = 0.029\ h^{-1}$ and $T_h = 0.233$ h, respectively) for third instar on *P. citri* than second instar *C. carnea* ($a = 0.0159 h^{-1}$ and $T_h = 0.77$h) (Table 20). Theoretically, the maximum number of *P. citri* (second and third instars) that could be consumed by a single second-and third-instar of *C. carnea* within 24 h (T/T_h) was 103.0 and 31.17, respectively.

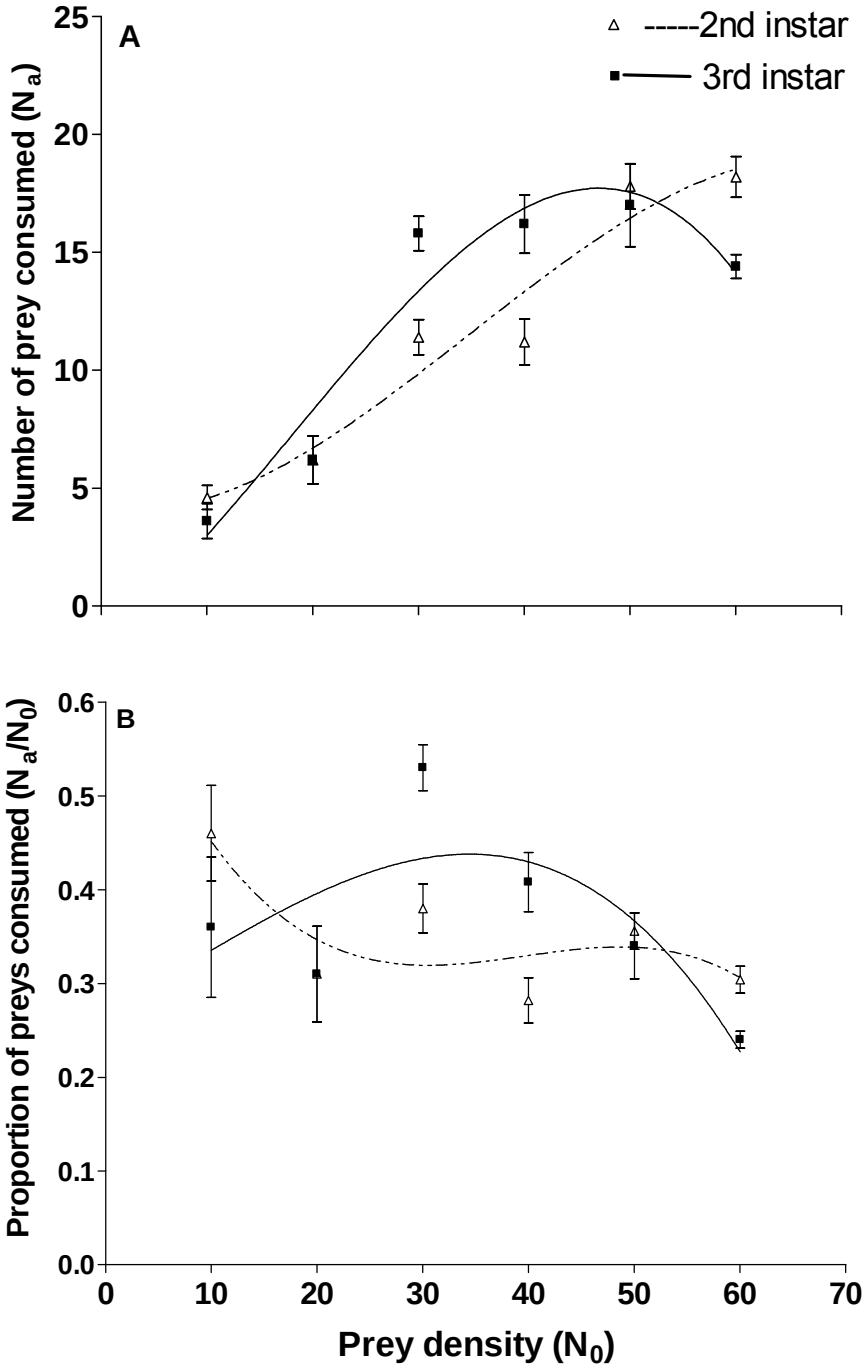


Fig. 26: Mean (±SE) number (A) and proportion (B) of *P. citri* killed by a single predator in response to initial prey density (N_0). The solid and dashed lines represent the good-fit type III and I functional response curves for second and third instars of *C.carnea* by the logistic regression models (second and third orders, respectively) at 25 ± 1.0 °C and 16 L:8 D for 24 h, an experimental period.

Table 18: Maximum likelihood estimates from polynomial (logistic) regression of the proportion of third instar *P.citri* consumed by first and second instars of *C. carnea* as a function of initial prey density at 25 ± 1.0 °C and 12 D:12 L for 24 h.

Predator instar	**Parameter**	**Estimate**	**SE**	**Chi-Square (χ^2)**	***P*-value**
2^{nd} instar	Intercept (P_0)	0.6444	0.8253	0.61	0.435
	Linear (P_1)	-0.1130	0.0825	1.88	0.171
	Quadratic (P_2)	0.00297	0.00244	1.49	0.223
	Cubic (P_3)	-0.0002	0.000022	1.30	0.254
3^{rd} instar	Intercept (P_0)	-1.558	0.435	12.83	0.0003
	Linear (P_1)	0.0859	0.0238	13.00	0.0003
	Quadratic (P_2)	-0.0013	0.0003	19.31	< 0.001

* A significant negative estimate for the parameter N_0 indicates that the slope of the functional response curve is declining, thus a type II functional response confirmed, whereas a significant positive estimate for P_1 and a significant negative estimate for the parameter P_3 indicates that the slope of the functional response curve is accelerating, thus a type III functional response confirmed, whereas A non-significant estimate for the parameter P_1 indicates that the slope of the functional response curve is constant, thus a type I functional response.

Table 19: Estimates of functional response parameters; attack rate (*a* for Type I and b for Type III)and handling time (T_h) for female (A) and male (B) of *R. cardinalis* in response to its prey, *P. citri* representing a type III and I, respectively at 25 ± 1.0 °C and 12 D:12 L for 24 h.

Parameter	Estimate		Asymptotic SE		Asymptotic 95% CI			
					Lower		Upper	
	A	B	A	B	A	B	A	B
a or b	0.0197[a]	0.0126[b]	0.007	0.00255	0.00532	0.00742	0.0340	0.0179
T_h	0.3194[B]	1.0148[A]	0.3319	0.4260	-0.3604	0.1421	0.9992	1.8876

*Means ± SE of attack rates followed by the same small letters and Means ± SE of handling times followed by the capital letters are not significantly different at 0.05 probability level.

Table 20: Estimates of functional response parameters; attack rate (*a* for Type II and b for Type III) and handling time (T_h) for second (A) and third (B) instars of *C. carnea* in response to its prey, *P. citri* representing a type II and III, respectively at 25 ± 1.0 °C and 16 D:8 L for 24 h.

Parameter	Estimate		Asymptotic SE		Asymptotic 95% CI			
					Lower		Upper	
	A	B	A	B	A	B	A	B
a or b	0.0159[b]	0.029[a]	0.0022	0.008	0.0113	0.129	0.0204	0.0444
T_h	0.77[A]	0.233[B]	0.224	0.1823	0.3077	-0.1404	1.2245	0.6065

*Means ± SE of attack rates followed by the same small letters and Means ± SE of handling times followed by the capital letters are not significantly different at 0.05 probability level.

Due to very little information about functional response of *C. carnea* specifically to mealybug populations, comparisons were made with other studies on other pests. However, most of these studies depend on unsuitable analytical methods to differentiate the three types of functional response and ignored to use the logistic regression model to determine the correctness of the curve shapes, specifically when the data set of type II response shows inclination towards type III response (Trexler et al. 1988). Besed on logistic (polynomial) analysis, third instar of C. carnea performed a type III, whereas second instar showed a type II functional response to increasing in density of citrus mealybug, *P. citri*. This implies that second and third instars are inverse-and density-dependent mortality agent, respectively. Results of the current study revealed that the third instar of *C. carnea*, have a good predation potential and probably because its larger size facilitated its increased dietary requirement for pupation resulted in more prey consumption than second instars. These results are in accordance with Scopes (1969) and Yuksel and Gocmen (1992) who reported that more aphids were consumed by third instar larvae than by second and first instars of *C. carnea*, Zheng *et al.* (1993) who reported that individual lacewing larvae provided with higher number of Mediterranean flour moth (*Anagasta kuehniella* Zeller) eggs had a significantly higher feeding potential, Atlihan *et al.* (2004) who reported that older larval instars of *C. carnea* displayed a higher rate of predation of *Hyalopterus pruni* than younger ones, Klingen *et al.* (2009) who studied the predation rate of *C. carnea* on eggs and first instar of the lepidopterous species *Mamestra brassicae* (L.) with the highest consumption for third instar, Rashid et al. (2012) found that the third instars of *C. carnea* were the most voracious feeder and consumed significantly high number of first, second and third instars nymphs of cotton mealybug, *Phenacoccus solenopsis* Tinsley as

compared to first and second instar larvae of the predator, and (Batool *et al.,* 2014) who found that larvae of *C. carnea* responded to increasing prey densities of fresh eggs of *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae) with increasing food consumption rate. The increase in feeding potential of *C. carnea* with the advancement in development stage is also agreement with the findings of Canard and Principi (1984) and Silva *et al.* (2002).

Atlihan *et al.,* (2004) studied the functional response of *C. carnea* to varying densities of *Hyalopterus prumi* (Geoffroy) and observed that the larvae responded to increasing prey densities with increasing food consumption. The behaviour of each of the three larval instars matching type II of functional response described by Holling (1959). Similarity, Hassanpour *et al.,* (2009) who studied functional response of three larval instars of *C. carnea* on adult females of *Tetranychus urticae*. The density responsiveness exhibited by all larval instars of *C. carnea* to varying prey (eggs of *S. cerealella*) densities depicts the type II functional response (Iason *et al.,* 2002; Biao *et al.,* 2008; Batool *et al.,* 2014). The predator larvae showed an increasing trend with increase in prey density, however, the instantly increase decreased at higher prey density which coincide with the findings of (Saleh *et al.,* 2010). For the type II response, consumed prey is not density dependent (i.e. the intensity of consumed prey does not increase with prey density Hassell, (1978). Abd El-Gawad *et al.* (2010) determined a type II response for *C. carnea* to *Phthorimaea operculella* Zeller. Stark and Witford, (1986) referred to similar type of functional response of *C. carnae* feeding on *Heliothis virescens* (Fabricius) eggs.

In the present study, the third instar exhibited higher rate of attack and shorter time of handling than second instar of *C. carnea*. Atlihan *et al.,* (2004) reported the attack rate of older instars of *C. carnea* increased with increasing prey density. The parameters estimated for functional response

are not accurate measurement by laboratory testing and could not be directly linked to the field conditions, because of the very low prey density or because most prey are already consumed. It is only useful in comparing the effectiveness of natural enemies (Ives *et al.*, 1993; Gitonga *et al.*, 2002; Lee and Kang, 2004). In laboratory conditions the attack rate is limited by handling time that time need to capture and adsorb one prey whereas, in field it is limited to searching behaviour. Therefore, the response of *C. carnea* may be different from its response in nature.

5

CONCLUSION

5-Conclusion

1. The main mealybug species attacking citrus trees in Mansoura district were the citrus mealybug *Planococcus citri* (Risso) , the cottony cushion scale *Icerya purchasi* Maskell, the Egyptian mealybug *Icerya aegyptiaca* (Douglas) and the Seychelles fluted scale *Icerya seychellarum* (Westwood).
2. The citrus mealybug *P. citri* recorded the highest attraction to common balady orange followed by mandarin in the first year and lemon in the second year.
3. The cottony cushion scale *I. purchasi* and the Egyptian mealybug *I. aegyptiaca* recorded the highest attraction to common balady orange followed by mandarin during two successive years.
4. The Seychelles fluted scale *I. seychellarum* recorded the highest attraction to common balady orange followed by lemon during the two years of study.
5. Succari (sweet) orange and Navel orange attracted the lowest number for the main mealybug species during two successive years.
6. The main predatory insects associated with the main mealybug species attacking citrus trees in Mansoura district were *Rodolia cardinalis* , *Chrysoperla carnea* and *Nephus includens* .
7. Vedalia beetle, *R. cardinalis* were the dominant predator and recorded the highest average number during two successive years. Meanwhile *N. includens* recorded the lowest average number during the two years of study.

8. The total developmental period was the shortest when I. seychellarum reared on Balady orange which represented by 48.7±3.7 under fluctuated temperature of 22.4 ±3.1ºc.
9. The survival rates during the nymphal stage of *I. seychellarum* were the highest on common balady orange, followed by Lemon , Navel orange and the lowest observed on Succari (sweet) orange and Mandarin .
10. Both sexes of *R. cardinalis* exhibited different types of functional response to its prey. *P. citri*. Predation rates by females were higher than those of males, resulting a type I and III, respectively. Therefore, the attack rate was higher and handling time for females was shorter than those of males.
11. Predation rates of *P. citri* with the third instar nymphs of *C. carnea* were higher than those caused by second instars with increasing prey density, representing type III and II of functional responses, respectively. Thus, third instar predators had higher attack rates and shorter times of handling a prey.
12. The functional and numerical responses of female of *R. cardinalis* are synergistic and inter-linked, in that prey consumed by the predator is directly used for egg production, resulting in maximizing field populations.
13. From the practical point of view, in biological control programs, field releases of either *R. cardinalis* with sex ratio bias females or late instars of *C. carnea* might improve the control of the pseudaucoccid, *P. citri*.

6

SUMMARY

6. Summary

The present studies were carried out in the experimental farm belonging to the Faculty of Agriculture, Mansoura University, Mansoura, Egypt to evaluate the population abundance of the citrus mealybug *Planococcus citri* (Risso) , The cottony cushion scale *Icerya purchasi* Maskell , the Egyptian mealybug *Icerya aegyptiaca* (Douglas) and The Seychelles fluted scale *Icerya seychellarum* (Westwood) on different citrus host plants as Mandarin, Lemon, Common balady orange , Washington navel orange and Succari (sweet) orange trees. Furthermore, the seasonal activity of the main associated predators with the mealybug species during the two successive years 2014/15 and 2015/16 was evaluated. As well as, Laboratory experiments were carried out to study the influence of different host plants on some biological characteristics of *I. seychellarum*. The experiments were carried out in the insectary of the Economic Entomology Department, Behavioural responses of *Chrysoperla carnea* (Chrysopidae: Neuroptera) and *Rodolia cardinalis* (Coccinellidae: Coleoptera) to Citrus mealybug, *P. citri* (Pseudaucoccidae: Hemiptera).

The obtained results could be summerized as follow:-

6.1. Ecological studies :-

6.1.1. Mealybug species :-

6.1.1.1. The citrus mealybug *Planococcus citri* (Risso)

Common balady orange attracted the highest number of *P. citri* during the two successive years 2014/15 and 2015/16 and represented by 2591 indiv. (40.08 %) and 3197 indiv. (33.68%) , respectively. while , Succari orange came in the last category and represented by 716 indiv. (11.08 %) and 1234 indiv. (13.00%), respectively.

The highest average number was recorded during summer on common balady orange which represented by 171.3±18.2 and 201.5±12.8 indiv./100 leaves during the two years , respectively.

The highest annually average number was recorded on common balady orange (99.2±11.4) followed by mandarin (44.8±4.5) , lemon (42.3±2.8), navel orange (36.0±3.6) and succari orange (27.7±2.7) with significantly differences between the citrus host plants during the first year, while, the highest annually average number was recorded on common balady orange (142.9±10.6) followed by lemon (88.2±7.0), mandarin (70.8±6.8) , navel orange (63.4±7.9) and succari orange (53.6±5.1) with significantly differences between the citrus host plants during the second year.

6.1.1.2. The cottony cushion scale *Icerya purchasi* Maskell :-

Data presented confirmed that, Common balady orange attracted the highest number of *I. purchasi* during the two successive years 2014/15 and 2015/16 and represented by 1457 indiv. (34.67 %) and 707 indiv. (32.11 %), respectively. while , Navel orange came in the last category during the first year 589 indiv. (14.02 %) and Succari orange came in the last category during the second year 344 indiv. (15.62 %) .

The highest average number was recorded during summer on common balady orange during the first year and represented by 83.0±5.2 indiv./100 leaves, while, it recorded during Autumn on common balady orange during the second year and represented by 44.1±2.0 indiv./100 leaves.

The highest annually average number was recorded on common balady orange (56.1±5.7) followed by mandarin (30.6±4.5) , lemon (27.8±2.3), succari orange (24.9±2.3) and navel orange (22.9±2.5) with significant differences between the different citrus host plants during the first year, while, the highest annually average number was recorded on common balady orange (32.4±2.3) followed by mandarin (17.7±2.1) , lemon (16.9±1.1), navel orange (15.5±1.5)

and succari orange (14.8±1.5) with significant differences between the different citrus host plants during the second year.

6.1.1.3. The Egyptian mealybug *Icerya aegyptiaca* (Douglas):-

Data presented revealed that, Common balady orange attracted the highest number of *I. aegyptiaca* during the two successive years 2014/15 and 2015/16 and represented by 778 indiv. (32.54 %) and 1049 indiv. (28.19%), respectively. while , lemon came in the last category and represented by 302 indiv. (12.63 %) and 514indiv. (13.81%), respectively.

The highest average number was recorded during autumn on common balady orange which represented by 44.3±2.3 and 63.5±3.3 indiv./100 leaves during the two years , respectively.

The highest annually average number was recorded on common balady orange (30.1±3.0) followed by mandarin (21.1±2.4) , succari orange (15.2±1.7) , navel orange (14.6±1.6) and lemon (11.5±1.9) with significant differences between the different citrus host plants during the first year, while, the highest annually average number was recorded on common balady orange (46.2±3.6) followed by mandarin (39.7±5.1) , succari orange (27.5±2.6) , navel orange (26.5±3.2) and lemon (21.9±3.2) with significant differences between the different citrus host plants during the second year.

6.1.1.4. The Seychelles fluted scale *Icerya seychellarum* (Westwood):-

Data assured that, Common balady orange attracted the highest number of *I. seychellarum* during the two successive years 2014/15 and 2015/16 and represented by 3956 indiv. (30.82%) and 4309 indiv. (24.62%)%), respectively. while , mandarin came in the last category and represented by 2076 indiv. (16.17%) and 2962indiv. (16.92%) in the two years, respectively.

The highest average number was recorded during autumn on common balady orange and represented by 198.8±8.9 and 222.5±10.8 indiv./100 leaves during the two years , respectively.

The highest annually average number was recorded on common balady orange (153.5±8.1) followed by lemon (94.6±5.3) , navel orange (88.5±4.8) , Succari orange (82.1±4.4) and mandarin (81.1±4.3) with significant differences between the different citrus host plants during the first year , while, the highest annually average number was recorded on common balady orange (200±4.2) followed by lemon (171.9±7.5) , navel orange (164.1±4.2) , Succari orange (136.2±6.7) and mandarin (131.9±10.7) with significantly difference between the different citrus host plants during the second year.

6.1.2. Predatory inseacts :-

6.1.2.1. On mandarin :-

The highest peaks on mandarin for the predators *Rodolia cardinalis* , *Chrysoperla carnea* and *Nephus includens* in the beginning of October 2014 and represented by 72 , 56 and 38 indivi. / 100 leaves. respectively. while, the highest peaks on mandarin in 9th of September 2015 for the three predators and represented by 92 , 64 and 39 indivi. / 100 leaves. respectively.

The relationship between *P. citri* and *I. aegyptiaca* and their associated predators on mandarin trees showed a highly positive significant effect. while , the relationship between *I. seychellarum* and the three predatory insects showed insignificantly positive effects during the first year 2014/15. Meanwhile, during the second year 2015/16, the relationship between *I. aegyptiaca* , *I. purchasi* and *I. seychellarum* and their associated predators on mandarin trees showed a highly positive significant effect, while , the relationship between *P. citri* and the three predatory insects showed an insignificantly positive effects.

6.1.2.2. On Lemon :-

Vedalia beetle *R. cardinalis* recorded the highest peak on lemon trees at the third week of September , *C. carne* at the first week of September and *N. includens* at the first week of August 2014 and represented by 60 , 45 and 25 indivi./100 leaves. respectively.

R. cardinalis recorded the highest peaks on lemon at 9th of September 2015 and represented by 74 indivi./100 leaves , *C. carnea* and *N. includens*. recorded at 12th of August 2015 and represented by 54 , 30 ,respectively.

The relationship between the different mealybug species and their associated predators on lemon trees during the first year 2014/15 showed a highly positive significant effects or positive significant effects, except *I. seychellarum* and *N. includens* which showed a positive insignificant effect.

the relationship between the different mealybug species and their associated predators on lemon trees during the second year 2015/16 showed a highly positive significant effects or positive significant effects except *I. seychellarum* and their associated predators which showed a positive insignificant or highly positive significant effect.

6.1.2.3. On Common balady orange :-

Vedalia beetle *R. cardinalis* and *N. includens* were recorded the highest peaks on Common balady orange trees at the third week of September **,** and represented by 199 and 61 indivi. / 100 leaves, respectively. While *C. carnea* reached the highest peak at the third week of October 2014 and represented by 82 indivi. / 100 leaves.

R. cardinalis and *N. includens* were recorded the highest peaks on Common balady orange trees at 9th of September and represented by 122 and 30 indivi. / 100 leaves, respectively. While *C. carnea* reached the highest peak at 23th of September 2015 and represented by75 indivi. / 100 leaves .

The relationship between the different mealybug species and their associated predators on Common balady orange trees during the first year 2014/15 showed a highly positive significant effects, except *I. seychellarum* and *N. includens* which showed positive significant effect.

The relationship between the different mealybug species and their associated predators on Common balady orange trees during the second year

2015/16 showed a highly positive significant effects, except *I. seychellarum* , *I. purchasi* and *N. includens* which showed positive insignificant effect.

6.1.2.4. On Navel orange :-

Vedalia beetle, *R. cardinalis* and *C. carne* were recorded the highest peaks on Navel orange trees at the third week of September which represented by 42 and 39 indivi. / 100 leaves. respectively , while , *N. includens* recorded the highest peak of abundance at the last week of August 2014 and represented by 21 indivi. / 100 leaves.

R. cardinalis and *C. carne* reach the highest peaks on Navel orange trees at the 9th of September which represented by 50 and 41 indivi. / 100 leaves. respectively. while, *N. includens* recorded the highest peak of abundance at 26th of August 2015 and represented by 25 indivi. / 100 leaves.

The relationship between *P. citri* , *I. purchasi* and *I. aegyptiaca* and their associated predators on Navel orange trees during the first year 2014/15 showed a highly positive significant effect, while , the relationship between *I. seychellarum* and its associated predators showed a positively insignificant effect, while, the relationship between the different mealybug species and their associated predators on Navel orange trees during the second year 2015/16 showed a highly positive significant effect.

6.1.2.5. On Succari (sweet) orange :-

Vedalia beetle *R. cardinalis* and *N. includens* reach the highest peaks on succari orange trees at the third week of September which represented by 55 and 19 indivi. / 100 leaves, respectively. On the other hand , *C. carnea* recrded the highest peak of abundance at the beginning of October 2014 and represented by 48 indivi. / 100 leaves.

R. cardinalis , *C. carnea* and *N. includens* reach the highest peaks on on succari orange at the 9th of September 2015 and represented by 71 , 54 and 22 indivi. / 100 leaves. respectively.

The relationship between the *P. citri* , *I. purchai* , *I. aegyptiaca* and their associated predators on succari orange during the first year 2014/15 showed a highly positive significant effects , on the other hand, *I. seychellarum* and its associated predators showed a negative or positive insignificant effect.

The relationship between the *P. citri* , *I. purchase* , *I. aegyptiaca* and their associated predators on succari orange during the second year 2015/16 showed a highly positive significant effects , on the other hand, *I. seychellarum* and its associated predators showed a positive insignificant effect.

6.2. Biological studies :-

6.2.1. Effect of different citrus species as host plants on the biological aspects of the Seychelles fluted scale *Icerya seychellarum* (Westwood).

Laboratory experiments were carried out to study the effect of different citrus species as host plants on the biological aspects of the Seychelles fluted scale *Icerya seychellarum* .The experiments were carried out in the insectary of the Economic Entomology Department, Faculty of Agriculture, Mansoura University under Fluctuated temperature degree of 22.4 ± 3.1°c .

Results represented that the total developmental period was the shortest when *I. seychellarum* reared on Balady orange which represented by 48.7±1.3 under fluctuated temperature of 22.4 ±3.1°c.

The survival rates during the nymphal stage of *I. seychellarum* were the highest on Balady orange, followed by Lemon , Navel orange and the lowest observed on Succari orange and Mandarin . According to the previous results, the index of suitability of different citrus host plants arranged in descending order are as follows : on Balady orange, Lemon, Navel orange, Succari orange and Mandarin under fluctuated temperature of 22.4 ± 3.1°c.

The oviposition period , adult longevity and the fecundity was the highest when the adult females were reared on Balady orange (23.5 ± 1.1 , 59.4 ± 2.3

days and 56.2 ± 4.1 eggs/female), respectively under fluctuated temperature of 22.4 ± 3.1°c.

6.2.2. Behavioural responses of *C. carnea* and *R. cardinalis*) to Citrus mealybug *P. citri*.

This study assessed some behavioural attributes of *Rodolia cardinalis* (Coccinellidae: Coleoptera)- and *Chrysoperla carnea* (Chrysopidae: Neuroptera) to *Planococcus citri* (Pseudaucoccidae: Hemiptera) densities by deriving functional responses for male and female of *R. cardinalis* at prey densities ranging from 10 to 60s and third-instar mealybugs per arena. The relationship between the functional and numerical responses for *R. cardinalis* females was also determined. Whereas, the functional response only of second and third instars of *C. carnea* to the same densities of *P. citri* was also evaluated. Predation rates of male and female of *R. cardinalis* were fit by type I and III functional response models respectively with parameters as follows: male (a = 0.0126 $hours^{-1}$ and T_h = 1.0148 h) and female (b = 0.0197 $hours^{-1}$ and T_h = 0.3194 h). Predation rates of second and third instars of *C. carnea* were fit by type II and III models, respectively, with the following parameters: second (a = 0.0159 $hours^{-1}$ and T_h = 0.77 h) and third (b = 0.029 $hours^{-1}$ and T_h = 0.233 h) instars. The shape of the reproductive response was similar to that of functional response for female of *R. cardinalis* showing that both responses are synergistic and function simultaneously. The trend of the conversion rate of food into prey biomass was higher at lower densities, as it decreased at higher prey densities. The lower rate at higher prey densities probably because the well-fed females laying higher number of eggs at higher prey densitie, but investing much in maintenance and metabolic costs. The parameters estimated for functional response are not accurate measurement by laboratory testing and could not be directly linked to the field conditions. In laboratory conditions the attack rate is limited by handling time, that time need to capture and adsorb one prey, whereas

in field it is limited to searching behaviour. Therefore, the response of natural enemy under laboratory conditions may be different from its response in nature. However, these studies are useful in comparing the effectiveness of natural enemies or their developmental stages.

7

REFERENCES

7. REFERENCES

Abbas, M.S.T. and Hebbeis, M.M.A. (1998). Survey of mealybugs and their natural enemies in Sultanate of oman. Egypt. J. Biol. Pest Control 8: 1-2.

Abd El-Gawad, Hany A. S. ; Atef, M. M. S. and Sayed A. A. 2010. Functional response of *Chrysoperla Carnea* (Stephens) (Neuroptera: Chrysopidae) larvae to *Phthorimaea operculella* Zeller (Lepidoptera: Gelechiidae) eggs. Aust. J. Basic & Appl. Sci., 4(8): 2182-2187.

Abdel - Aleem, R. Y. (2008): Biological studies on the mealybug *Icerya seychellarum* (Westwood) (Homoptera , Margarodidae). Fayoum J. Agric. Res.& Dev. 22 (2):120-128.

Abdelkhalek, L.; Afellah, M. and Smaili, C. (1998). Biology and biological control of *Planococcus citri* R. (Hom., Pseudococcidae) on citrus in the Loukos region of Morocco. [French]. Mededelingen - Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen, Universiteit Gent; 1998. 63(2b):483-488.

Abdel-Mageed, Sanaa A. M. (2005) Influence of certain natural enemies on some mealybug populations. M. Sc. Thesis, Fac. Agric., Mansoura Univ. pp. 140.

Abdel-Rahman, M. M . ; M. S. Salem ; Maha, I. El-Said and A. M., Abdel Ghany. (2006). Resistance of Alphonso mango cultivar to the Margarodid Mealybug *Icerya seychellarum* in relation to leaf quality and leaf secondary metabolites. Egypt. J. Agric. 84 (l) ll5-121.

Abdel-salam, A. H. ; A. A. Ghanim ; H. A. ElKady ; M. E. El-Nagar and Hagar S. S. Awadalla (2013a). Effect of different host plants on the attractiveness of the mealybug species and their associated predators at Mansoura district . J. Plant Protection and Pathology. Mansoura Univ. 4 (3) : 287-292.

Abdel-salam, A. H. ; A. A. Ghanim ; H. A. ElKady ; M. E. El-Nagar and Hagar S. S. Awadalla (2013b). Influence of different constant temperature degrees on the biological characters and predaceous efficiency of the predator *R. cardinalis* (Mulsant). J. Plant Protection and Pathology. Mansoura Univ. 4 (3) : 317-324.

Abdollahi, Ahi, Gh., Afshari1, A., Baniameri, V., Dadpour, H., Asadeh, Gh.Yazdanian, M. (2010). Functional response of fourth larval instars and female adults of *Cryptolaemus montrouzieri* Mulsant (Col.: Coccinellidae) to citrus mealybug, *Planococcus citri* (Risso) (Hom.: Pseudococcidae) in laboratory conditions". In: Proc. 19th Iranian Plant Prot. Congress. pp. 1-69

Abul-Nasr, S. S. Swailem and Dawood, M. (1975). Survey of aphids and Mealy-bugs infesting some cut flowering plants in certain regions of Egypt. Bull.Soc.Entomol-de Egypte. 59: 281-288.

Afzal, M. and Khan, M.R.,(1978). Life history and feeding behavior of green lacewing, *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae). Pakistan J. Zool., 10:98-90.

Agarwala, B.K. and Bardhanroy, P. (1997). Oviposition behavior and re-production efficiency in ladybeetles (Coccinellidae: Coleoptera). A case study of Menochilus sexmaculata (Fabricus). J. Aphidol. 11: 49–59.

Aly, A. G. (1980): Studies on palm trees insects belonging to super family Coccoidea in Egypt. Thesis , Ph. D. Fac. Agric. Al-azhar Univ. pp.188.

Arif, M. I., M. Rafiq and A. Ghaffar (2009). Host plants of cotton mealybug, (*Phenacoccus solenopsis*): a new menace to cotton agro-ecosystem of Punjab, Pakistan Int. J. Agri. Biol., 11, 163-167.

Assem, Shadia M. ; Z. K. Mohamed and A. E. Elwan, (1991). On the host range of *Icerya seychellarum* (Westwood) (Homoptera: Margarodidae). Fourth Arab congress of plant protection. Cairo, 1-5 Dec, 84-90.

Athan R. and Guldal H. (2009). Prey density-dependent feeding activity and life history of *Scymnus subvillosus* Goeze. (Coleoptera: Coccinellidae). Phytoparasitica 37: 35–41.

Atlihan, R., Kaydan, B. and Ozgokee, M.S., (2004). Feeding activity and life history characteristics of generalist predator *Chrysoperla carnea* (Neuroptera: Chrysopidae) at different prey densities. J. Pest. Sci.,77: 17-21.

Awadalla, Hagar S. S . (2013). Ecological and biological studies on certain mealybug species and their associated natural enemies at Mansoura district . Ph.D. Thesis , Fac. Agric. Mansoura Univ. pp 198.

Awadalla, Hagar S. S .(2015a). Effect of prey quality on progeny development and fitness of the coccinellia predator *Rodalia cardinalis* Mulsant . Egypt. J. Boil. pest control (in press).

Awadalla, Hagar S. S .(2015b). Influence of different stages of *Icerya seychellarum* on the developmental stages , adult longevity , fecundity and predatory potential of vedalia beetle *Rodalia cardinalis* under laboratory conditions (in press).

Awadalla, Hagar S. S. (2010): Studies on biological and life tables parameters of certain predacious insects which associated with some mealybugs. M. Sc. Thesis, Fac. Agric. , Mansoura Univ. pp. 125.

Awadalla, S. S.; H. M. Fathy; A. H. Abdel-Salam and M. A. Fahad (2015). Influence of different host plants on the biological characteristics of the Seychellarum mealybug *Icerya seychellarum* (Westwood). J. Plant Protection and Pathology. Mansoura Univ. 6 (2): 245- 254.

Awadalla. Hagar S. S, and A. A. Ghanim (2016). Population density of the main mealybug species attackin mango trees and their predatory insects in Mansoura region. J. Plant prot. and path. Mansoura Univ. 7(1): 31-41.

Bailey, Alastair ; Chandler, David ; Grant, Wyn P.; Greaves, Justin; Prince, Gillian and Tatchell, Mark (2010) Biopesticides : Pest Management and Regulation. Cambridge, MA, USA: CAB International, p 79.

Bakry, M. M. S. (2009). studies on some scale insects and mealybugs infesting Mango trees in Qena governorate.M.sc. Thesis, Fac. Agric., Minia Univ. , p181.

Batool, A.; Abdullah, K. ; Mamoon-ur-Rashid M.; Khattak M. K. and Abbas, S. S. (2014). Effect of Prey Density on Biology and Functional Response of *Chrysoperla carnea (*Stephens) (Neuroptera: Chrysopidae). Pakistan J. Zool., vol. 46(1), pp. 129-137.

Bayoumy, M. H. and Michaud, J. P. (2012). interacts with mutual interference to limit foraging efficiency in larvae of *Nephus includens* Coleoptera: Coccinellidae). Biol. Control 62, 120-126.

Bayoumy, M. H.; Abou-Elnaga, A. M. ; Ghanim, A. A. and Mashhoot, G. A. (2015). Functional and Numerical Responses of *Coccinella undecimpunctata* L. (Coleoptera: Coccinellidae), an Analytical Approach for Predator's Gender in Two aphid Feeding Systems. Egyptian J. of Bio. Pest Control, 25(2), 2015, 359.366

Beddington, J.R., Hassell M.P., Lawton J.H. (1976). The components of arthropod predation. II. The predator rate of increase. J. Anim. Ecol. 45: 165–185.

Bennett, F. D., M. J. W. Cock, and I. W. Hughes. (1985). Biological control of insect pests in Bermuda. Bulletin of Entomological Research 50: 423-436.

Berlinger, M. J.; Tzahor, J. and Golberg, A. M. (1979). Contribution to the phenology of *Chilocours bipustulatus* L(Coccinellidae)in citrus groves and the control of *Planococcus citri* (Pseudococcidae) in Iseral. Mededelingn van de Faculteit Landbouwwetenschappen Rijksuniversiteit Gent, 44: 49-54.

Biao, Z. J. ; Tao, W. ; Bao, W. J. ; Fu, H. J.; Qing, L. Y.; Sheng, Z. L. (2008). Functional response and numerical response of great spotted wood pecker Picoides major on Asian longhorned beetle *Anoplopjorag labripennis* larvae. Acta Zoologica Sinica. 54:1106-1111.

Blumberg, D., Klein, M., and Z. Mendel (1995). Response by encapsulation of four mealybug species (Homoptera:Pseudococcidae) to parasitism by *Anagyrus pesudococci*. Phytoparasitica 23, 157-163.

Bozsik, A. (2006). Susceptibility of adult *Coccinella septempunctata* (Coleoptera: Coccinellidae) to insecticides with different modes of action. Pest Manag. Sci., 62, 651-654.

Caltagirone, L. E. and R. L. Doutt. (1989). The history of the vedalia beetle importation to California and its impact on the development of biological control. Annual Review of Entomology 34: 1-16.

Canard, M. and M.M. Principi, (1984). Life histories and behavior. In Biology of Chrysopidae (M. Canard, Y. Semeriaand T. R. New (eds.). Dr W. Junk Publishers, The Hague, pp: 57-149.

Chiu, S. C.; K. C. Lo ; C. C. Chien and C. F. Chen (1985). Biological control of citrus pests in Taiwan. Taiwan Agric. Res. 19 (1): 1-8.

Copland, M. J. W.; Perera, H. A. S. and Heidari, M. (1993). Influence of host plant on the biocontrol of glasshouse mealybug. Bulletin –OILB-SROP, 16(8)44-47.

DeBach, P. (1964). Biological Control of Insect Pests and Weeds.Chapman and Hall, London.

Doutt, R.L. (1958) Vice, virtue and the vedalia. Bull. of the Entomol. Society of America 4, 119-123.

El-Kady, H. A. (2013). Host preference and chemical control of citrus mealybug, *planococcus citri* Risso (homoptera, pseudococcidae) on citrus. J. Plant Protection and Pathology. Mansoura Univ. 4 (4) : 385 – 396.

El-Said, M.I. (2006). Studies on some Eco-Physiological factors affecting resistance of five mango cultivars to the Margarodid. mealybugs, *Icerya seychellarum* (Westwood). Ph.D. Thesis, Fac. Agric., Cairo Univ., 121 pp.

El-Serafi, H. A.; Ghanim, A. A.; El-Heneidy, A. H. and El-Sherbenie, M. K.(2004). Ecological studies on certain insects infesting guava orchards and their predatory insects at Mansoura District. Egyptian J. of Biol. Pest Control 14(1):77-85.

El-sherbenie, Merfat K. G. (2004). Role of established predatory insects in suppressing the population density of injurious insects infesting guava orchards at Dakahlia Governorate. M. Sc. Thesis, Fac. Agric., Mansoura Univ. pp. 121.

Ettiffouri, M. and Ferran A. (1993). Influence of larval rearing diet on the intensive searching behaviour of *Harmonia axyridis* (Coleoptera: Coccinellidae) larvae. Entomophaga 38: 51–59.

Fahad, M. A. (2015). Ecological and biological studies on Seychellarum mealybug , *Icerya seychellarum* (Westwood) and its associated predatory insects. M. Sc. Thesis, Fac. Agric., Mansoura Univ. pp. 89.

FAO, (1997) .Report Food and Agriculture Organization. www.**fao**.org/statistics

Faust, Robert M., O. Koul, and G. Cuperus (2008). "General introduction to area wide pest management." *Areawide Pest Management theory and implementation. Cambridge, MA, USA: CAB International* 1-14.

Gautam, R.D. and A. Tesfaye, (2002). Potential of green lacewing, *Chrysoperla carnea* (Stephens) in crop pest management. New Agriculturist, 13(1/2): 147-158.

Geetha, B. and Swamiappan, M.,(1998). Improved adulterating cages for the predator, *Chrysoperla carnea*. Madras Agric. J., 85:333-334.

Gerini, V. (1977). Contribution to the knowledge of the principal insect present on citrus in Cyprus. Rivista-di-Agric.-Subtrop.-e-trop. 71(7/12): 147-159.

Ghanim A. A.; A. H. Abdel-salam; H.A. ElKady; M.E. El-Nagar and Hagar S. S. Awadalla (2013a). Ecological studies on some mealybug species attacking mandarin trees and their predatory insects at Mansoura district. J. Plant Protection and Pathology. Mansoura Univ. 4 (3): 303- 315.

Ghanim, A. A. ; A. H. Abdel-salam ; H. A. ElKady ; M. E. El-Nagar and Hagar S. S. Awadalla (2013b). Effect of different mealybug species as preys on some biological characters and predaceous efficiency of the coccinellid predator *Rodolia cardinalis* (Mulsant) (coleopteran: coccinellidae) under laboratory conditions. J. Plant Protection and Pathology. Mansoura Univ. 4 (3) : 293-301.

Ghanim, A. A.; El-Serafi, H. A. K. and Mohamed, N. E. (2006). Effect of mealybug species as preys on the developmental time, feeding capacity and fecundity of vedalia beetle, *Rodolia cardinalis* (Mulsant) (Coleoptera: Coccinellidae) under laboratory conditions. J. Agric. Sci. Mansoura Univ., 31(3): 1679-1687.

Gitonga, L. M. ; Overholt, W. A. ; Lohr, B. ; Magambo, J. K. and Mueke, J.M. (2002). Functional response of *Orius albidipennis* (Hemiptera: Anthocoridae) to *Megalurothrips sjostedti* (Thysanoptera: Thripidae). Biological Control. 24:1-6.

Grafton, E. E.; Gu, P. and Montez, G. H. (2005). Effect of temperature on development of vedalia beetle, *Rodolia cardinalis* (Mulsant). Biological control, 32: 473-478.

Hamad, B. Sh. ; Ryadh, A. Okaily ; George. S. B. Yousif ; Ahmed M. Abdullatif and Hussain . F. Alrubeai (2013). The functional response of, *Chrysoperla carnea* (Stephens) larvae on nymphal instars of Dubas bug *Ommatissus libycus* De Berg. Agricultural Research , center of I. P. M. , Ministry of sci. and Technolo. , fac.of sci. , Diyala Unvi. Iraq.

Hamed, A. R. and Hassanein, F. A. (1991). Survey of parasitoids and predators of important scale insects, mealybugs and white flies in Egypt. Egypt. J. Biol. Pest. Control, 1(2): 147-152.

Hamed, A. R. and Saad, B. (1989). Adaptation of *Rodolia cardinalis* (Mulsant) (Coleoptera: Coccinellidae) to *Icerya aegyptiaca* (Douglas) and *Icerya seychellarum* (Westwood) (Hom., Margrodidae). Proc. First Int. Conf. Econom. Entomol., 11: 33-36.

Hassanpour, M. ; Nouri-Ganbalani ,G. ; Mohaghegh J.and Enkegaard A.(2009). Functional response of different larval instars of the green lacewing, *Chrysoperla carnea* (Neuroptera: Chrysopidae), to the two-spotted spider mite, Tetranychus urticae (Acari: Tetranychidae). Journal of Food, Agriculture & Environment Vol.7 (2) : 424-428.

Hassell, M.P., (1978). The dynamics of Arthropod predator-prey system. Princeton University Press, New Jersey, pp: 248.

Hodek, I. and Honek A. (1996). Ecology of Coccinellidae. Dordrecht Boston London: Kluwer Academic, 464 pp.

Holling, C.S. (1959). Some characteristics of simple types of predation and parasitism. Can. Entomol. 9:385-398.

Iason, G. R. ; Manso, T. D. ; Sim, A. and Hartley, F. G. (2002). The functional response does not predict the local distribution of European rabbits (*Oryctolagus cuniculus*) on grass swards: experimental evidence. Functional Ecology. 16:394-402.

Ibrahim, M. M. (2005). Ecological and biological studies on persimmon (*Diospyros kaki* L.) pests and their natural enemies. Ph.D. Thesis, Fac. Agric. Mansoura Univ. pp. 154.

Ives, A. R. ; Kareiva, R. and Perry, R. (1993). Response of a predator to variation in prey density at three hierarchical scales lady beetles feeding on aphids. Ecology. 74(7):1929- 1938.

Jalali, M. A., L. Tirry and P. D. Clerq (2009). Food consumption and immature growth of *Adalia bipunctata* (Coleoptera: Coccinellidae) on a natural prey and a factitious food. Europ. J. Ento., 106, 193-198.

Juliano SA. (2001). Non-linear curve fitting: Predation and functional response curves. In: Scheiner SM and Gurevitch J, editors. *Design and analysis of ecological experiments*. 2nd edition, 178–196. New York: Chapman and Hall.

Khalaf, J. (1987). Biological control of *Icerya purchasi* in Fars. Entomol.-et-Phytopath.-Appl. 54(2):123-128.

Khan A. A. and Zakif. A. (2008). Predatory response of *Chrysoperla carnea* (Stephens) (Neuroptera:Chrysopidae) feeding on the Euonymus aphid , *Aphis fabae* solanella Theobald (Homoptera: Aphididae) in Kashmir. J. Biol. Control, 22(1): 149-154.

Klingen, I., Johansen, N.S. and Hofswang, T.,(2009). The predation of *Chrysoperla carnea*(Neuroptera: Chrysopidae) on eggs and larvae of Mamestra brassicae (Lepidoptera: Noctuidae). J. appl. Ent., 120:363-367.

Lee, J. and Kang, T. (2004). Functional response of *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) to *Aphis gossypii* Glover (Homoptera: Aphididae) in the laboratory. Biological Control. 31:306-310.

Mangoud, A. A. H. (2000). Integrated pest management of apple trees. PH.D. Thesis, Fac. Agric., Cairo Univ., 196 pp.

Matsuka, M. and Watanabe, M. (1981). Laboratory rearing of vedalia beetles *Rodolia cardinalis*. Bull. of the Faculty of Agric. Tamagawa Univ. , 20: 1-8.

Matsuka, M.; watanaba, M. and Niijima, K. (1982): longevity and oviposition of vedalia beetles on artificial diets. Eviron. Entomol. 11(4): 816-819.

McKenzie, H. L. (1967). Mealybugs of California with Taxonomy, Biology, and Control of North American Species (Homoptera: Coccoidea: Pseudococcidae), 524 pp. University of California Press, California**.**

Mesbah, H. A.; Moursi, K. S.; Mourad, A. K.; Zakzouk, E. A. and Abdel-Fattah, R. S.(2012). Ecological studies on the common white mealybug, *Icerya seychellarum* (Hemiptera: Monophlebidae) associated with Dodonia viscosa in Alexandria, Egypt. Egyptian Academic J. of Biol. Sci. s: Entomol. ; 5(3):27-31.

Ministry of Agriculture , **Citrus Research Department (2012).** Agricultural Economic Report (In Arabic)

Ministry of Agriculture and Reclaiming land (2012). Agricultural Economic Report (In Arabic)

Mohamed , Nadia E. (2013). Ecological studies on some mealybug species infesting grapevine trees and their associated predatory insects at Mansoura district. J. Plant Protection and Pathology. Mansoura Univ. 4(10): 821- 836.

Mohamed, G. H. and Goma'a, E. F. (2004). Presence of coccoid insects on Ficus nitida and the effect of three species of them on the anatomical structure of infested seedlings. Annals of Agricultural Science, Moshtohor; 42(2):807-819.

Moustafa, A. S. H. (1998). Studies on some scale insects and mealybugs infesting certain horticulture crops in newly reclaimed areas Ph. D. Thesis., Fac. Agric., Zagazig Univ. 212 pp.

Moustafa, M. (2012). Scale insects (Coccoidae: Hemiptera) infested citrus trees and their natural enemies, with a key of these pests in Egypt. Egyptian Academic J. Biol. Sci. Entomol. 5(1):1-23. Ain Shams Univ.

Muniappan, Rangaswamy ; Shepard, B. Merle ; Carner, Gerald R. and Ooi, Peter Aun-Chuan (2012) Arthropod Pests of Horticultural Crops in Tropical Asia. MA, USA: CAB International, p 76.

Murdoch, W.W. and Oaten, A.A. (1975). Predation and population stability. Advan. Ecologic. Res. 9: 1–131.

Nagrare, V. S., S. Kranthi, V. K. Biradar, N. N. Zade, V.Sangode, G. Kakde, R. M. Shukla , D. Shivare,B. M. Khadi and K. R. Kranthi (2009). Widespread infestation of the exotic mealybug species, *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcidae) on cotton in India., 99, 537-541.

Nakamuta, K. (1982). Switch over in searching behavior of *Coccinella septempunctata* (L.) (Coleoptera: Coccinellidae) caused by prey consumption. Appl. Entomol. Zool. 17: 501–506.

Nordlund, D. A. and Morrison, R.K. (1990). Handling time, prey preference, and functional response for *Chrysoperla rufilabris* in the laboratory. Entomol. Experimental. Applicat. 57: 237–242.

Ofuya, T. I. and Akingbohungbe, A.E. (1988). Functional and numerical responses of *Cheilomenes lunata* (Fabricus) (Coleoptera: Coccinellidae) feeding on cowpea aphid, Aphis craccivora (Koch) (Hemiptera: Aphididae). Insect Sci. Applicat. 9: 543–546.

Omkar, James B.E. (2004). Influence of prey species on immature survival, development, predation and reproduction of *Coccinella transversalis* (Fabricus) (Coleoptera: Coccinellidae). J. Appl. Entomol. 128: 150–157.

Omkar, Pervez A. (2003a). Ecology and biocontrol potential of a scale predator, Chilocorus nigritus. Biocontrol Science and Technology 13: 379–390.

Omkar, Pervez A. (2004). Functional and numerical responses of *Propylea dissecta* (Mulsant) (Coleoptera: Coccinellidae). J. Appl. Entomol. 128: 140–146.

Ozkan A.; Aktepe, S. A.; Turkyilmaz N.; Zeren, G.; Kumas, F.; Tuncer, E. and Damdere, H. (1991). Insect pests of citrus. Neranciye Arastirma Enstitusu Mudurlugu 15. pp. 129.

Prasad ,Y. K. (1985). The searching efficiency of *Rodolia cardinalis* (Mulsant) (Coleoptera: coccinellidae), and its response to prey pathes. S.B. Sc. (Zoology Honours), M. Sc. (I.A.R.I., NEW DELHI) pp145.

Prasad, Y. K. (1989). The role of natural enemies in controlling *Icerya purchasi* in South Australia. Entomophaga 34: 391-395.

Ramadan, Marwa M. E. (2011). Ecological studies on certain insect pests attacking ornamental plants and their insect predators in Mansoura District. M.Sc. Thesis, Fac. Agric. Mansoura Univ. pp 206.

Rashid, M.M., Khattak, M.K., Abdullah, K., Amir,M., Tariq, M. and Nawaz, S., (2012). Feeding potential of *Chrysoperla carnea* and *Cryptolaemus montrouzieri* on cotton mealybug, *Phenacoccus solenopsis.* J. Anim. Pl. Sci., 22: 639-643.

Rocca, M.; Greco, N. M.; Mareggiani, G. S (2009). Abundance of *Icerya purchasi* (Hemiptera: Margarodidae) and its parasitoid *Cryptochaetum iceryae* (Diptera: Cryptochaetidae) in Argentina blueberry crops. Envir. Entomol. ; 2009. 38(2):380-386.

Rogers. D (1972). Random search and insect population methods. J. Anim. Ecol. 41, 369-383.

Saad. A. G. A. (1980): Studies on palm trees insects belonging to Superfamily Coccoidea in Egypt. Ph.D. Diss., Fac. Agric., Al-Azhar Univ. Egypt, 188 pp.

Saleh, A. ; Ghabeish, I. ; Al-Zyoud, F.; Ateyyat, M. and Swais, M. (2010). Functional response of the predator *Hippodamia variegata* (Goeze) (Coleoptera: Coccinellidae) feeding on the aphid *Brachycaudus helichrysi* (Kaltenbach) infesting chrysanthemum in the Laboratory. Jordan Journal of Biological Sciences. 3:17-20.

Salisbury, A. and Booth, R. G. (2004). *Rodolia cardinalis* (Mulsant), the vedalia ladybird (Coleopetra: Coccinellidae) feeding on *Icerya purchasi* Maskell, cottony cushion scale (Margerodidae: Homoptera) in London gardens. British J. of Entomol. and Natural History, 17(2): 103-104.

Saljoqi, A.-Ur-Rahman, M. Nasir, Javed Khan, Ehsan-ul-Haq, Saminathan, Bashir Ahmad, Hayat Zada, Sadur-Rehman(2015). Functional response study of *Cryptolaemus Montrouzieri* Mulsant (Coleoptera: Coccinellidae) fed on Cotton mealy bug, *Phenacoccus Solenopsis* Tinsley under Laboratory Conditions. J. of Entomo.and Zoology Studies 3(3): 411-415.

Saminathan, V.R., R.K. Baskaran and N.R. Mahadeva, (1999). Biology and predatory potential of green lacewing (*Chrysoperla carnea*) (Neuroptera: Chrysopidae) on different insect host. Indian J. Agri. Sci., 69(7):502-505.

SAS Institute Inc., (2000). SAS On-line Docs, Version S. SAS Institute Inc., Carey, NC.

Sayed, A. M. M. (2008). Studies on the mealybugs infesting some fruits trees and its natural enemies. Ph.D. Thesis, Fac. of Agric., Al-Azhar Univ., Egypt, 312 pp.

Scopes, N. E. A. (1969). The potential of *Chrysoperla carnea* as a biological control agent of Myzus persicae on glasshouse chrysanthemums. Ann.Appl. Biol., 64, 433-439.

Siddpapaji, C.; Puttaraju, T. B. and Venkatagiriyappa, S. (1984). *Icerya aegyptiaca* (Douglas) a new pest of mulberry (*Morus alba* Linn.) in India and its control. Current Science, India, 53 (24): 1298-1299.

Silva, G. A., C. F. Carvalho and B. Souza (2002). Biological aspects of *Chrysoperla externa* (Hagen, 1861) (Neuroptera: Chrysopidae) fed on *Alabama argillacea* (Hubner, 1818) (Lepidoptera: Noctuidae) larvae. Cienc.Agrotecnol., 26, 682–698.

Soares, A. O.; Elias, R. B. and Schanderl, H. (1999). Population dynamics of *Icerya purchasi* Maskell (Hom.; Margarodidae) and *Rodolia cardinalis* Mulsant (Col.; Coccinellidae) in two citrus orchards of Sao Miguel island (azores). Bolletin de Sanidad Vegetal, Plagas, 25(4): 459-467.

Solomn, M. E. (1949). The natural control of animal population. J. Anim. Ecol. 18, 1-35.

Stark, S.B. and F. Witford, (1987). Functional response of *Chrysopa carnea* (Neuroptera: Chrysopidae) larvae feeding on *Heliothis virescens* (Lep. : Noctuidae) eggs on cotton in field cages. Entomophaga, 32(5):521-527.

Tauber, M.J., C.A. Tauber; K.M. Daane and K.S. Hagen, (2000). Commercialization of predators: recent lessons from green lacewings (Neuroptera: Chrysopidae: *Chrysoperla*). Am. Entomol., 46: 26-38.

Tawfik, M. H.a Mohammad, Z. K. (2001). Ecological studies of two scale insects (Hemiptera, Coccoidea) on Morus alba in Egypt. Proc. Issis Ix Internat. Symp. On scale insect studies. *Agraria Bachicoltura*. 33(3):267-273.

Timms, J. E., Oliver, T. H., Straw, N. A. and Leather, S. R. (2008). The effects of host plant on the coccinellid functional response: Is the conifer specialist *Aphidecta obliterate*(L.) better adapted to spruce than the generalist *Adalia bipunctata*(L.) (Coleoptera: Coccinellidae)? Biol. Control 47, 273 281.

Trexler, J.C.; McCulloch, C. E. and Travis J. (1988). How can the functional response best be determined? Oecology 76: 206–214.

Valuli K. (1992): Mealybug and scale insects of ornamental plants and their control. M.Sc. thesis, kasetsart Univ. Bangkok , Thailand.(Ct. from Abdel – Aleem 2008).

Waage, J. K. and Greathead D.J. (1988). Biological control: challenges and opportunities . Phil. Transact. Royal Soci. London B 318: 111–128.

Williams, D. J. and Watson, G. W. (1988). The Scale Insects of the Tropical South Pacific Region. Part 2. The Mealybugs (Pseudococcidae), 257 pp. CAB International, Wallingford.

Williams, F.M. and S.A. Juliano, (1996). Functional responses revised. Environ. Entomol., 25: 549-550.

Yuksel, S. and Gocmen H. (1992). The effectiveness of *Chrysoperla carnea* (Stephens) (Neuroptera:Chrysopidae) as a predator on cotton aphid Aphis *gossypii Glov*. (Homoptera: Aphididae).Proc. the Sec. Turk. National Cong. Entomol. Pp 209-216.

Zheng, Y., Daane, K., Hagen, M. K. S. and Mittler,T.E., (1993). Influence of larval food consumption on the fecundity of lacewing *Chrysoperla carnea*. Ent. Exp.Appl., 67: 9-14.

8

ARABIC SUMMARY

جامعة المنصورة
كلية الزراعة
قسم الحشرات الإقتصادية

أنواع البق الدقيقي التي تهاجم أشجار الموالح والمفترسات الحشرية المرتبطة بها في منطقة المنصورة

رسالة مقدمة من

مصطفى عباس جبر الجبوري

بكالوريوس في العلوم الزراعية (وقاية النبات)- جامعة كربلاء ٢٠١٢

كجزء من المتطلبات للحصول على درجة الماجستير في العلوم الزراعية
(حشرات اقتصادية)

تحت إشراف

الأستاذ الدكتور

لبيب محمود شنب

أستاذ الحشرات الاقتصادية
كلية الزراعة- جامعة المنصورة

الأستاذ الدكتور

سمير صالح عوض الله

أستاذ الحشرات الاقتصادية
كلية الزراعة- جامعة المنصورة

الدكتور

محمد حسن بيومي

أستاذ الحشرات الاقتصادية المساعد
كلية الزراعة- جامعة المنصورة

٢٠١٦

Mansoura University
Faculty of Agriculture
Economic Entomology Department

SUPERVISION

Title of Thesis:

Mealybug species attacking citrus trees and their associated predatory insects at Mansoura district

The Researcher:

MUSTAFA ABBAS JEBUR ALJBOURI

The thesis is supervised by:

No	Name	Position	Signature
1	*Prof. Dr. Labib M. Shanab*	Professor of Economic Entomology, Economic Entomology Department, Faculty of Agriculture, Mansoura University.	
2	*Prof. Dr. Samir S. Awadalla*	Professor of Economic Entomology, Economic Entomology Department, Faculty of Agriculture, Mansoura University.	
3	*Dr. Mohamed H. Bayoumy*	Associate Professor of Economic Entomology, Faculty of Agriculture, Mansoura University	

Head of Dept. **Vice Dean of Higher Studies and Research affairs** **Dean**

Prof. Dr. ***Prof. Dr.*** ***Prof. Dr.***
Hala A. EL-Serafi **Yasser M. N. Shabana** **Yasser M. S. EL-Hadid**

APPROVAL SHEET

Title of Thesis:

Mealybug species attacking citrus trees and their associated predatory insects at Mansoura district

The Researcher:

MUSTAFA ABBAS ALJBOURI

The thesis is supervised by:

No	Name	Position
1	*Prof. Dr. Labib M. Shanab*	Professor of Economic Entomology, Economic Entomology Department, Faculty of Agriculture, Mansoura University.
2	*Prof. Dr. Samir S. Awadalla*	Professor of Economic Entomology, Economic Entomology Department, Faculty of Agriculture, Mansoura University.
3	*Dr. Mohamed H. Bayoumy*	Associate Professor of Economic Entomology, Faculty of Agriculture, Mansoura University

Approval Committee:

No	Name	Position	Signature
1	*Prof. Dr. MOHAMED BAHGAT SHAWER*	Professor of Economic Entomology, Economic Entomology Department, Faculty of Agriculture, Kafr El-sheikh University.	
2	*Prof. Dr. Abdel – Badie A. Ghanim*	Professor of Economic Entomology, Economic Entomology Department, Faculty of Agriculture, Mansoura University.	
3	*Prof. Dr. Labib M. Shanab*	Professor of Economic Entomology, Economic Entomology Department, Faculty of Agriculture, Mansoura University.	
4	*Prof. Dr. Samir S. Awadalla*	Professor of Economic Entomology, Economic Entomology Department, Faculty of Agriculture, Mansoura University.	
5	*Dr. Mohamed H. Bayoumy*	Associate Professor of Economic Entomology, Faculty of Agriculture, Mansoura University	

Head of Dept. **Vice Dean of Higher Studies and Research affairs** **Dean**

Prof. Dr. ***Prof. Dr.*** ***Prof. Dr.***

إقرار حداثـة

أقر أنا الباحث/ مصطفى عباس جبر الجبوري المسجل لدرجة الماجستير بقسم الحشرات الاقتصادية - كلية الزراعة - جامعة المنصورة بأن الموضوع المتعلق برسالة الماجستير المقدمة تحت عنوان: (أنواع البق الدقيقي التي تهاجم أشجار الموالح والمفترسات الحشرية المرتبطة بها في منطقة المنصورة).

موضوع حديث وغير منقول من أي جهة أخرى.

لجنة الإشراف:

م	الاسم	الوظيفة
١	أ.د./لبيب محمودشنب	أستاذ الحشرات الاقتصادية - كلية الزراعة - جامعة المنصورة
٢	أ.د./سمير صالح عوض الله	أستاذ الحشرات الاقتصادية - كلية الزراعة - جامعة المنصورة
٣	د. /محمد حسن بيومي	أستاذ مساعد بقسم الحشرات الاقتصادية - كلية الزراعة - جامعة المنصورة

اسم الباحث: مصطفى عباس جبر الجبوري

التوقيـــــع:

قسم الحشرات الاقتصادية- كلية الزراعة – جامعة المنصورة

الملخص العربي

أجريت الدراسات الأيكولوجيه بالمزرعة البحثية التابعه لكليه الزراعة – جامعه المنصورة ، جمهورية مصر العربية ، وذلك لحصر و تقدير الوفرة العدديه لبق الموالح الدقيقي *Planococcus citri* (Risso)، البق الدقيقي الاسترالي *Icerya purchasi* Maskell، البق الدقيقي المصري *Icerya aegyptiaca* (Douglas) و البق الدقيقي السيشلارم *Icerya seychellarum* (Westwood) على مختلف عوائل الموالح النباتية ومنها أشجار اليوسفي ، الليمون، البرتقال البلدي، البرتقال ابو صرة و أشجار البرتقال السكري. وايضا لحصر وتقدير النشاط الموسمي للمفترسات الحشرية الرئيسية المرتبطة مع أنواع البق الدقيقي خلال سنتين متتاليتين 2015/2014 و 2016/2015 .

كذلك أجريت التجارب المعملية لدراسة تأثير أصناف مختلفة من الموالح كعوائل نباتية على الصفات البيولوجية لبق السيشلارم الدقيقي *I. seychellarum* ، التجارب أجريت بمعمل الحشرات في قسم الحشرات الاقتصادية ، كلية الزراعة – جامعة المنصورة تحت درجات حرارة متغيرة 22.4±3.1°م. والاستجابة السلوكية من أسد المن *Chrysoperla carnea* (Chrysopidae: Neuroptera) وابو العيد *Rodolia cardinalis* (Coccinellidae: Coleoptera) لبق الموالح الدقيقي (*P. citri* (Pseudaucoccidae: Hemiptera .

النتائج المتحصل عليها يمكن تلخيصها بالتالى :-

أولاً: الدراسات ألأيكولوجية :-

1- بق الموالح الدقيقي *P. citri* (Risso) **:-**

جذب البرتقال البلدي اعلى تعداد من بق الموالح الدقيقي *P. citri* خلال سنتين متتاليتين 2015/2014 و 2016/2015 وتمثل ب 2591 فرد (40.08%) و 3197 فرد (33.68%) ، على التوالي. بينما، البرتقال السكري جاء فى المرتبة الأخيرة وتمثل ب 716 فرد (11.08%) و 1234 فرد (13.00%)، على التوالي.

سجلت النتائج ان أعلى متوسط تعداد كان خلال الصيف على البرتقال البلدي والذي تمثل ب 171.3±18.2 و 201.5±12.8 فرد لكل 100 ورقة خلال سنتين متتاليتين.

سجل أعلى متوسط تعداد سنوي على البرتقال البلدي (99.2±11.4) يليه اليوسفي (44.8±4.5)، ثم الليمون (42.3±2.8)،البرتقال ابو صرة (36.0±3.6) والبرتقال السكري (27.7±2.7) مع وجود فروق عالية المعنوية بين عوائل الموالح النباتية خلال السنة الاولى. بينما ، أعلى متوسط تعداد سنوي سجل على البرتقال البلدي (142.9±10.6) يليه الليمون (88.2±7.0)،ثم اليوسفي (70.8±6.8)، البرتقال ابو صرة (36.4±7.9) والبرتقال السكري (53.6±5.1) مع وجود فروق عالية المعنوية بين عوائل الموالح النباتية خلال السنة الثانية.

2- البق الدقيقي الاسترالي *I. purchasi* :-

بينت النتائج ان البرتقال البلدي جذب اعلى تعداد من البق الدقيقي الاسترالي *I. purchasi* خلال سنتين متتاليتين 2015/2014 و 2016/2015 وتمثل ب 1457 فرد (34.67%) و 707 فرد (32.11%) ، على التوالي. بينما، البرتقال ابو صرة جاء فى المرتبة الأخيرة خلال السنة الاولى 589 فرد (14.02%) و البرتقال السكري جاء فى المرتبة الأخيرة خلال السنة الثانية 344 فرد (15.62%)، على التوالي.

سجلت النتائج ان أعلى متوسط تعداد كان خلال الصيف على البرتقال البلدي خلال السنة الاولى والذي تمثل ب 83.0±5.2 فرد لكل 100 ورقة ، بينما سجل خلال الخريف على البرتقال البلدي خلال السنة الثانية وتمثل ب 44.1±2.0 فرد لكل 100 ورقة.

سجل أعلى متوسط تعداد سنوي على البرتقال البلدي (56.1±5.7) يليه اليوسفي (30.6±4.5)، الليمون (27.8±2.3)، البرتقال السكري (24.9±2.3) و البرتقال ابو صرة (22.9±2.5) مع وجود فروق عالية المعنوية بين عوائل الموالح النباتية خلال السنة الاولى. بينما ، أعلى متوسط تعداد سنوي سجل على البرتقال البلدي (32.4±2.3) يليه اليوسفي (17.7±2.1)،ثم الليمون (16.9±1.1)، البرتقال ابو صرة (15.5±1.5) والبرتقال السكري (14.8±1.5) مع وجود فروق عالية المعنوية بين عوائل الموالح النباتية خلال السنة الثانية.

3- البق الدقيقي المصري *I. aegyptiaca* :-

أوضحت النتائج ان البرتقال البلدي جذب اعلى تعداد من البق الدقيقي المصري *I. aegyptiaca* خلال سنتين متتاليتين 2015/2014 و 2016/2015 وتمثل ب 778 فرد (32.54%) و 1049 فرد (28.19%) ، على التوالي. بينما، الليمون جاء فى المرتبة الأخيرة وتمثل ب 302 فرد (12.63%) و 514 فرد (13.81%)، على التوالي.

سجلت النتائج ان أعلى متوسط تعداد كان خلال الخريف على البرتقال البلدي والذي تمثل ب 44.3±2.3 و 63.5±3.3 فرد لكل 100 ورقة خلال سنتين الدراسة على التوالي.

سجل أعلى متوسط تعداد سنوي على البرتقال البلدي (30.1±3.0) يليه اليوسفي (21.1±2.4) ، ثم البرتقال السكري (15.2±1.7)، البرتقال ابو صرة (14.6±1.6) و الليمون (11.5±1.9) مع وجود فروق عالية المعنوية بين عوائل الموالح النباتية خلال السنة الاولى. بينما ، أعلى متوسط تعداد سنوي سجل على البرتقال البلدي (46.2±3.6) يليه اليوسفي (39.7±5.1)،ثم البرتقال السكري (27.5±2.6) ، البرتقال ابو صرة (26.5±3.2) و الليمون (21.9±3.2) مع وجود فروق عالية المعنوية بين عوائل الموالح النباتية خلال السنة الثانية.

4- البق الدقيقي السيشلارم *I.seychellarum*:-

أوضحت النتائج ان البرتقال البلدي جذب اعلى تعداد من البق الدقيقي السيشلارم *I.seychellarum* خلال سنتين متتاليتين 2015/2014 و 2016/2015 وتمثل ب 3956 فرد (30.82%) و 4309 فرد (24.62%) ، على التوالي. بينما، اليوسفي جاء فى المرتبة الأخيرة وتمثل ب 2076 فرد (16.17%) و 2962 فرد (16.92%)، على التوالي.

سجلت النتائج ان أعلى متوسط تعداد كان خلال الخريف على البرتقال البلدي والذي تمثل ب 198.8±8.9 و 222.5±10.8 فرد لكل 100 ورقة خلال السنتين على التوالي.

سجل أعلى متوسط تعداد سنوي على البرتقال البلدي (153.5±8.1) يليه الليمون (94.6±5.3) ، ثم البرتقال ابو صرة (88.5±4.8) ، البرتقال السكري (82.1±4.4) و اليوسفي (81.1±4.3) مع وجود فروق عالية المعنوية بين عوائل الموالح النباتية خلال السنة الاولى. بينما ، أعلى متوسط تعداد سنوي سجل على البرتقال البلدي (200±4.2) يليه الليمون (171.9±7.5) ،ثم البرتقال ابو صرة (164.1±4.2) ، البرتقال السكري (136.2±6.7) و اليوسفي (131.9±10.7) مع وجود فروق عالية المعنوية بين عوائل الموالح النباتية خلال السنة الثانية.

5- المفترسات الحشرية :-

أ- على اليوسفي :-

سجلت النتائج أعلى ذروة تعداد على اليوسفي للمفترسات ابو العيد فيداليا *R. cardinalis* ، أسد المن *C. carnea* و أبو العيد *Nephus includens* في بداية أكتوبر 2014 وتمثل ب 72، 56، و 38

فرد لكل 100 ورقة على التوالي. بينما سجلت أعلى ذروة تعداد على اليوسفي للمفترسات الثلاثة في 9 سبتمبر 2015 وتمثل ب 92، 64 و 39 فرد لكل 100 ورقة على التوالي.

كما أظهرت نتائج التحليل الإحصائى لمعامل الإرتباط بين بق الموالح الدقيقي *P. citri* و البق الدقيقي المصري *I. aegyptiaca* والمفترسات الحشرية المرتبطة بهما على أشجار اليوسفي وجود أرتباط موجب عالى المعنوية. في حين العلاقة بين البق الدقيقي السيشلارم *I. seychellarum* والمفترسات الحشرية الثلاثة المرتبطة بها أظهر عدم وجود أرتباط موجب غير معنوي. خلال السنة الأولى 15/2014. أما خلال السنة الثانية 16/2015 أظهر نتائج التحليل الإحصائى لمعامل الإرتباط بين البق الدقيقي المصري *I. aegyptiaca* ، البق الدقيقي الاسترالي *I. purchasi* و البق الدقيقي السيشلارم *I. seychellarum* والمفترسات الحشرية المرتبطة بها على أشجار اليوسفي وجود أرتباط موجب عالى المعنوية، بينما العلاقة بين بق الموالح الدقيقي *P. citri* والمفترسات الحشرية الثلاثة المرتبطة بها أظهر عدم وجود أرتباط موجب غير معنوي.

ب- <u>على الليمون :-</u>

سجل المفترس ابو العيد فيداليا *R. cardinalis* أعلى ذروة تعداد على أشجار الليمون في الأسبوع الثالث من سبتمبر ، أسد المن *C. carnea* في الاسبوع الاول من سبتمبر و أبو العيد *Nephus includens* في الأسبوع الأول من أغسطس 2014 وتمثل ب 60، 45 و 25 فرد لكل 100 ورقة على التوالي.

بينما سجل المفترس ابو العيد فيداليا *R. cardinalis* أعلى ذروة تعداد على أشجار الليمون في 9 سبتمبر 2015 وتمثل ب 74 فرد لكل 100 ورقة، أسد المن *C. carnea* و أبو العيد *Nephus includens* سجل في 12 أغسطس 2015 وتمثل ب 54، 30 فرد لكل 100 ورقة على التوالي.

كما أظهرت نتائج التحليل الإحصائى لمعامل الإرتباط بين أنواع البق الدقيقي والمفترسات الحشرية المرتبطة بها على أشجار الليمون خلال السنة الاولى 15/2014 وجود أرتباط موجب عالى المعنوية او أرتباط موجب ماعدا البق الدقيقي السيشلارم *I. seychellarum* و المفترس أبو العيد *Nephus includens* أظهر عدم وجود أرتباط موجب او معنوي.

أظهرت نتائج التحليل الإحصائى لمعامل الإرتباط بين أنواع البق الدقيقي والمفترسات الحشرية المرتبطة بها على أشجار الليمون خلال السنة الثانية 16/2015 وجود أرتباط موجب عالى المعنوية او

أرتباط موجب المعنوية ماعدا البق الدقيقي السيشلارم *I. seychellarum* و المفترس أبو العيد *Nephus includens* أظهر عدم وجود أرتباط موجب او وجود أرتباط موجب المعنوية.

جـ – على البرتقال البلدي :-

سجل المفترس ابو العيد فيداليا *R. cardinalis* و أبو العيد *Nephus includens* أعلى ذروة تعداد على أشجار البرتقال البلدي في الاسبوع الثالث من سبتمبر وتمثل ب 199 و 61 فرد لكل 100 ورقة على التوالي. بينما أسد المن *C. carnea* وصل أعلى ذروة تعداد في الاسبوع الثالث من أكتوبر 2014 وتمثل ب 82 فرد لكل 100 ورقة.

سجل المفترس ابو العيد فيداليا *R. cardinalis* و أبو العيد *Nephus includens* أعلى ذروة تعداد على أشجار البرتقال البلدي في 9 سبتمبر وتمثل ب 122، 30 فرد لكل 100 ورقة على التوالي. بينما أسد المن *C. carnea* وصل أعلى ذروة تعداد في 23 سبتمبر 2015 وتمثل ب 75 فرد لكل 100 ورقة.

كما أظهرت نتائج التحليل الإحصائى لمعامل الإرتباط بين أنواع البق الدقيقي والمفترسات الحشرية المرتبطة بها على أشجار البرتقال البلدي خلال السنة الاولى 15/2014 وجود أرتباط موجب عالى المعنوية ، ماعدا البق الدقيقي السيشلارم *I. seychellarum* و المفترس أبو العيد *Nephus includens* أظهر وجود أرتباط موجب المعنوية.

أظهرت نتائج التحليل الإحصائى لمعامل الإرتباط بين أنواع البق الدقيقي والمفترسات الحشرية المرتبطة بها على أشجار البرتقال البلدي خلال السنة الثانية 16/2015 وجود أرتباط موجب عالى المعنوية ماعدا البق الدقيقي السيشلارم *I. seychellarum* ، البق الدقيقي الاسترالي *I. purchase* و المفترس أبو العيد *Nephus includens* أظهر عدم وجود أرتباط موجب المعنوية.

د – على البرتقال أبو صرة :-

سجل المفترس ابو العيد فيداليا *R. cardinalis* و أبو العيد *Nephus includens* أعلى ذروة تعداد على أشجار البرتقال أبو صرة في الاسبوع الثالث من سبتمبر وتمثل ب 42 و 39 فرد لكل 100 ورقة على التوالي. بينما سجل أسد المن *C. carnea* أعلى ذروة تعداد في الاسبوع الاخير من أغسطس 2014 وتمثل ب 21 فرد لكل 100 ورقة.

سجل المفترس ابو العيد فيداليا *R. cardinalis* و أسد المن *C. carnea* أعلى ذروة تعداد على أشجار البرتقال أبو صرة في 9 سبتمبر وتمثل ب 50 و 41 فرد لكل 100 ورقة على التوالي. بينما سجل

أبو العيد *Nephus includens* أعلى ذروة تعداد في 26 أغسطس 2015 وتمثل ب 25 فرد لكل 100 ورقة.

كما أظهر نتائج التحليل الإحصائى لمعامل الإرتباط بين بق الموالح الدقيقي *P. citri* ، البق الدقيقي الاسترالي *I. purchasi* والبق الدقيقي المصري *I. aegyptiaca* و المفترسات الحشرية المرتبطة بها على أشجار البرتقال أبو صرة خلال السنة الاولى 15/2014 وجود أرتباط موجب عالى المعنوية، بينما أظهرت العلاقة بين البق الدقيقي السيشلارم والمفترسات الحشرية المرتبطة به عدم وجود أرتباط موجب المعنوية. بينما أظهر نتائج التحليل الإحصائى لمعامل الإرتباط بين أنواع البق الدقيقي والمفترسات الحشرية المرتبطة بها على أشجار البرتقال أبو صرة خلال السنة الثانية 16/2015 وجود أرتباط موجب عالى المعنوية.

هـ – على البرتقال السكري :-

سجل المفترس ابو العيد فيداليا *R. cardinalis* و أبو العيد *Nephus includens* أعلى ذروة تعداد على أشجار البرتقال السكري في الاسبوع الثالث من سبتمبر وتمثل ب 55 و 19 فرد لكل 100 ورقة على التوالي. من ناحية أخرى سجل أسد المن *C. carnea* أعلى ذروة تعداد في بداية أكتوبر 2014 وتمثل ب 48 فرد لكل 100 ورقة.

بينما سجلت المفترسات الحشرية الثلاثة أعلى ذروة تعداد على أشجار البرتقال السكري في 9 سبتمبر 2015 وتمثل ب 71، 54 و 22 فرد لكل 100 ورقة على التوالي.

كما أظهر نتائج التحليل الإحصائى لمعامل الإرتباط بين بق الموالح الدقيقي *P. citri* ، البق الدقيقي الاسترالي *I. purchasi* والبق الدقيقي المصري *I. aegyptiaca* و المفترسات الحشرية المرتبطة بها على أشجار البرتقال السكري خلال السنة الاولى 15/2014 وجود أرتباط موجب عالى المعنوية. من ناحية أخرى ، أظهرت العلاقة بين البق الدقيقي السيشلارم والمفترسات الحشرية المرتبطة به عدم وجود أرتباط سالب المعنوية.

أظهر نتائج التحليل الإحصائى لمعامل الإرتباط بين بق الموالح الدقيقي *P. citri* ، البق الدقيقي الاسترالي *I. purchasi* والبق الدقيقي المصري *I. aegyptiaca* و المفترسات الحشرية المرتبطة بها على أشجار البرتقال السكري خلال السنة الثانية 16/2015 وجود أرتباط موجب عالى المعنوية. من ناحية أخرى ، أظهرت العلاقة بين البق الدقيقي السيشلارم والمفترسات الحشرية المرتبطة به عدم وجود أرتباط موجب المعنوية.

ثانياً: الدراسات البيولوجية:-

1- تأثير أصناف مختلفة من الموالح كعوائل نباتية على الصفات البيولوجية لبق السيشلارم الدقيقي:-

التجارب المعملية أجريت لدراسة تأثير أصناف مختلفة من الموالح على بعض الخصائص البيولوجية للبق الدقيقي السيشلارم . التجارب أجريت بمعمل الحشرات في قسم الحشرات الاقتصادية ، كلية الزراعة – جامعة المنصورة تحت درجات حرارة متغيرة 22.4± 3.1 °م .

أوضحت النتائج أن ألأطوار غير الكاملة لحشرة البق الدقيقي السيشلارم كانت الأقصر عمراً عندما تم تربية الحشرة على أشجار البرتقال البلدي حيث كانت 48.7 ±1.3 يوماً.

أظهرت النتائج أن معدل البقاء خلال طور الحورية للبق الدقيقي السيشلارم كانت الأعلى على أشجار البرتقال البلدي يليها أشجار الليمون يليها البرتقال ابو صرة وكانت الأقل على البرتقال السكري واليوسفي . بأعتبار معدل البقاء كمؤشر لملائمة العوائل النباتية المختلفة يمكن ترتيبها تنازلياً كالآتي البرتقال البلدي – الليمون – البرتقال ابوصرة – البرتقال السكري – اليوسفي.

كما أظهرت النتائج أن أطول فترة وضع بيض ، أطول فترة حياة للحشرة الكاملة و أعلى خصوبة كانت للأناث البالغة التي تم تربيتهاعلى أشجار البرتقال البلدي (23.5±1.1 ، 59.4±2.3 يوماً و 56.2±4.1 بيضة / الانثى) على التوالي.

2- الاستجابة السلوكية لمفترس ابو العيد الفيداليا ومفترس اسد المن الاخضر لحشرة بق الموالح الدقيقى:-

أجريت هذه الدراسة لتقييم بعض الخصائص السلوكية لمفترس ابو العيد الفيداليا واسد المن الاخضر لكثافات حشرة بق الموالح الدقيقي عن طريق اشتقاقات الاستجابة الوظيفية لكل من ذكور واناث المفترس على كثافات تتراوح من (10-60)(عمر ثاني – عمر ثالث- بق الموالح الدقيقي) لكل مساحة بحثية. تم تقييم ايضا العلاقة بين الاستجابة الوظيفية والاستجابة العددية لاناث مفترس ابو العيد الفيداليا في حين تم تقييم الاستجابة الوظيفية فقط للعمر اليرقي الثاني والثالث لمفترس اسد المن الاخضر. معدلات الافتراس بواسطة ذكور واناث مفترس الفيداليا ابدت استجابة وظيفية من النوع الاول والثالث طبقا لمعادلات الاستجابة الوظيفية على التوالي مع قيم كالاتي [(a) معدل الهجوم=0.0197 $^{-1}$ساعه (Th) وقت الاداء= .03194 ساعه) الانثى: معدل

الهجـــوم=0.0197ساعه-1 و وقـــت الاداء=.03194ساعه)]. امـــا معـــدلات الافتـــراس للعمـــر اليرقـــي الثـــاني والثالـــث لمفتـــرس اســـد المـــن الاخضـــر تتطـــابق مـــع النمـــاذج الرياضـــية للاســـتجابة الوظيفيـــة مـــن النـــوع الثـــاني والثالـــث علـــى التـــوالي مـــع مقـــاييس كالتـــالي [(العمـــر الثـــاني: معـــدل الهجـــوم=0.0159ساعه-1 وقـــت الاداء=0.77ساعه) (العمر الثالث: معدل الهجوم=0.029ساعه-1 وقت الاداء=0.23ساعه)].

اوضـــحت النتـــائج ان منحنـــى الاســـتجابة الانتاجيـــة كـــان متشـــابه لمنحنـــى الاســـتجابة الوظيفيـــة لانثـــى مفتـــرس ابـــو العيـــد الفيـــداليا وهـــذا يوضـــح ان كـــلا الاســـتجابتين تعمـــلان بصـــورة تعاونيـــة وكوظيفـــة واحـــدة. اوضـــحت النتـــائج ان ميـــل منحنـــى معـــدل تحويـــل الغـــذاء الـــى فريســـه (تعـــداد) كـــان عـــالي علـــى الكثافـــات المنخفضـــة ومـــنخفض علـــى الكثافـــات العاليـــة مـــن الفريســـة. هـــذا المعـــدل المـــنخفض علـــى الكثافـــات العدديـــة العاليـــة مـــن الفريســـة مـــن المحتمـــل بســـبب ان الانـــاث المتغذيـــة جيـــدا تضـــع عـــدد كبيـــر مـــن البـــيض علـــى الكثافـــات العاليـــة مـــن الفريســـة ولكـــن تســـتثمر اكثـــر فـــي عمليـــات الميتـــابوليزم (النشـــاط الايضـــي). مـــن المعـــروف ان مقـــاييس الاســـتجابة الوظيفيـــة يكـــون غيـــر واقعيـــة بالاختبـــارات المعمليـــة لانهـــا لاتـــرتتبط بصـــورة مباشـــرة بمـــا يحـــدث تحـــت الظـــروف الحقليـــة، حيـــث انـــه تحـــت الظـــروف المعمليـــة يكـــون معـــدل الهجـــوم محـــدد بوقـــت الاداء (الوقـــت الـــلازم لمســـك فريســـة واحـــدة والتغذيـــة عليهـــا) فـــي حـــين انـــه تحـــت الظـــروف الحقليـــة يكـــون محـــدد بالســـلوك البحثـــي. لـــذلك فـــان اســـتجابة العـــدو الطبيعـــي تحـــت الظـــروف المعمليـــة ربمـــا تختلـــف عـــن اســـتجابته تحـــت ظـــروف الطبيعـــة الا ان هـــذه الدراسات تكون مفيدة في مقارنة كفاءة الاعداء الطبيعية او اطوار نموها.