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Seasonal fluctuation of the cotton mealybug, *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) and its natural enemies on mulberry trees in Egypt

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Abstract:

The seasonal fluctuation of the cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) was studied for two years (January 2014 until mid of December, 2015) on mulberry trees at Giza Governorate. The obtained results showed that, P. *solenopsis* has two peaks and presence of three overlapping generations in both years under field conditions. The 1st generation started from mid April to early August /mid of July with duration of 3-3.5 months at field condition during two years respectively. The 2nd generation occurred from early of August to mid of October /mid of July to mid of October with duration of 2.5-3 months in both years respectively. The 3rd generation occurred between mid of October to mid of December and they lasted 2 months in both years respectively. The favorable time for its abundance on mulberry branches occurred in early and late summer season due to the high temperature, whereas decrease until disappear during in winter season referred to the cold weather. On the other hand, the relationship between the meaybug fluctuation and abiotic factors (minimum, maximum temperatures and relative humidity) were studied where the simple correlation of the maximum and minimum temperatures was positive and high significant but R.H. % gave negative and insignificant effect. The natural enemies (predators and parasitoids) were surveyed and identified.

The results indicated that three species of predators, these are *Hyperaspis vinciguerrae* Capra (Coleoptera: Coccinelledae), Dicrodiplosis *manihoti* Harris (Diptera: Cecidomiidae), *Scymnus syriacus* Mars. (Coleoptera: Coccinellidae). Also, there were two different primary parasitoids associated with the mealybug, *Acerophagus gutierreziae* Timberlake (Hymenoptera: Encyrtidea) and *Chartocerus dactylopii* (Ashmead) (Hymenoptera: Signiphoridae). The results also observed, *H. vinciguerra* and *D. manihoti* had two and three peaks during the two years of study, respectively.

Introduction

The newly world species of mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) has emerged as a serious pest of cotton in Pakistan and India, and is now being as a serious threat to cotton in China. It has been infested from 175 host plant species in 45 families, and from 26 countries in different ecological zones (Abbas *et al*., 2010). *P. solenopsis* cause crinkling, twist and condense flower, bud, bolls growth and finally it cause yield loss (Sahito *et al*., 2009).In Egypt, this pest was recorded for the first time infesting *Hibiscus* sp. In September, 2009 by Abd-Rabou *et al*. (2010). This pest spread rapidly on different host plants to the extent that recorded it on 29 host plant species belonging to 16 plant families including field crops (3), vegetables (3), ornamentals (7), weeds (13) and fruits (3) (Abdel-Razzik *et al*., 2015).

Mulberry (*Morus* spp.) is cultivated throughout the world wherever silkworms are raised where their leaves were used as food for silkworms. Mulberry fruit may be eaten raw or cooked (mad into Jam, syrup or juice) (Duke, 1983). Many countries cultivate mulberry trees in field such as China, Korea and India. Others cultivate them as wild trees around the field of different crops or at the side of roads and streams. Egypt is one of the second categories in mulberry cultivations (Hosny *et al*., 1995).

The present work is to study the activity period of *P. solenopsis* on mulberry trees, annual generations and effect of biotic and abiotic factors on the populations of this mealybug.

Materials and methods

1. Seasonal fluctuation of *Phenacoccus solenopsis:*

These experiments were carried out in a free insecticides private farm in El-Saff district, Giza Governorate, Egypt during two successive seasons from January, 2014 to December, 2015 on 15 years old mulberry trees. Twelve infested trees, nearly of the same age and size were used for sampling. Samples of sixty branches (15cm length) were picked from the four cardinal directions and center core of each tree with rate of five branches every two weeks throughout two years. Branches were preserved in labeled paper bags and transferred to the laboratory and carefully inspected using a binocular microscope and the insect population was counted and stored into:

1.1. Alive unparasitized individuals:

Numphs, adult females and ovipositing females that were counted on the mulberry branches using a binocular microscope . The total number of live individuals in each sample was taken as the population index.

1.2. Parasitized individuals:

To calculate age structure per sample, the mean number of each stage was divided by total and multiplied by 100. This way gave each stage a percent proportion of the total per sample regardless the total number of presented insects (*i.e* population density). The number of generations was determined using the obtained data throughout the two successive years using the age-structure technique per sample over the year. Generation was defined as the time required for an insect to complete its life cycle (*i.e.* egg to egg). In the case of Monophelibid, eggs were oviposited under the female in ovisac until they hatch and crawl out. Ovipositing females were defined as female with eggs. The presence of ovipositing females (*i.e.* the transformation of adult females to ovipositing females) was considered in this study as presence of the egg stage. This phenomenon was used to determine the end of each generation and the beginning of the next one (El-Amir, 2009).

Weather factors data assumed to effect studied insects (i.e. maximum, minimum daily temperatures and mean percentage of daily relative humidity) were obtained for the Giza area from the Egypt-Weather Underground https:/www.wunderground.com/global/EG.html.

Obtained data was summarized for each fourteen days previous to the sampling date. Considered weather factors means over each determined generation was calculated and presented. To investigate the relationship between the climatic factors and the population density of *P. solenopsis* were tested using simple correlation, and multiple regression analysis. All statistical analyses were done using the software package (Costat, 2005).

2. Survey of natural enemies of *Phenacoccus solenopsis:*

Mulberry branches were examined on different months in Giza Governorate. Samples of mulberry branches infested with *P. solenopsis* were collected. The specimens were confined in glass jar kept in laboratory for securing any emerging parasitoids or predators. The immature and mature stags of the predators were counted on the branches mulberry using a binocular microscope every two weeks. The total number of the alive individuals in each sample was taken as the population index.

Results and Discussion

1. Seasonal fluctuation of *Phenacoccus solenopsis*:

Figures (1 and 2) showed that the half-monthly means of nymph, adult female and ovipositing female population density of *P. solenopsis* infesting mulberry trees throughout the two successive years of investigation (2014-2015). The figures also showed the half monthly (maximum &minimum of temperature) and relative humidity recorded during the same two years. In 2014, population density of *P. solenopsis* nymphs on mulberry branches was lowest during January and February (winter season), according to prevailing

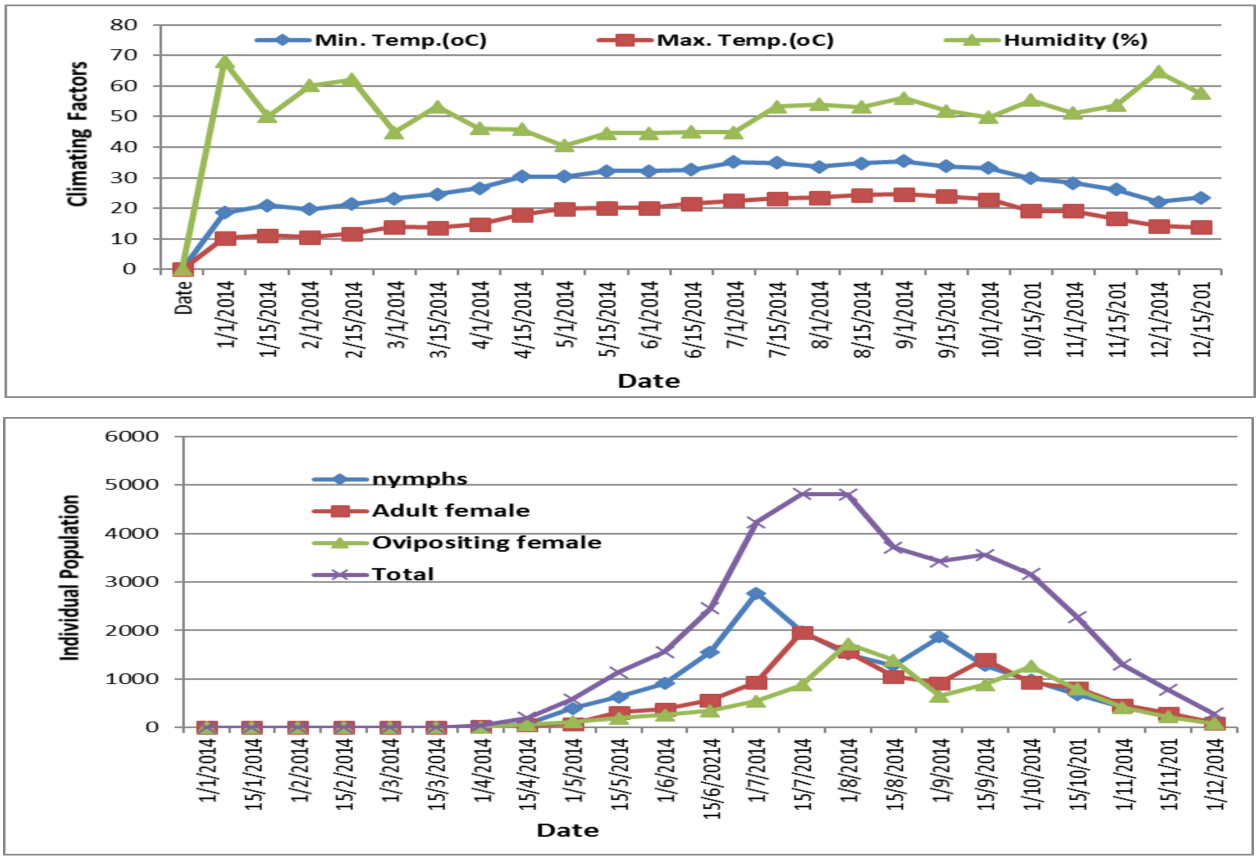

Figure (1): Seasonal fluctuation of *Phenacoccus solenopsis* population in response to max., min. temperature and relative humidity on mulberry trees at El-Saff, Giza Governorate during 2014.

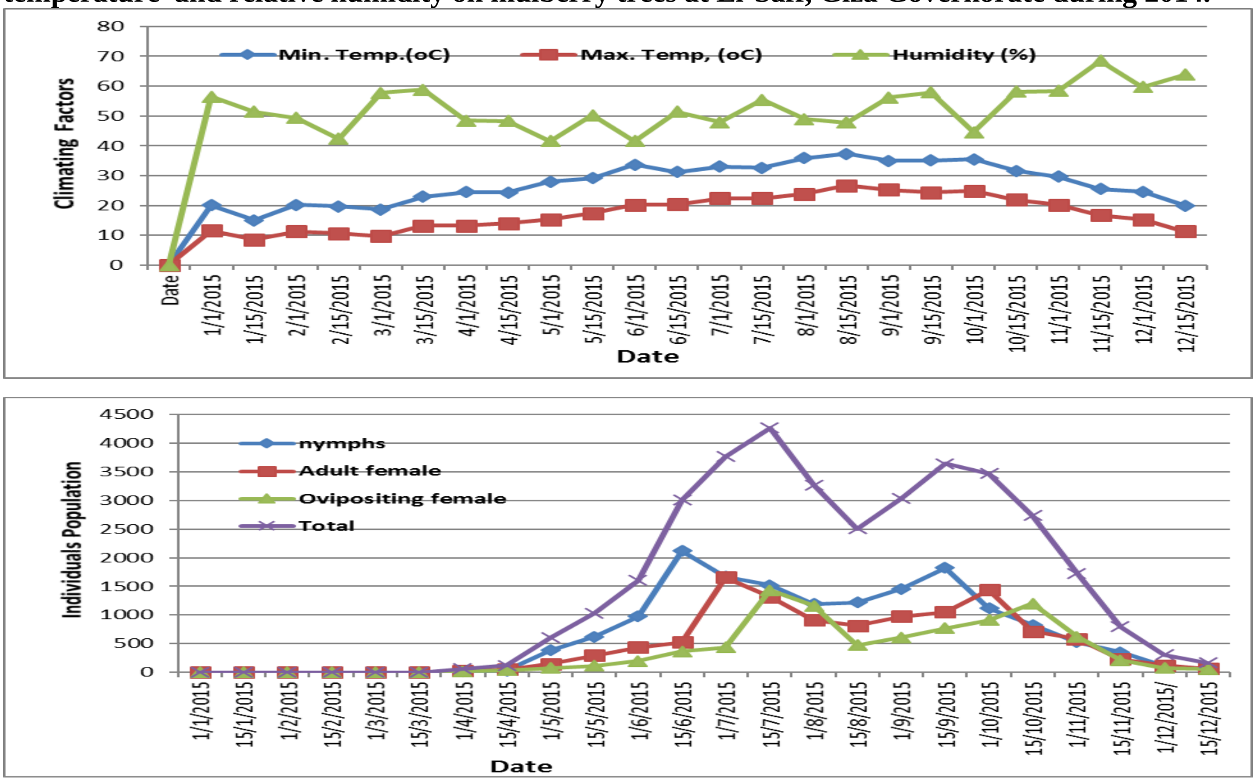

Figure (2): Seasonal fluctuation of *Phenacoccus solenopsis* population in response to max., min. temperature and relative humidity on mulberry trees at El-Saff, Giza Governorate during 2015.

environmental conditions. In April, the population starts to increase gradually, the population high increased to reach large first peak by first July (2765 nymphs/60brumches). Intermediate peak of nymphs was recorded on the first September (1866 nymphs/60 branches). Also, two peaks of adult females were observed on mid July (1958 females/60 branches) and mid September (1405 females /60 branches). Ovipsiting female also had two peaks, the first peak showed in first August (1724 ovipositing female/60 branches) and second peak in mid September (1263 ovipositing females). Over all combined numbers of total population (Nymphs, adult females and ovipositing females) on mulberry branches indicated that activity of *P. solenopsis* extended from April to November with large activity peak on mid July (4815 individuals/60 branches) and intermediate peak of total population occurred during September (3561 individuals/60branches).

The results of the second year of investigation (2015) as represented in Figure (2) showed that population trends and number of peaks of nymphs, adult females, ovipositing female and total population of *P. solenopsis* were nearly similar to those recorded in the previous season (2014). The population of *P. solenopsis* was not finding during January, February and March according to prevailing environmental conditions. In April, the population of nymphs starts to increase gradually and highly increased during June recording the 1st peak on mid June (2117 nymphs/60 branches) then the population decreased again. In July gradually increased and reached to 2nd peak on mid September (1822 nymphs/60 branches). The adult female population has the same trend as the nymphal population, the population gradually decreased from January until April after that it gradually increased in June, the population highly increased and reached to 1st peak by early July with (1654 adult female/60 branches) then decreased again from mid-July until early September Gradual increase was observed in the adult population during mid-September, the population highly increased recording 2nd peak on first October (1437 adult female /60branches). The ovipositing female stage also had two peaks in this year. The population greatly increased in mid July recording the 1st peak (1431 ovipositiog female/60 branches). The ovipositing females gradually decreased during August and September in early October, it increased and reached to high number in mid October recording the 2nd peak (1198 ovipositing female/60branches). On the other hand, the total population (nymphs, adult females and ovipositing females) on mulberry branches indicated that activity of *P. solenopsis* extended to increase from April to October with 1st activity peak on mid July (4268 individuals/60 branches). 2nd peak of total population recorded during mid September (3641 individuals/60 branches). Large activity peak on mid July (4815 individuals/60 branches) and intermediate peak of total population occurred during September (3561 individuals/60branches).

The obtained results showed that, P. *solenopsis* have two peaks during July and September While the results of Arve *et al.* (2011) and Singh and Kumar (2012) indicated that the peaks during October and December of the year in India. Also, they result observed mealybug population decreased from January to March with agreement with the results conducted here. The results here also indicated that the favorable time for its abundance on mulberry branches occurred in early and late summer season due to the high temperature, whereas decrease until disappear during in winter season referred to the cold weather. The data of Arif *et al*. (2012) indicated the same trend. They result showed that, after winter, population build-up of mealybug took place and its number was high in March on weeds and in April on crops, being 328 and 434 per sample respectively. Its number remained low in mid cotton season followed by a second peak of 320 mealybugs per sample on weeds and 474 on crops in November. Population declined in December. On ornamental plants, incidence of mealybug started increasing in May. Its highest number of 432 mealybugs per sample was recorded in July followed by a decline. Second peak of 304 mealybugs per sample was observed in November followed by a gradual fall. Cotton mealybug was active throughout the year on various crops, ornamental plants and weeds with two population peaks in Multan and nearby districts. Population peaks of mealybug on vegetables (okra, brinjal etc.) in March/April and other crops (cotton etc.) in October/November were observed near their maturity/termination.

2. Duration and number of generations:

Number of annual field generations was estimated from the graphical representation of age structure technique to the seasonal abundance data of *P. solenopsis* obtained over the two years on mulberry trees and illustrated on Figures (3 and 4). The first generation started at the beginning of mid April in both years and extended until early August in the 1st year and mid July in the 2nd one. The duration of the 1st generation lasted 3.5-3 months in both years respectively. The 1st generation peaked in first July in 1st year and mid June in 2nd year. The second generation

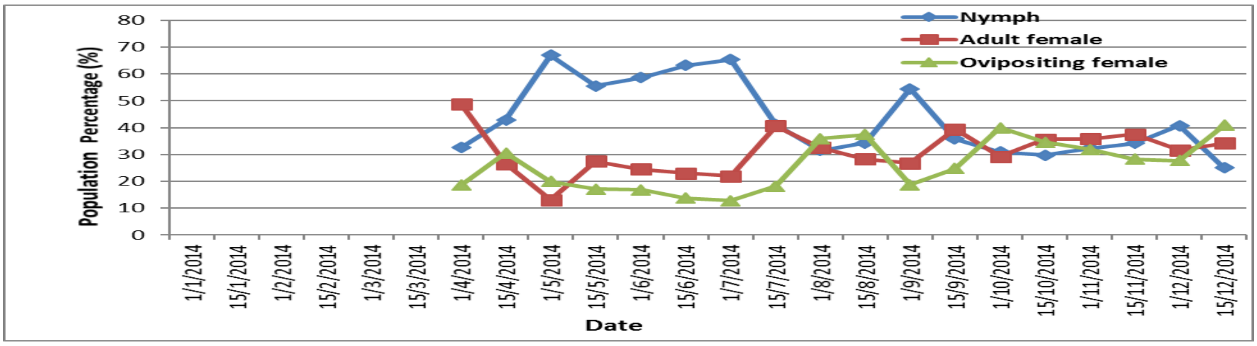

Figure (3): Age structure of *phenacoccus solenopisis* on mulberry trees 2014.

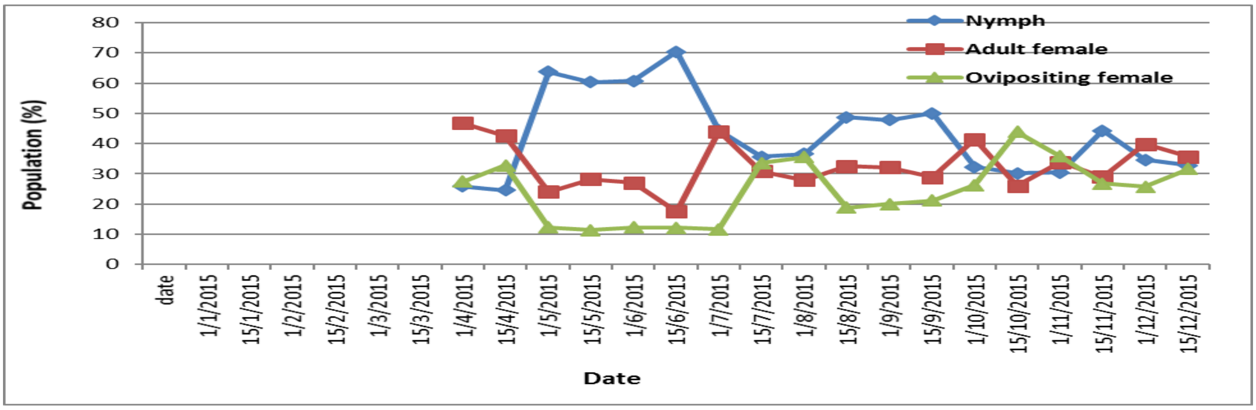

Figure (4): Age structure of *Phenacoccus solenopisis* on mulberry trees during 2015 .

started from first Aug. until mid October 2014 with duration of 2.5 months and mid July until mid October 2015 with duration of 2.5-3 months, it peaked early/mid September in the two years respectively. The third generation which started from early October until mid December with duration 2 months in both years respectively. The obtained results showed that, P. *solenopsis* had three overlapping generations in both years While, Anonymous (2013) in Australia stated that depending on temperature, mealybug can produce 6-8 generations per year.

3. Effect of ecological factors on *Phenacoccus solenopsis* population fluctuations:

The effectiveness abiotic factors on *P. solenopsis* total population were studied during two successive years (2014-2015) in Giza Governorate as in Table (1).

3.1. Effect of daily maximum temperature:

Results of the statistical analysis of simple correlation on *P. solenopsis* total population during the two studied years showed that, the simple correlation gave positive highly significant correlation with (r) value = (.842±0.1and 0.875±0.10) in both years (2014-2015). Also, the partial regression value (P.reg=24.155±1.8 & 21.9±1.9) showed highly positive significant in the two years respectively.

3.2. Effect of the night minimum temperature:

The effect of night minimum temperature on the total population during two studied years indicated highly positive significant correlation, (r) value= (0.880±0.1&0.912±0.09) respectively. On the other hand, the partial regression showed positive significant relation with (P.reg=21.9±1.9 and12.451±1.9) in the two years respectively.

3.3. Effect of daily mean relative humidity:

The daily mean relative humidity had negative relation, insignificant on the total population (r=-0.1488±0.211 and -0.362±0.214) in the two years respectively. The single effect of this factor on the total population activity appeared from the partial regression coefficient value was insignificant effect with (P.reg=53.1±7.31 and 53.5±3.88) in both years respectively.

3.4. The combined effect of daily mean temperature and humidity:

The combined effect of climatic factors on the cotton mealybug *P. solenopsis* during the two studies years was significant (F=36.516 and 35.651) and the explained variance (E.V) presented (50.2% and 58%) during the two years of study, respectively. The results conducted here indicated that the simple correlation of the maximum and minimum temperatures was positive and high significant but relative humidity % gave negative and insignificant effect. The same results conducted by Dhawan *et al.* (2009). They stated that there was positive correlation among the mealybug population with temperature, whereas negative correlation was observed with relative humidity.

4. Survey of natural enemies associated with *Phenacoccus solenopsis*:

4.1. Predators:

The present data showed the presence of three species of insect predators identified as *Hyperaspis vinciguerrae* Capra (Coleoptera: Coccinelledae), *Dicrodiplosis manihoti* Harris (Diptera: Cecidomiidae), *Scymnus syriacus* Mars. (Coleoptera: Coccinellidae) associated with *P. solenopsis.*

4.2. Parasitoids:

Also, the present data indicated that two primary parasitoids associated with *P. solenopsis*. These parasitoids are as following:

a. *Acerophagus gutierreziae* Timberlake (Hymenoptera: Encyrtidea)

b. *Chartocerus dactylopii* (Ashmead) (Hymenoptera: Signiphoridae)

Two species of encyrtid and signiphorid parasitoids were recorded from samples of *P. solenopsis*, these species are *A. gutierreziae* and *C. dactylopii* (Attia and Kamal, 2016).

5. Population fluctuations of the cotton mealybug, *Phenacoccus solenopsis* predators:

5.1. *Hyperaspis vinciguerra* Capra:

Data in Figures (5 and 6) revealed that the population density of *H. vinciguerra*, had two peaks during the two years of study. The1stpeak recorded in first August /first July in the two years, while the second peak was recorded in first October /early September in the two years under considerations, respectively. Laila *et al*. (2015) reported that *H. vinciguerra* when associated with *P. solenopsis* had four peaks on lantana plants during two years of study. Kedar *et al.* (2011) recorded that, the coccinellid predators play a good role in reducing the infestation of *P. solenopsis*

Statistical	First year (2014)			Second year (2015)		
Parameters	Temperature		R.H.%	Temperature		R.H.%
	Tmax.	Tmin.		Tmax.	Tmin.	
Simple correlation						
Corr.Coef.(r)	0.842 ±0.115	0.880±0.101	-0.148±0.211	0.875 ±0.103	0.912 ± 0.17	-0.362±0.214
Probability(p)	< 0.0001	< 0.0001	0.4908	0.0001	0.0001	0.1070
Correlation significant	Yes	Yes	No	Yes	Yes	No
Partial Regression						
Partial Regres. Coef (b)	24.155±1.770	7.733 ± 3.20	58.855 ±	21.90±1.946	12.451±1.946	53.466± 3.883
Regression Coefficient r^2	0.710	0.774	0.022	0.766	0.832	0.131
F-value	53.762	75.427	0.491	72.190	108.705	2.863
Probability (p)	< 0.0001	< 0.0001	0.4908	0.0001	0.0001	0.1070
Regression significant	Yes	Yes	No	Yes	Yes	No
Combined factors						
E.V (Explained variance)	50.1			58		
F-value	36.516			35.651		

Table (1): Effect of both temperature and relative humidity on *Phenacoccus solenopsis* population on mulberry trees at El-Saff, Giza Governorate, Egypt during the studied years.

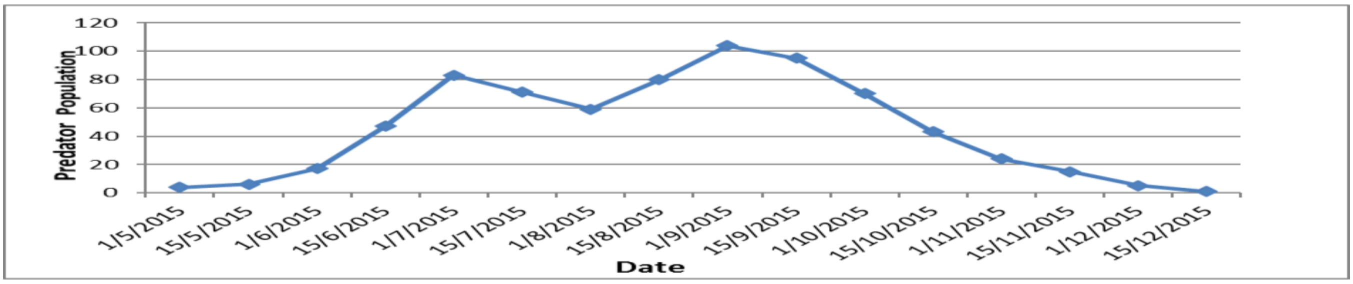

Figure (5):Population density of *Hyperaspis vinciguerrae* on mulberry branches at El-Saff, Giza Governorate. during 2014.

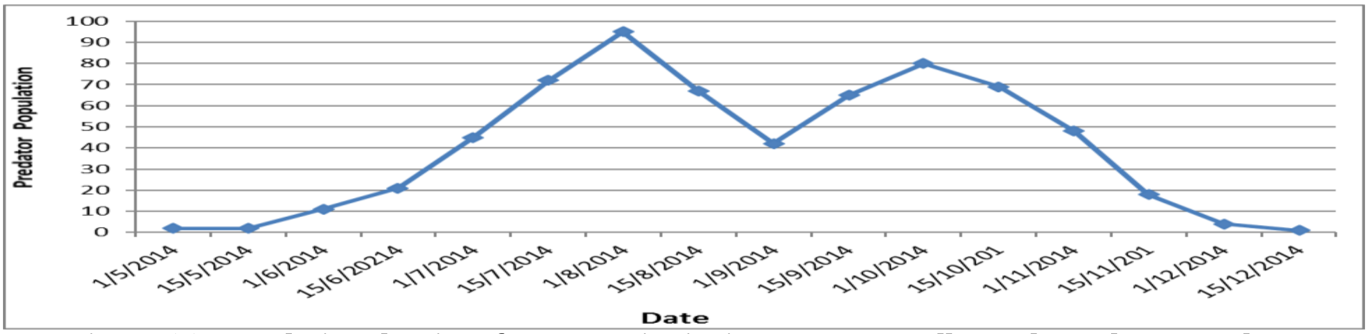

Figure (6):Population density of *Hyperaspis vinciguerrae* on mulberry branches at El-Saff, Giza governorate. during 2015.

5.2. *Dicrodiplosis manihoti* Harris:

The obtained results in Figures (7 and 8) revealed that *D. manihoti* had three peaks in 2014 and 2015 years. The1st peak recorded in first July in the two years, while the second peak was recorded in mid August /mid September in two years respectively. The third peak occurred in mid October /first November in the two years under considratios, respectively. *D. manihoti* was found to associate with the long-tailed mealybug, *P. longispinus* and the citrus mealybug, *P. citri*. *D. manihoti* was obtained during almost months whenever its prey, *P. longispinus* or *P. citri* occurred. The highest number of the predator, *D. manihoti* collected from the sample of mealybug was 93 individuals in November 1994 in Sultanate of Oman (Abbas, 1999). It is concluded that from the results here, in general, the population fluctuation of insect pests in the agricultural field is helpful for assessing the pesticide productivity and timing of pesticide application.

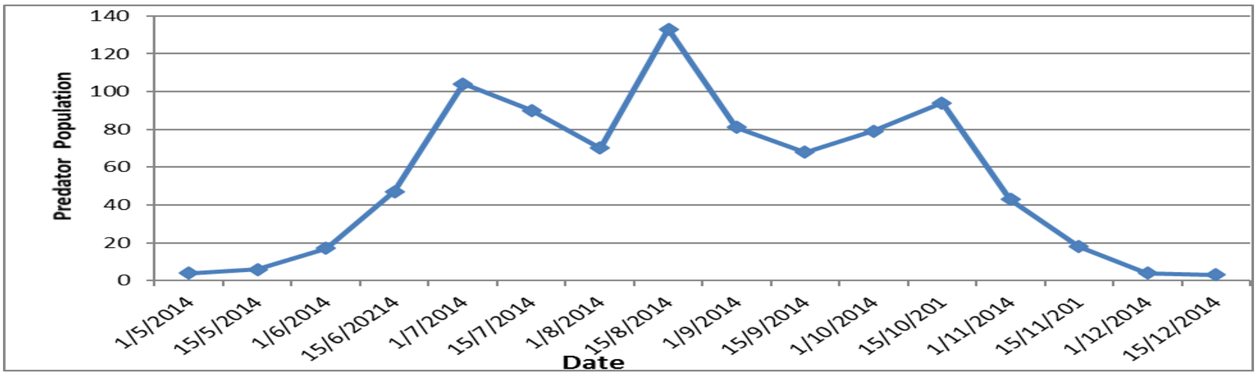

Figure.(7):Population density of *Dicrodiplosis manihoti* Harris on mulberry branches at El-Saff, Giza Governorate during 2014

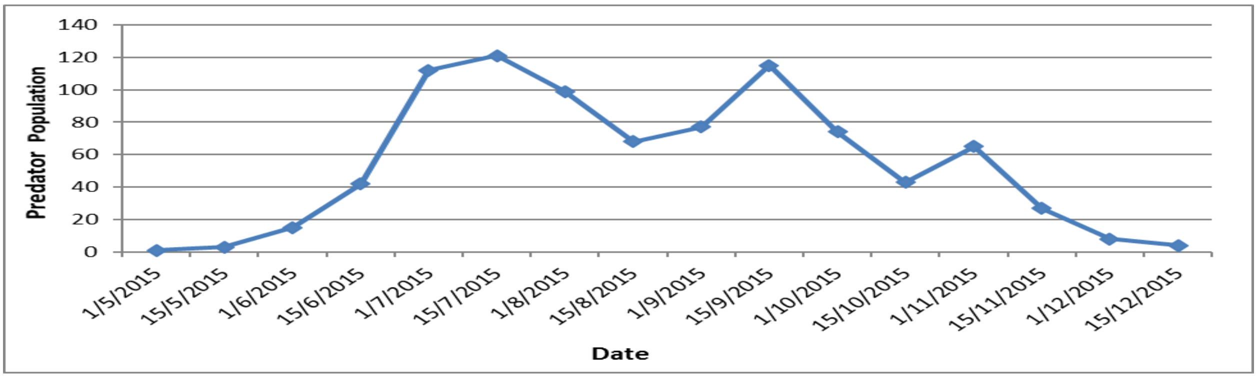

Figure (8):Population density of *Dicrodiplosis manihoti* Harris on mulberry branches at El-Saff, Giza Governorate during 2015 .

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