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The Most Invasive Scale Insects and Mealybugs on Coffee Plants, *Coffea arabica* L. In Egypt, Their Associated Natural Enemies and Their Management with Recommended Insecticides

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Abstract: During the last decade, *Coffea arabica* L. was considered a promising crop in Egypt, which was attacked by various species of mealybugs and scale insects, and causing generous damage to plants. This study was carried out in Giza governorate, during two successive seasons 2020-2021 and 2021- 2022 on coffee plants on experimental research garden of the Horticultural Research Institute, Agricultural Research Center, Giza Governorate, Egypt. The presented work was carried out to survey many species of mealybugs and scale insects which attacked coffee plants and the associated predators and parasitoids as well as investigate the population fluctuation of the striped mealybug, *Ferrisia virgata* and the associated natural enemies in addition to, the effects of the main climatic factors on the *F. virgata* population. Biweekly samples were taken for the following years, 2020-2021 and 2021-2022.The results indicated that all stages of the striped mealybug, *F. virgata* in the first season had one peak on the leaves of coffee plants, which was recorded at the beginning of October during the first year of study also, had only one peak occurred during the second season of study, which was at the beginning of November. The results showed that the maximum and minimum temperatures and relative humidity had significant positive effects on all individuals of *F. virgata.* Finally, controlling of *F. virgata* by using some recommended treatments. The application of spraying was applied during October, 2020 and November 2021 which was the most suitable time for chemical control as well as, the most efficient on all individuals of *F. virgata*. As well as, all treatments had higher effectiveness on the nymphal stage than adult females. Also, data indicated that the most efficiency treatment was the mixture of Malathion 57 %EC + KZ oil followed by Malathion 57 %EC. Bioranza was high effect than Biovar and KZ oil had less effectiveness on *F. virgata* different stages.

Key words: *Ferrisia virgata*; *Coffea arabica* L; Ecological studies; Chemical control.

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INTRODUCTION

Coffea arabica L. Arabica coffee is an important economic crop in Asia, Africa and South America. It is currently one of the most important strategic agriculture crops in the world, and it ranks second in world trade after oil and its industrial derivatives. It is a national source for more than 50 countries in the world; on top of them are Brazil, Vietnam, Colombia, Indonesia, and Ethiopia. As well as, it considered as a promising crop in Egypt recently. Coffee trees have been planted in Egypt since 1970 **Abd El Gawad *et al.* (2012).** Shaded agriculture was found to be the determining factor for the success of coffee cultivation in Egypt, which is why coffee trees were planted under mango treesin Giza, Qalubiya, andEL- Behaira governorates, **Abd Rabou *et al.* (2011) and ICO (2019).** Coffee plants belong to the family Rubiaceae. The most commercially important and widespread species in Rubiaceae were C. *arabica* (Arabica) and *C. canephora* (Robusta)**Davis, *et al*. (2021).** As well, scale insects and mealybugs have precarious effects on coffee plants. The striped mealybug can transmit plant pathogens (**Santa-Cecília *et al*. (2007 and 2014) and Nabil. *et al*. (2013).**

F. virgata (Hemiptera: Coccoidea: Pseudococcidae) is the most precarious mealybug species, which infested coffee plants in Egypt as well as, many crops all over the world (**El-Batran *et al*., 2016 and Adly *et al*., 2016).** It can infest Coffee plants' shoots, twigs, leaves, and coffee fruits, causing various damages that depend on sucking sap from plant leaves as well as weakening the tree and increasing the infestation of secondary insect pests (**Ata *et al*., 2019).** *F. virgata* has high levels of infestation, causing severe damage that will decrease the production of coffee orchards. Also, it can produce honey dew **(Mittler and Douglas, 2003)** and **Mohamed (2015),** which helps in the growth and spread of black sooty mould fungi that will reduce the process of photosynthesis and work on decreasing the respiration of plants. It will be highlighted in this study on the most widespread mealybugs and scale insects and their natural enemies on coffee plants. also the fluctuation of *F. virgata* populations and the number of generations per year; the effects of some climatic factors and associated natural enemies on the *F. virgata* population; and the relationship between the insect and climatic factors. Finally, the effects of some pesticides on different individual stages of *F. virgata* as well as the determination of the most suitable time for the management of *F. virgata* on coffee plants

MATERIALS AND METHODS

Survey of Scale insects and mealybugs and associated natural enemies

A mealybug and scale insect survey was carried out on eight coffee trees with a random sample of 100 leaves from each orchard, symbolising the four cardinal directions and cores of coffee trees in the Experimental Farm of the Horticultural Research Institute, Agricultural Research Centre, Giza Governorate, Egypt, during two successive seasons (2020-2021 and 2021-2022). Samples of this study were taken every two weeks, and coffee trees weren't subjected to any chemical control, and there were some agricultural practices. All samples were placed in plastic bags and transported to the laboratory for examination. Scale insects and mealybugs on these previous samples were separately categorized into small crawlers, adult females, and gravid females and were counted and recorded. The associated predatory and parasitic species were identified and recorded. Samples of infested leaves were put in boxes of paperboard and kept at 25–30 °C and 65-70% R.H. for emerging. All natural enemies were identified by Prof. Dr. Angel *R. Attia* of the Plant Protection Research Institute, the Agricultural Research Centre, and Giza, Egypt. The dominant percentages of scale insects and mealybugs on coffee plants were estimated by the formula of Balogh **(Harde *et al*., 1984).**

$$\text{Dominance percentages} = a_1 / \Sigma a_1 * 100$$

Ecological aspects of *F. virgata* Cockerell and its natural enemies

Ecological studies of *F. virgata* on *Coffea arabica*L. were achieved in the experimental farm of the Horticultural Research Institute, Agricultural Research Centre, Giza Governorate, Egypt, during two successive seasons, 2020–2021 and 2021–2022. Ten coffee trees were selected. During the prior period, samples were collected randomly every two weeks from all directions of the tree, and all trees were untreated with any chemical treatments. Samples were put in paper bags and transferred to the laboratory, where a stereoscopic binocular microscope was used to classify and count all existing individuals. All stages of *F. virgata* and all stages of parasitoids were counted and recorded. The generations of *F. virgata* and their durations were calculated by **Audemard and Milaire (1975) and Iacob (1977).**

Impact of some climatic factors on *F. virgata* (Cockerell) and its natural enemies in Giza Governorate, Egypt during two successive seasons 2020-2021 and 2021-2022

Central Laboratory for Agricultural Meteorology, Agricultural Research Center, Ministry of Agriculture provided us with data of maximum and minimum air temperature (°C) and relative humidity percentage (RH %) in Experimental farm of the Horticultural Research Institute, Agricultural Research Center, Giza Governorate, Egypt. The effects of each weather factor on *F. virgate* populations were studied.

Using of different alternative pesticides and fungicides for controlling *F. virgata* on (*C. arabica* L.) during two succeeding seasons 2020-2021 and 2021-2022

Experiments were performed on the coffee orchard in Experimental farm of the Horticultural Research Institute, Agricultural Research Center, Giza Governorate, Egypt for controlling and suppressing population of *F. virgata* by using some treatments of pesticides. All treatments were applied during peaks of *F. virgata* in beginning of October 20201 and mid of November 2021. As shown in (Table, 1). Before spraying, samples size of 25 leaves was picked up from each replicate directly as a pretreatment replicates. The post-treatment replicates were collected after 5, 7 and 14 days from spraying application. The corrected reduction percentages of *F. virgata* mealybugs were estimated according to the equation of **(Henderson and Tilton, 1955).**

$$\% \text{ Reduction Percentage} = 100 \{1- (Cb/Ca \times Ta/Tb)\}$$

Where:

Ta = No. of a live individuals after treatment application on treated trees.

Tb = No. of a live individuals before treatment application on treated trees.

Ca = No. of a live individuals after treatment application on untreated trees.

Cb = No. of a live individuals before treatment application on untreated trees.

Table (1). Tested Treatments and their rates of applications

Treatments	Rate of application/100 L water
KZ Oil (95 % EC Mineral oil)	1.5 L/100 L water
Malathon (Malathion 57%EC)	150 cm/100 L water
Bio-var[@] (10% *Beauvaria bassiana*)	200g/100Lwater
Bio-ranza r[@] (10% *Metarhizium anisopliae*)	200g/100Lwater

Statistical analysis

All data of simple correlation simple regression , partial regression and coefficient of determination percentage between different stages of *F. virgata* population and the climatic factors (max. temp., min. temp. and relative humidity) were calculated by using SPSS program Version 16.

RESULTS AND DISCUSSION

Scale insects and mealybug and associated natural enemies on *C. Arabica* plants

There were various species of scale insects and mealybug on coffee plants which surveyed on leaves, brunches and Fruits of the coffee trees. Data in Table, (2) investigated that, there were two species from family (Coccidae) were *S. coffeae* (Walker) and *C. viridis* (Green) which recorded on leaves and branches two species of Pseudococcidae were *F. virgata* (Cockerell) and *M. hirsutus* (Green) which found on leaves, Fruits and branch finally, we found one species of mealybugs from Monophlebidae was *I. seychellarum* (Westwood) which was on leaves and branch. *F. virgata* (Cockerell) and *M. hirsutus* (Green) had the highest dominance rate during two seasons of study were 54.90% and 22.06% respectively and *C.viridis* (Green) recorded the lowest dominance rate during two seasons of study was 5.08%. Whereas, there were four species of predators which recorded to be associated with *F. virgata* (Cockerell) and *M. hirsutus* (Green) and *I. seychellarum* (Westwood) during two successive seasons 2020-2021 and 2021-2022 were *S. syriacus* (Mars.), *H. vinciguerrae* Capra, *R.cardinalis* (Mulsant) and *C. carnea* (Steph.). In addition to, *B. insularis* (Cameron), *L. abnormis* (Girault), *A. kamali* Moursi and *C. subaeneus* (Foerster) were recorded on *F. virgata* (Cockerell) and *M. hirsutus* (Green) as well as, *C. scutellaris* (Dalman) and finally, *M. flavus* (Howard) were recorded on soft scale insects, *S. coffeae* (Walker), *C. viridis* (Green), during two successive seasons 2020-2021 and 2021-2022.These results were agreed with those obtained by **Mani, 1992**; **Adly, *et al*., 2016**; **Fornazier *et al*., 2019 and Ivana *et al*., 2023**.

Ecological aspects on *F. virgata* and its associated natural enemies

Data summarized in Fig (1) showed that the population fluctuation of *F. virgata* was started during first season of study 2020-2021 on Mid- May, 2020 with total number 127 insects /100 leaves and the population increased gradually on June, July, August, November and September to reach the main peak of *F. virgata* during mid-October with total number 2250 insects/ 100 leaves After that, the population was decreased from November until December, 2020.As well as, data presented in Fig (1) indicated that, the population fluctuation of *F. virgata* during second season of study during 2021-2022 was started in Mid-May2021 with total number of insects 248 insects/ 100 leaves and the populations increased during June, July, August, November and September to reach the highest peak during beginning of October, 2021 with total number 2532 insects/ 100 leaves, afterward the population decreased until the end of December, 2021.

According to the data in Fig (1) the striped mealybug *F. virgata* had one peak /year was recorded in October through two seasons of study 2020-2021 and 2021-2022. Whereas, the total population of *F. virgata* was higher in the second year of study were 12217 insects/year than in the first year was 10811 insects /year. In addition to, the period from January to beginning of May was the lowest population of *F. virgata* during second season of study.

Data obtained in Table (2) and Fig. (1) Showed that the effect of maximum, minimum temperatures and the relative humidity on population of *F. virgata* were positive and insignificant during first season of study (2020- 2021), (r= 0.40, r= 0.5537 and r=0.359). As well as, the maximum, minimum temperatures and the relative humidity also recorded positive and insignificant effects during second season of study (2021-2022), (r= 0.376, r= 0.513 and r=0.276). Whereas, the regression coefficient was positive and insignificant during two seasons of study.

Table (2). List of Scale insects, mealybugs and their natural enemies on Coffee trees (*C. arabica* L.) during two successive seasons 2020-2021 and 2021-2022

Order	Family	Pests	Genus or Species	Plant sites	Dominance (%)	Associated natural enemies
Hemiptera	Coccidae	brown scale	*Saissetia coffeae* (Walker)	leaves and branches	9.52	*Metaphycus helvolus* (Compere)
		Green coffee scale	*Coccus viridis* (Green-)	leaves and branches	5.08	*Coccophagus scutellaris* (Dalman)
						Metaphycus helvolus (Compere)
	Pseudococcidae	Striped mealybug	*Ferrisia virgata* (Cockerell)	leaves, Fruits and branches	54.90	*Scymnus syriacus* (Mars.)
						Blepyrus insularis (Cameron)
						Chartocerus subaeneus (Foerster)
						Anagyrus kamali Moursi
		Pink-hibiscus mealybugs	*Maconellicoccus hirsutus* (Green)	leaves, Fruits and branches	22.06	*Scymnus syriacus* (Mars.)
						Hyperaspis vinciguerrae Capra
						Leptomastidea abnormis (Girault)
	Monophlebidae	Seychellarum mealybugs	*Icerya seychellarum* (Westwood)	leaves and branches	8.44	*Rodolia cardinalis* (Mulsant)
						Chrysoperla carnae Steph

Data obtained in Figs. (3 and 4) showed that, *F. virgata* on Coffee plants had two generations /year. During the first season of study, the 1st generation was started from Mid- May to Mid- August whereas, the 2nd generation was started from beginning of September to Mid of December. As well as, *F. virgata* passed through two generations/year; the first lasted for days from the period Mid- May to beginning of September and the last one lasted for days from Mid- May to Mid- December. Second generation was the highest one compared with the first generation.

According to Figs. (5 and 6) it was found that, two species of parasitoids were, *B. insularis* (Cameron) and the hyperparasitoids, *C. subaeneus* (Foerster) which associated with *F. virgata* during two seasons of study. During two seasons of study 2020-2021 and 2021-2022the *B. insularis* (Cameron) population was started on Mid of May and increased gradually and recorded the highest peak on Mid of August then the second peak was in beginning of November then, the population was decreased gradually and disappeared on december the second year **(Abd Rabou, 2001)** and **(Attia, 2012)** who mentioned that, there were various species of parasitoids from Encyridae associated with mealybugs of Pseudococcidae in Egypt.

These results were agreement with that obtained by (**El-Shazly, 2006)** who recorded two peaks of *F. virgata* the first one was in July and the second one was through September to October as well as, (**Adly, *et al*., 2016; Ata, *et al*., 2019 and Abd El-Gayed, *et al*., 2020)** who recorded that the *F. virgata* had the highest population in September, November and October during two seasons of study in Egypt on corn shrubs, *Dracena fragrans*. Also, (**Ammar *et al.*, 1979** and **Nabil, *et al*., 2013**) were showed the effects of weather factors on the population activities of mealybugs in Egypt. As well as, (**Shanbhag and Sundaraj 2017)** who mentioned that, *F. virgata* had one peak of seasonal population on sandalwood in, India as well as, (**Nabil, *et al*., 2020)** who mentioned that, *F.virgata* had two generations / year on Acalypha shrubs *Acalypha wilkesiana* therefore, the highest peak was on summer and autumn and the lowest peak was on spring and winter.

Impact of some treatment against *F. virgata* (Cockerell) in Coffee plants during two seasons of study 2020-2021 and 2021-2022

Data illustrated on Fig. (5 and 6) indicated that, the effects of some treatments which used in decreasing the population of *F. virgata* on Coffee plants during peaks of insect in Giza governorate, Egypt, 2020-2021 and 2021-2022 according to formula (Henderson and Tilton 1955). The higher peak of mealybug populations occurred in beginning of October during first season 2020-2021 and mid of November during second season of study 2021-2022.

As shown in Fig. (5) the highest reduction percentage of individuals of *F. varigata* during first season of study 2020-2021was 88.02, 92.08 and 95.52 % after 5, 7 and 14 days of treatment were recorded on mixture of K.Z. oil and Malathion followed by Malathion 80.43, 85.17 and 92.01 %after 5, 7 and 14 days of treatment. The lowest reduction percentage were recorded on K.Z. oil 50.68, 56 and 60.64 %. Whereas, the reduction percentages of individuals of *F. virgata* by using Bio-ranza were 65.5, 71.92 and 79.13 %. As well as, 57.13, 63.82 and 73.21 % recorded on Bio-var. The higher reduction percentage was recorded after seven and fourteen days from treatment on Mixture of mineral oil followed by Malathion followed by Bio-ranza and Bio-var. The lower effect was recorded by KZ oil only.

Then, data summarized in Fig. (6) assured that, the reduction in *F. virgata* population during second season 2021-2022 increased at 7 and 14 day after treatment recorded in mixture treatment with Malathion + KZ oil 87.26, 90.3 and 91.06 %followed by Malathion 57% EC only. Whereas, the lower effect was recorded by KZ oil. On the other hand, the *F. virgata* reduction in population when used Bio-ranza after 5 days was low (62.04, 66.21 and 72.43%) and (51.52, 54.24 and 68.24 % when used Bio-var)**.** Generally, after 5 days the reduction percentage in *F. virgata* population was low then it was

increased and reached its highest rate of reduction 14 days. **(El-Gepaly *et al*., 2018)** who mentioned that, Malathion had highest effectiveness against *F. varigata* different individual stages after 14-21 days' post treatments. While, (**Malsam *et al*., 2002 and Wraight *et al*., 2016**) who studied the effects of some entomopathogenic fungi against Whiteflies and *Aphis gossypii* and they mentioned that, these fungicides play very important role in suppressing the population of these pests.

As well as,(**Rezk *et al*., 2019**) who studied the effects of some insecticides belonging to mangy chemical groups were sulfoxaflor, abamectin + thiamethoxam, spirotetramat, thiamethoxam, imidacloprid, buprofezin, and pymetrozine, to study the effects of previous treatments on *P. solenopsis* mealybugs which belonging to family, Pseudococcidae and they recorded that, sulfoxaflor, abamectin + thiamethoxam and spirotetramat had highest reduction percentages of the *P. solenopsis* population after 14-21 days of application. Whereas, (**Ujjan *et al*., 2015**) who mentioned that, *Metarhizium anisopliae* was very efficient against Pseudococcidae mealybugs. Finally **(Haris, 2021)** who studied the effects of some insecticides on the cotton mealybug, *P. solenopsis* and he found that all treatments were effective on immature stages (Nymphs) of *P. solenopsis* than adults as well as, the reduction percentages was as high as possible after 14 days post treatments in addition to, mentioned that, mixture of KZ oil 95% EC (mineral oil) and Actellic 50 %EC was the most effective treatments followed by Actellic 50 %EC alone, While, the *Beauveria bassiana* and *Metarhizium anisopliae* recorded high effect after 7-14 days. Also, he recorded that the *Beauveria bassiana* and *Metarhizium anisopliae* treatments were considered safe treatments in controlling mealybugs.

Table (2). Statistical analysis based on multiple regression and correlation coefficient representative the impact of climatic factors on *F. virgata* (Cockerell) on Coffee plants during seasons 2020-2021 and 2021-2022

Weather factors	Simple correlation		Regression values			Explained variance%
	r	b	S. E ±	t	Prob.	
			2020-2021			
Max. Temp.	0.404487	5.609006	34.4126	0.162993	0.87216	57%
Min Temp.	0.53795	81.99451	42.09186	1.94799	0.06559	
RH%	0.359177	39.73856	10.17166	3.906791	0.000875	
F value			11.15			
			2021-2022			
Max. Temp.	0.376897	10.5739	59.29317	0.17833	0.860256	31.14%
Min Temp.	0.513309	87.33372	70.75655	1.234285	0.231404	
RH%	0.276771	24.71468	15.87827	1.55651	0.13527	
F value			4.46			

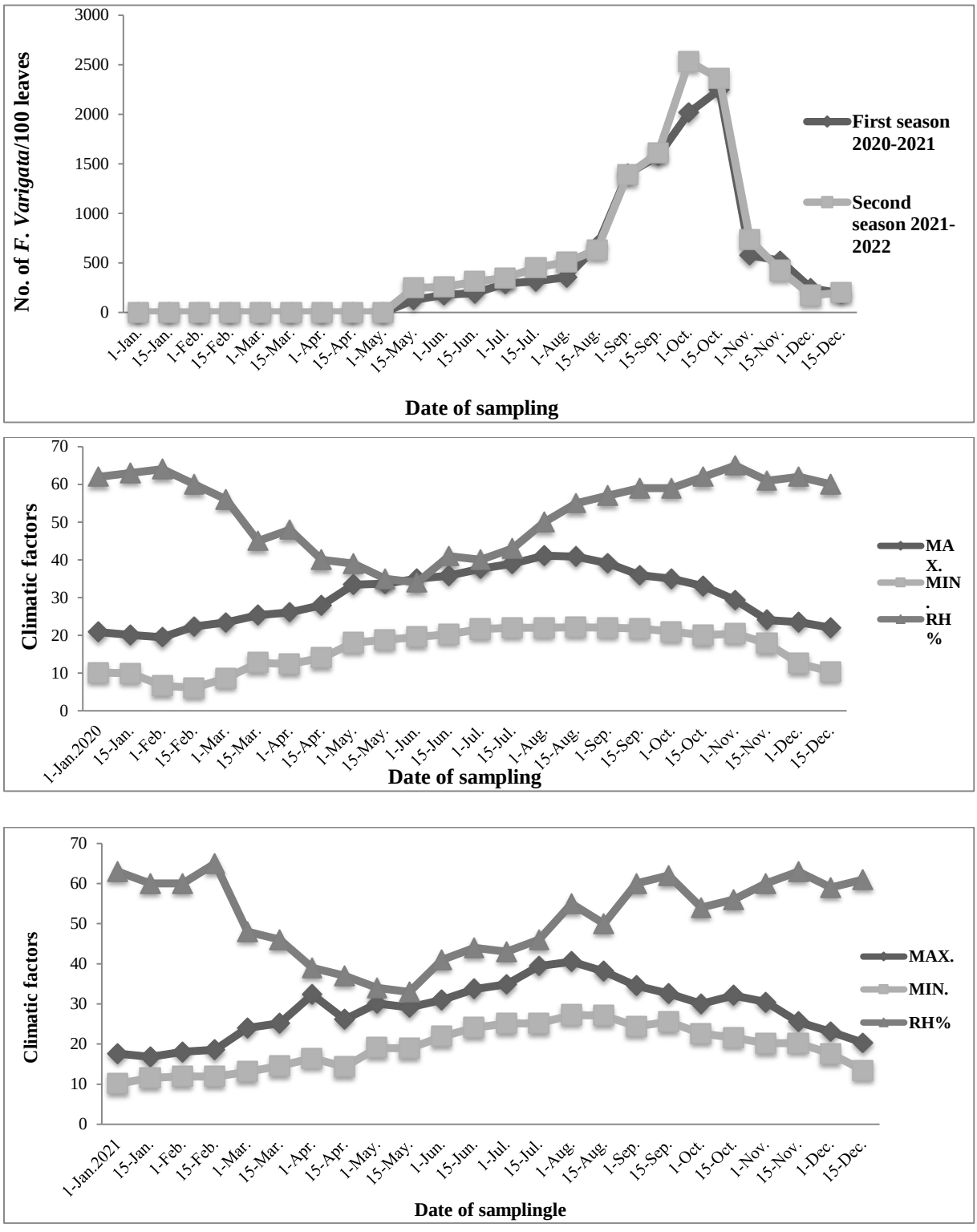

Fig. (1). Population density of the striped mealybug, *F. virgata* (Cockerell) with corresponding counts of climatic factors during second seasons of study2020-2021 and 2021-2022 at Giza governorate.

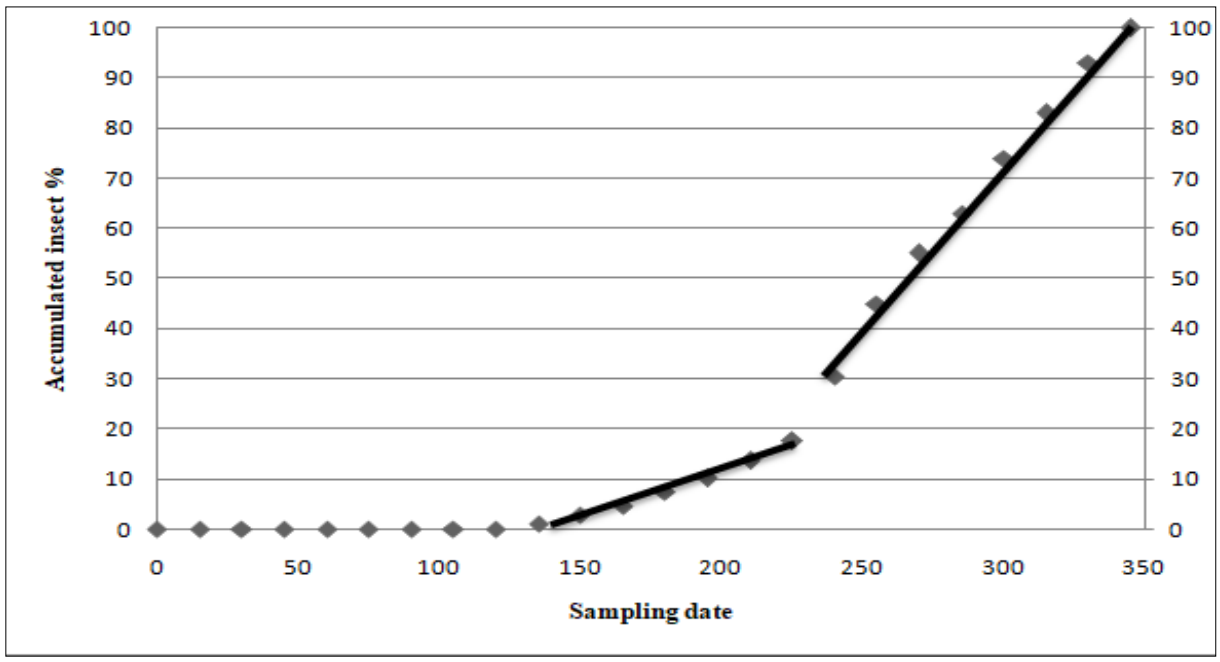

Fig. (2). Generations of *F. virgata* on Coffee trees (*C.arabica* L.) during first season2020-2021

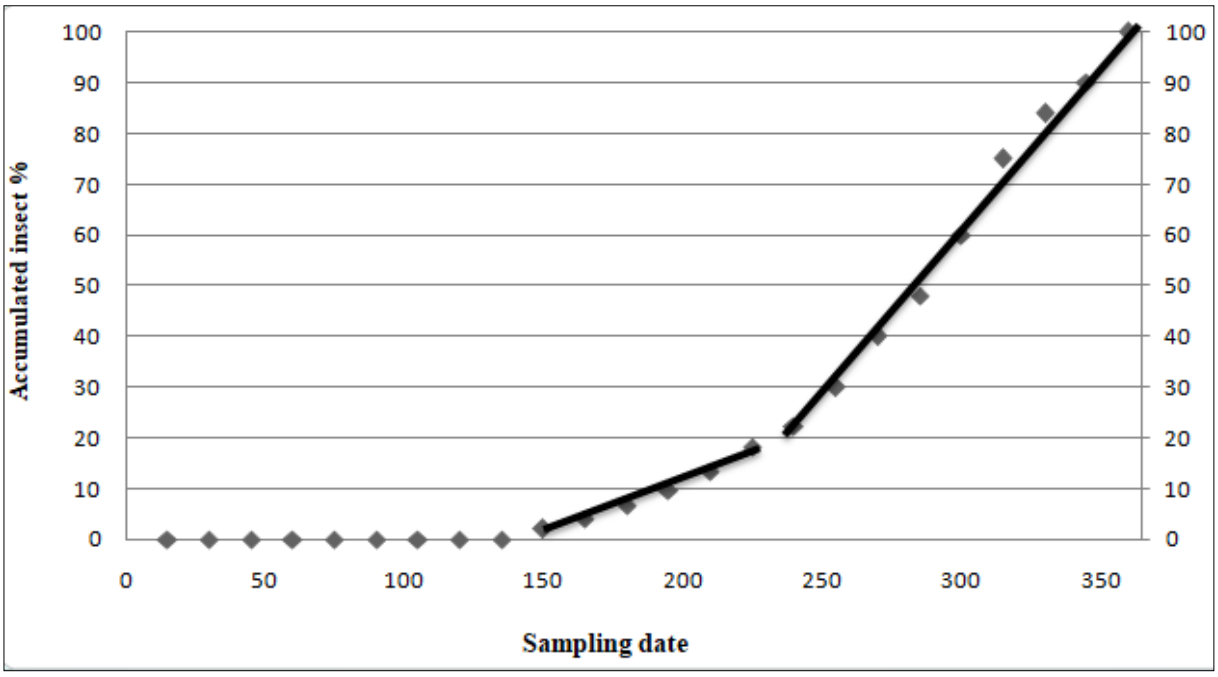

Fig. (3). Generations of *F. virgata* on Coffee trees (*C. arabica* L.) during second season2021-2022

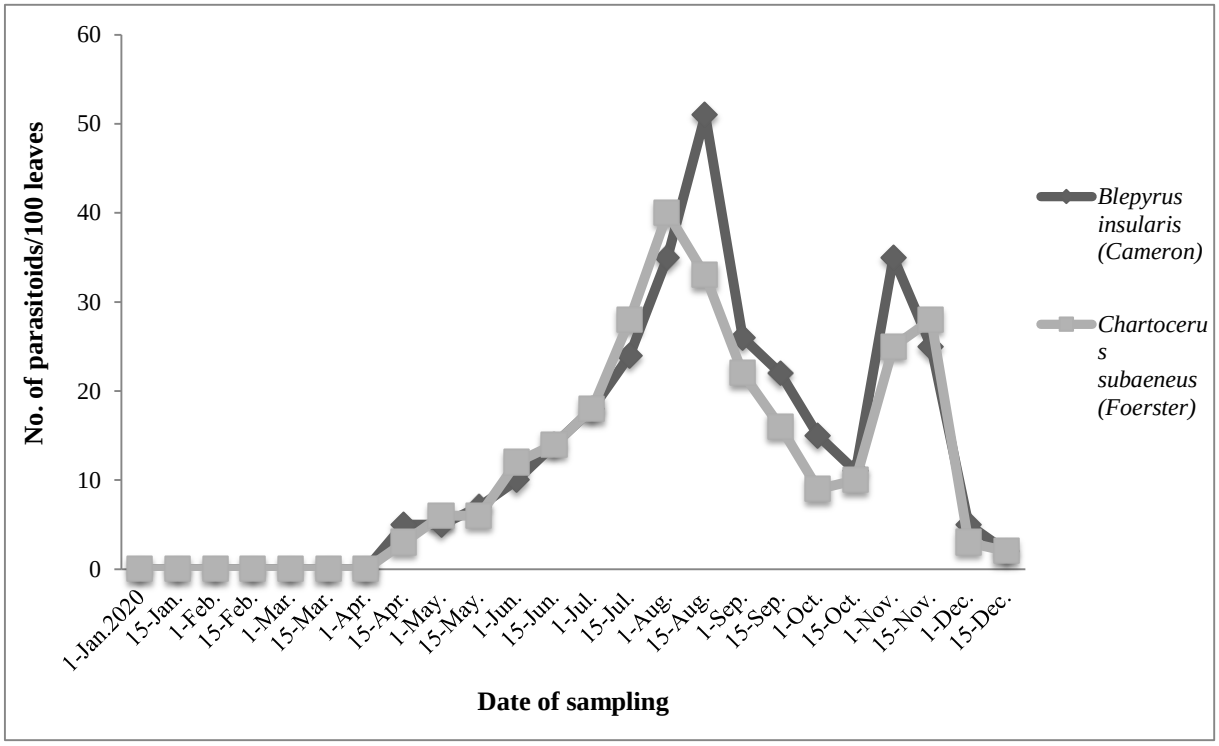

Fig. (4). Population density of parasitoids on *F. virgata* Cockerell Coffee trees during first season2020-2021.

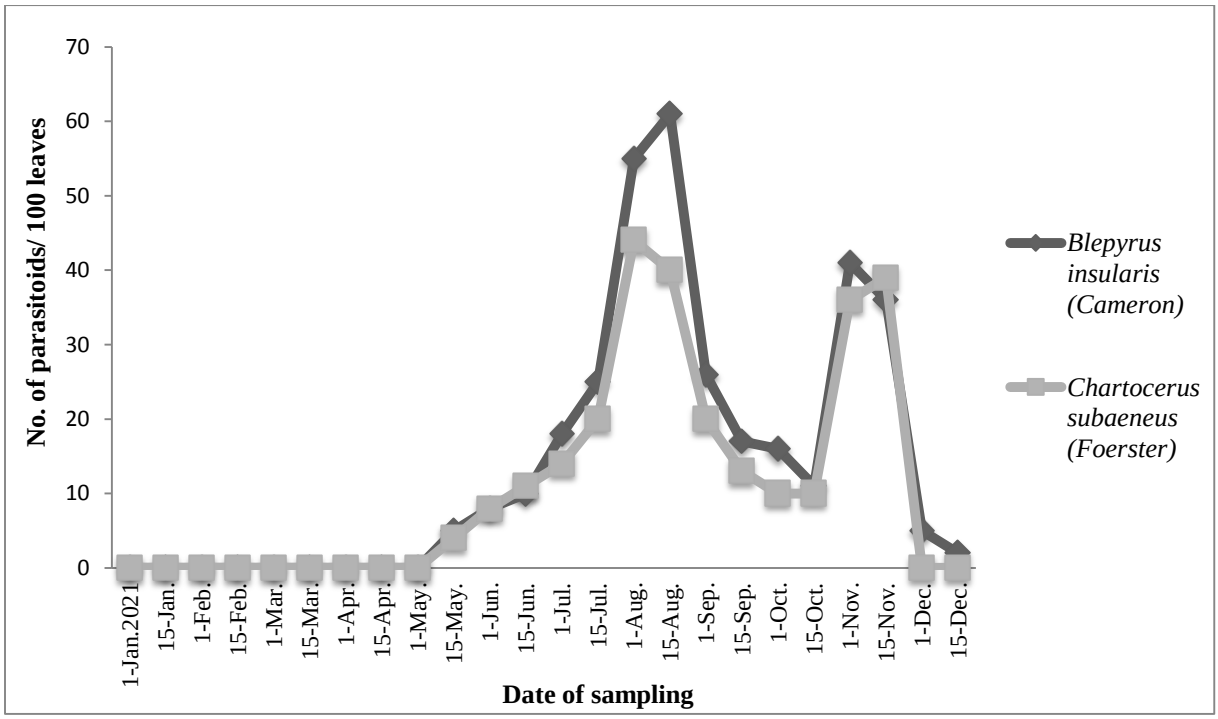

Fig. (5). Population density of parasitoids on *F. virgata* (Cockerell) Coffee trees during second season 2021-2022.

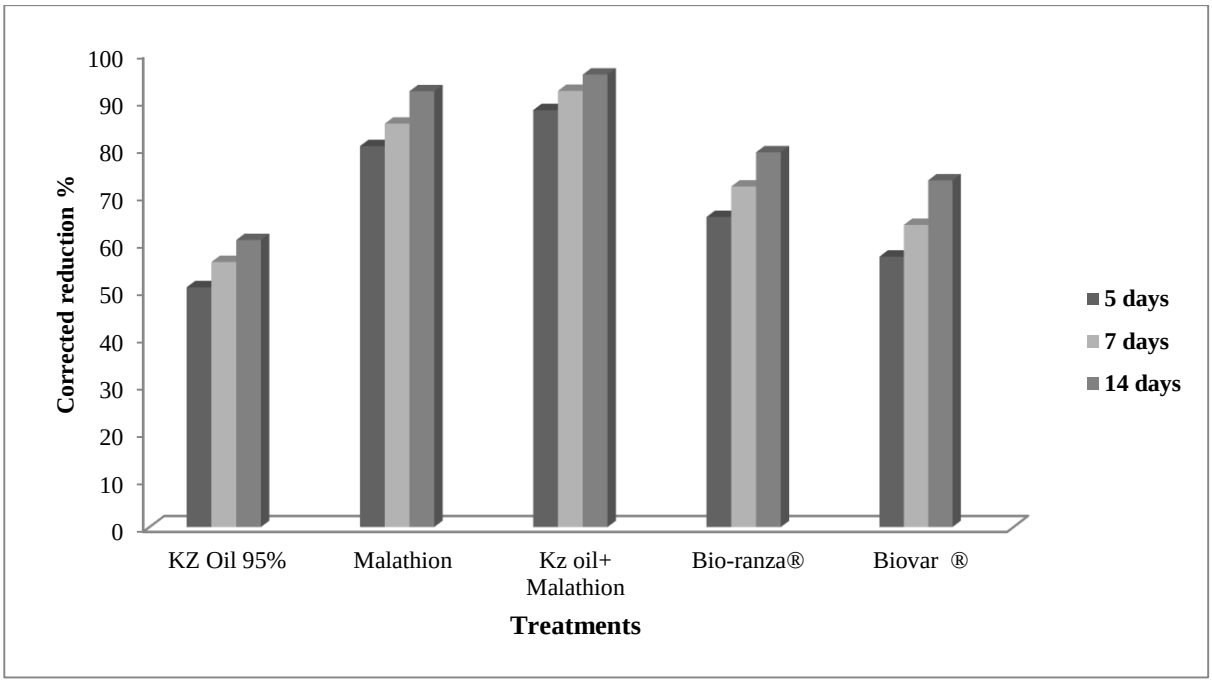

Fig. (6). % reduction of some treatments against *F. virgata* on Coffee trees (*C. arabica* L.) during first season 2020-2021.

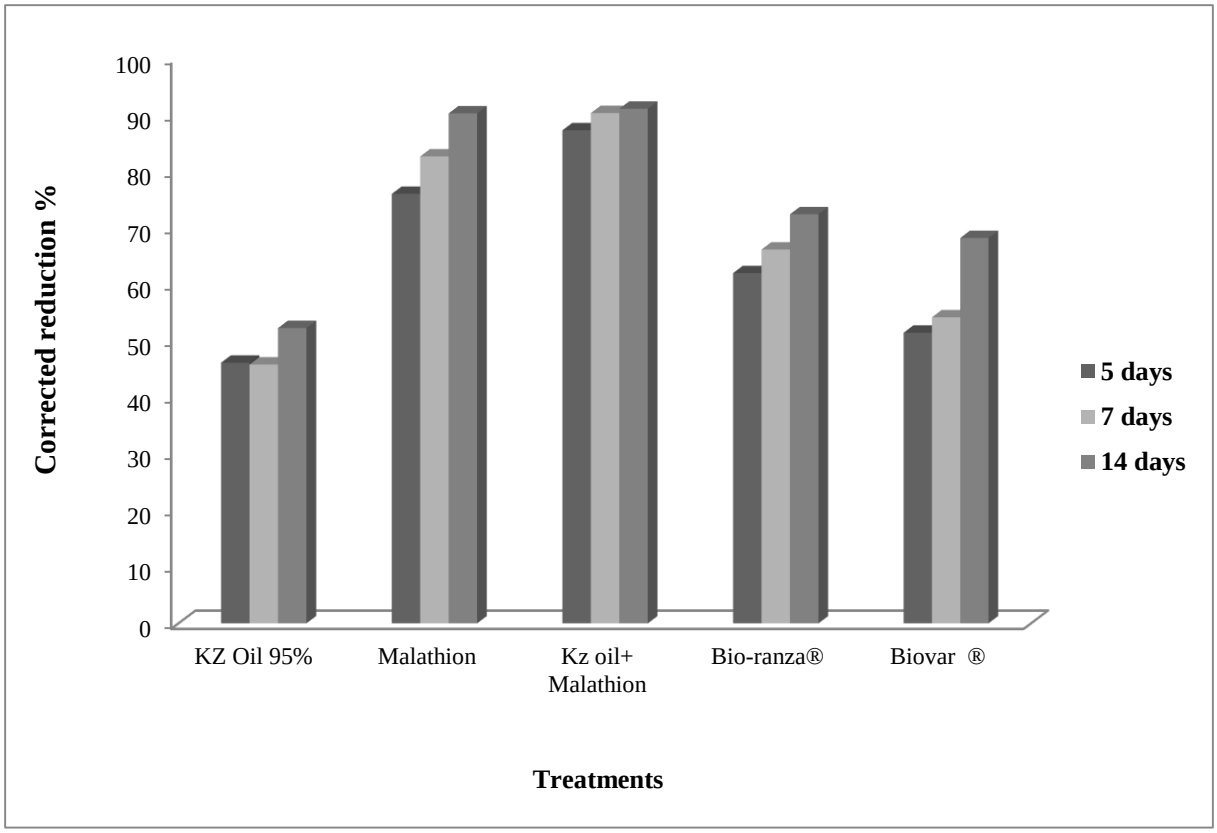

Fig. (7). % reduction of some treatments against *F. virgata* on Coffee trees (*C. arabica* L.) during second season 2021-2022.

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