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RESEARCH ARTICLE

The mealybug is a dangerous pest that attacks Sapota, *Manilkara zapota* (L.) tropical trees under Egyptian Agro-ecosystems

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Abstract

Sapota, *Manilkara zapota* trees are very important tropical fruit which cultivated in many countries in the world. In recent years, Sapota trees have been cultivated in Giza, Egypt, because of their great nutritional importance. Sapota trees were attacked by many types of mealybugs, as five types were monitored and recorded: *Maconellicoccus hirsutus*, *Planococcus citri*, *Ferrisia virgata*, *Phenacoccus solenopsis* and *Icerya seychellarum*. The results of this investigation revealed that, *M. hirsutus* was the most dangerous of these insect pests that attack Sapota trees during the study seasons and we found that, the *M. hirsutus* peak population was recorded in early November 1701 individuals / 100 leaves during 2020-2021 and 1513 individuals / 100 leaves in 2021-2022 season. Also, we recorded three species of natural enemies were associated with *M. hirsutus* on Sapota trees. On the other hand, the impact of various temperatures on some biological aspects on immature stages and adult stages of *M. hirsutus* were studied. Durations of eggs, three nymph instars, pre -oviposition period, oviposition period and post- oviposition period were longest at 15° C and were lowest at 25 and 30° C. As well as longevity of females and males were lowest at 25 and 30° C and longest at 15°C. Fecundity of females was increased with increasing in temperatures. These results are important for improving the control of this insect and must be taken into account when developing an integrated pest management program.

Keywords: Biological aspects; *Maconellicoccus hirsutus*; Sapota trees.

1. Introduction

Sapota trees belong to the (Family: Sapotacae), which contains about 800 species, most of them are tropical fruit trees, and the most important of them is *Manilkara zapota* (L.) Which its native region was tropical Americas, especially Mexico; the original region of Sapota (Balerdi *et al.*, 2013) from which it spread too many other subtropical and tropical regions, (Gilly. 1943). In 2002, Sapota was successfully cultivated in Giza, Egypt, as a kind of fruiting evergreen fruit tree (Fayek *et al.*, 2012). Sapota fruits are used commercially for preparing several value-added products such as Sapota jam, Sapota milk shake, Sapota cheese, Sapota butter, Sapota candy, Sapota slices, sapota biscuit, sapota shrikh and, sapota pulp, sapota ice cream, dehydrated Sapota slices, Sapota juice, Sapota chocolate and Sapota nectar, (Patel *et al.*, 2022; Singh *et al.*, 2021). Insect pests cause damage to Sapota trees, the most important insect pests of Sapota trees are, Fruit borer (*Heterographisbengalella*), Peach fruit fly (*Bactrocera zonata*), The sapodilla seed borer, (*Trymalitis margarias*), Mealy bugs (*Rastrococcus iceryoide*, *Planococcus citri*, *M. hirsutus*).One of the most damaging Sapota's pests are Mealybugs and scale insects (super-Family *Coccoidea*) which includes many families (*Pseudococcidae*, *Margarodidae* and *Coccidae*)

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which causing several damaged reducing yield of sapota orchards due to reduce the nutritional, Economic and Marketing value (Deshmukh, 2001and Mani *et al*., 2008). Mealybugs (Hemiptera: *Pseudococcidae*) are important plant insect pests all over the world and including about 5000 species of mealybugs have been identified from 246 plant groups (Arve *et al*., 2012). In recent years, *M. hirsutus* (green) (Hemiptera: Mealybug) has become one of the most injurious species of mealybugs, which has appeared in Egypt and is rapidly spreading and becoming a serious pest in Egyptian orchards (Abd- Rabou, 2000) and (Mousa, 2001). Therefore, the main purpose of this work included these points: survey of the most popular scale insects and mealybugs and their associated natural enemies on Sapota, Seasonal population of *M. hirsutus* and its predators and parasitoids during two seasons of study on Sapota also, studied some biological aspects on *M. hirsutus* under laboratory conditions. This study is considered the first in Egypt on Sapota trees to find out the extent of the danger of the mealybug, which is a major obstacle to the expansion of the cultivation of Sapota trees.

2. Materials and methods

2.1. Study area

Field experiments were conducted in the experimental research garden of the Horticultural Research Institute, Agricultural Research Center, Giza Governorate, Egypt. Where tropical Sapota fruit trees are cultivated in this region and the study was conducted during two consecutive seasons 2020-2021 and 2021-2022.

2.2. Mealybugs Sampling

A Survey of mealybugs was carried out on six Sapota trees, and Sample sizes of 100 leaves were randomly taken from each orchard represent the four cardinal directions and core of the trees. The samples were bi-monthly during two seasons of the study from January 2020 to December 2022.The Sapota trees were received some agricultural practices and weren't subjected to any chemical control. These samples were immediately 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 predators and parasitoids species were related and associated with insects and mealybugs, were identified and recorded. Samples of infested leaves were put in cartoon boxes and kept under 25-30°C and 65-70% R.H. for emerging. All natural enemies were identificated by Prof. Dr. Angel R. Attia, Plant Protection Research Institute, Agricultural Research Center, Giza, Egypt.

2.3. Seasonal populations of M. hirsutus and Natural enemies

The period of Seasonal populations of hibiscus mealybug, *M. hirsutus* on sapota and its associated natural enemies were carried out during two successive years from January 2020 to December 2022. The estimated number and durations of annual generations of pink hibiscus mealybug, *M. hirsutus* (Green) on white Sapota, *M.zapota* (L.) Van Royen was estimated by using the formula of Audemard and Milaire (1975) and Jacob (1977). Six trees were nearly on size, age. Samples were taken at 14-day intervals also, size of this sample were 100 leaves were taken randomly from orchard through two years of this study.

2.4. Biological study of M. hirsutus

Has been brought *Solanumtuberosum* L., red Potato tubers var. Spunta were carefully rinsed in tap water before placed it on moistened plastic dishes 30cm. Water was sprayed on the plastic plates every day to keep them moist and encouraging sprouting. Within two weeks days, the potatoes had sprouted 3-4 cm. The insects were then transferred to the potatoes sprouts by using small brush and grown in the laboratory at 26°C, 65±5% RH and a photoperiod of 12 hours.

Female of mealybugs were transferred on potatoes sprout for to laying eggs. New crawlers developed and beginning to feed, growing into adults. With using a fine camel hairbrush, the freshly new adult females were separated and placed on new potato sprouts and keeping it under the previous laboratory conditions. The biological experiment continued until the death of the adult female on the host. Number of eggs, crawlers and adults were monitored and recording by using a stereomicroscope. In this biological experiment, new second-generation crawlers were used. The crawlers were observed daily by the aid of binocular microscope to establish the durations of nymphal stages. As well as, the preoviposition, oviposition, postovipostion periods, longevity and life cycle for females were studied. Eggs of *Maconellicoccus hirsutus*were counted by using binocular microscope to determine fecundity and fertility of females. The effect of three constant temperatures 15, 25 and 30°C and 65 ± 5% RH and a photoperiod 12 hrs reared under laboratory conditions was examined. One gravid female was released / tray it was each treatment had three replicates.

2.5. Statistical Analysis

Significance of the developing of immature stages and adults of *M. hirsutus* (Green) at three constant temperatures under laboratory conditions was determined by one – way ANOVA (analysis of variance). The mean values were compared using Turkey's test at the (P < 0.05, LSD) level of significance. The adult longevity was analyzed by two-way ANOVA. Statistical analyses were run in (SPSS for Windows version 16, Chicago: SPSS Inc.)

3. Result and discussion

3.1. Survey of mealybugs and natural enemies

There were many species of scale insects and mealybugs were found on Sapota trees and attacked the Vegetative, flowering and Fruiting stages of the trees (Mani *et al.* 2008) and (García-M *et al*., 2016). Data in Table, (1) showed that, there were four species from family (Pseudococcidae) were *M. hirsutus* (Green), *Planococcuscitri* (Risso) *Ferrisiavirgata* Cockerell and *Phenacoccussolenopsis*Tinsley were recorded during June-November and *Iceryaseychellarum* (Westwood) from family (Monophlebidae) during period fron May-October and two species of (Coccidae) *Milviscutulusmangifera* (Green) and *Coccusviridis* (Green) were recorded in June-November, (Dix-Luna, *et al*. 2018).Also, data in Table, (2) showed that, there were various species of predators and parasitoids associated with scale insects and mealybugs. The species of predators were recorded, *Scymnus syriacus* (Mars.), *Rodolia cardinalis* (Mulsant), *Hyperaspis vinciguerrae* Capra *Chrysoperla carnea* (Steph.) and *Orius albidipennis* (Reuter) belonging to three families were, Chrysopidae (Neuroptera), Anthocoridae and Coccinellidae. (Coleoptera). Whereas, seven species of parasitoids were recorded, *Leptomastidea abnormis* (Girault), *Chartocerus subaeneus* (Foerster), *Blepyrus insularis* (Cameron), *Anagyrus kamali* Moursi, *Aenasius arizonensis* (Girault), *Coccophagus scutellaris* (Dalman), *Metaphycus flavus* (Howard), *Leptomastidea abnormis* (Girault) and *Coccophagus scutellaris* (Dalman) belong to three families were *Signiphoridae*, *Aphelinidae* and *Encyrtidae* (Hymenoptera), These results were in agreement with those obtained by (Abd-Rabou and Hendawy, 2005; Attia, 2012; Adly *et al*., 2016) they indicated that, there were various species of natural enemies were recorded on many mealybugs speciesin Egyptian orchards. These natural enemies were *Scymnussyriacus* (Mars.), *Anagyruskamali* Moursi, *Rodoliacardinalis* (Mulsant), *Hyperaspisvinciguerrae* Capra *Chrysoperlacarnea* (Steph.)

Table 1. Scale insects and mealybugs infested Sapota, *M. zapota* (L.) during two successive seasons2020-2021/ 2021-2022.

Pests	Scientific name	The infested crop stage	Period of Peaks occurrence	Status
Pink-hibiscus mealybugs	*Maconellicoccus hirsutus*(Green)	Vegetative, flowering and Fruiting	June-November	Major
citrus mealybugs	*Planococcus citri* (Risso)			Major
Striped mealybug	*Ferrisia virgata* Cockerell			Major
Cotton mealybugs	*Phenacoccus solenopsis* Tinsley			Major
Seychellarum mealybugs	*Icerya seychellarum* (Westwood)	Vegetative, flowering and Fruiting	May-October	Major
Soft green scales	*Coccus viridis* (Green)	Vegetative and fruiting	June-November	Major
Mango shield scale	*Milviscutulus mangifera* (Green)			Major

Table 2. List of natural enemies associated with scale insects and mealybugs Sapota, *M. zapota* (L.) which infested Sapota during two successive seasons2020-2021 /2021-2022.

Order	Family	The associated natural enemies	Stage	Host
Coleoptera	Coccinellidae	*Scymnus syriacus* (Mars.)	Larvae & Adults	*Ferrisia virgata* Cockerell
Hymenoptera	Encyrtidae	*Leptomastidea abnormis* (Girault)	Adults	
Hymenoptera	Signiphoridae	*Chartocerus subaeneus* (Foerster)	Adults	
Hymenoptera	Encyrtidae	*Blepyrus insularis* (Cameron)	Adults	
Hymenoptera	Aphelinidae	*Anagyrus kamali* Moursi	Adults	*Maconellicoccus hirsutus*(Green)
Neuroptera	Chrysopidae	*Chrysoperla carnea (Steph.)*	Larvae & Adults	
Hymenoptera	Encyrtidae	*Leptomastidea abnormis* (Girault)	Adults	
Coleoptera	Coccinellidae	*Scymnus syriacus (Mars.)*	Larvae & Adults	
Hymenoptera	Aphelinidae	*Anagyrus kamali* Moursi	Adults	*Phenacoccus solenopsis* Tinsley
Hymenoptera	Encyrtidae	*Aenasius arizonensis* (Girault)	Adults	
Neuroptera	Chrysopidae	*Chrysoperla carnea (Steph.)*	Larvae & Adults	
Coleoptera	Coccinellidae	*Hyperaspis vinciguerrae Capra*	Larvae	
Coleoptera	Coccinellidae	*Rodolia cardinalis* (Mulsant)	Larvae	*Icerya seychellarum* (Westwood)
Neuroptera	Chrysopidae	*Chrysoperla carnea* (Steph.)	Larvae & Adults	
Coleoptera	Anthocoridae	*Orius albidipennis* (Reuter)	Adults	
Hymenoptera	Encyrtidae	*Metaphycus flavus (*Howard*)*	Adults	*Coccus viridis* (Green)
Neuroptera	Chrysopidae	*Chrysoperla carnea (Steph.)*	Larvae & Adults	
Hymenoptera	Aphelinidae	*Coccophagus scutellaris* (Dalman)	Adults	

and *Oriusalbidipennis* (Reuter), *Metaphycusflavus* (Howard), *Leptomastideaabnormis* (Girault) and *Coccophagusscutellaris* (Dalman) during two successive seasons 2020-2021 and 2021-2022.

3.2. Fluctuations of M. hirsutus and natural enemies

Data in Fig. (1) indicated that, the total population of *M. hirsutus* (Green) started in January where 66 and 62 individuals/ 100 leaves, respectively during two seasons of study were. Thereafter, the population increased to reach the peak of population that was recorded in early November 1701 individuals/100 leaves during 2020-2021 and 1513 individuals/100 leaves. Moreover, the population decreased in December which recorded 344 and 285 individuals/100 leaves, respectively during two seasons of study. With regard to this data in Fig. (2 and 3) during the first year of study we were recorded one species of predators were associated with *M. hirsutus* (Green) on Sapta trees. The predators were *Scymnussyriacus* (Mars.), it was had three peaks were recorded in June, September and October when, the density was 12, 41 and 56 individuals/ 100 leaves, respectively during first season of study. Also, it had three peaks during second year of study, the first one occurred in July, the second in October and the last one was in November when, the density were 15, 74 and 84 individuals/ 100 leaves, respectively. As shown in Fig. (2 and 3), there were two species of parasitoids were associated with *M. hirsutus* (Green) on Sapota leaves. *Leptomastidea abnormis* (Girault) had three peaks August, October, and November during two seasons of study; the highest population density was in November 76 and 103 individual / 100 leaves, respectively. As well as *Anagyruskamali* Moursi had also, three peaks were early August, mid –September and mid-November when, the population density were 10, 19 and 22 individuals/ 100 leaves during first seasons of study 2020-2021. Also, it had three peaks were mid-July, mid-September, and mid-November when the population densities were 22, 40 and 61 individuals, respectively during second season 2021-2022, Fig. (3).

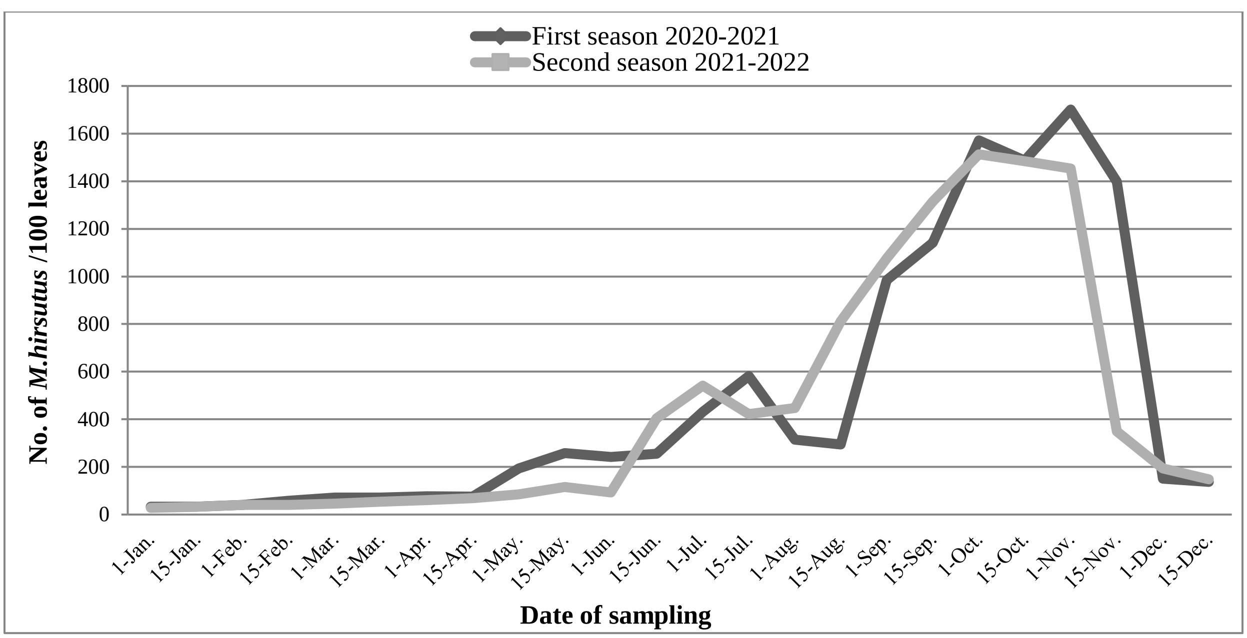

Figure 1. Population density of different stages of *M. hirsutus*on Sapota, *M. zapota* (L.), during two seasons 2020-2021/ 2021-2022.

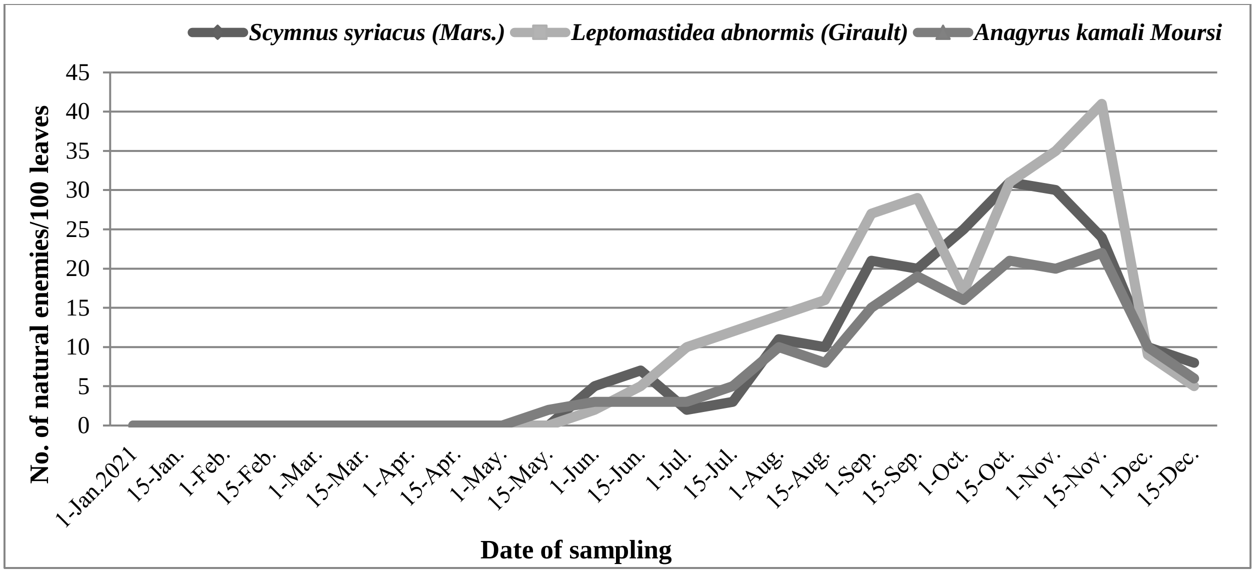

Figure 2. Population density of different natural enemies associated with, M. *hirsutus* on Sapota, *M. zapota* (L.) Van Royen during first season 2020-2021.

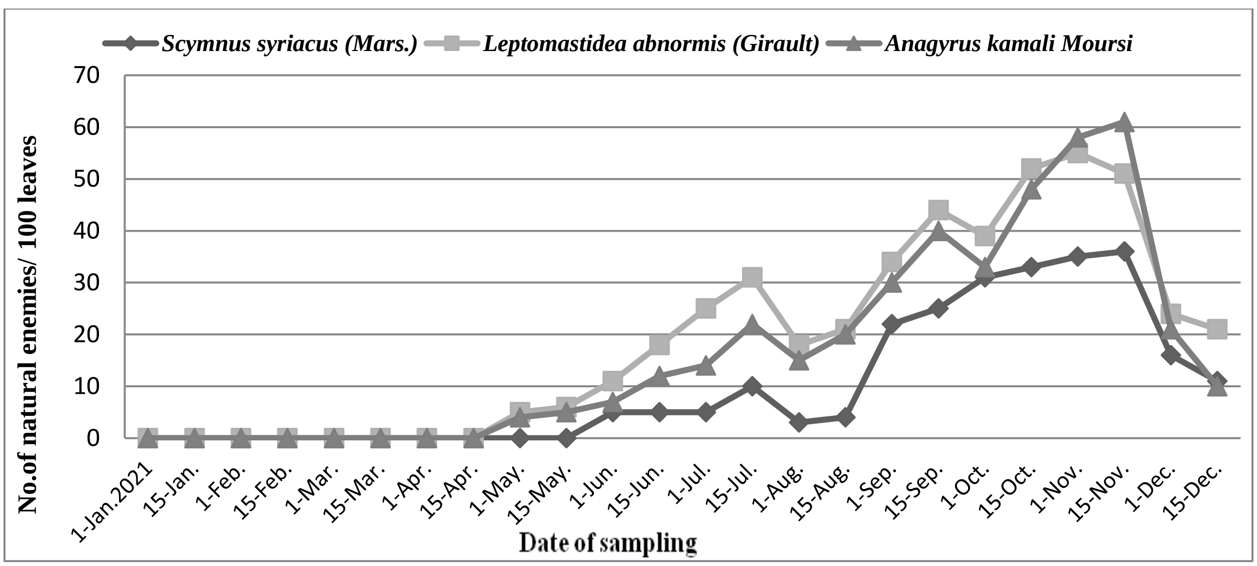

Figure 3. Population density of different natural enemies associated with, *M. hirsutus* on Sapota, *M. zapota* (L.), Van Royen during second season2021-2022.

These results were in agreement with those obtained by (El-Sherbeni, *et al.*, 2010) who stated that, *Anagyruskamali* was recorded with *M. hirsutus* (Green). It was found during March to December and recorded the highest populations of *A. kamali* occurred in September.

Data in Fig. (4) indicated that, *M. hirsutus* (Green) had three overlapping generations in the first seasons 2020-2021. However, the first generation appeared during the beginning of January to until early May about 135 days and it considered the longest generations with population of 442 individuals /100 leaves. The second generation extended from Mid- May to Mid-August about 90 days and it was the lowest generations with population of 1989 individuals/100 leaves. At last, the third generation was appeared from Early September to mid-December about 120 days and the population size was 7616 individuals/100 leaves.

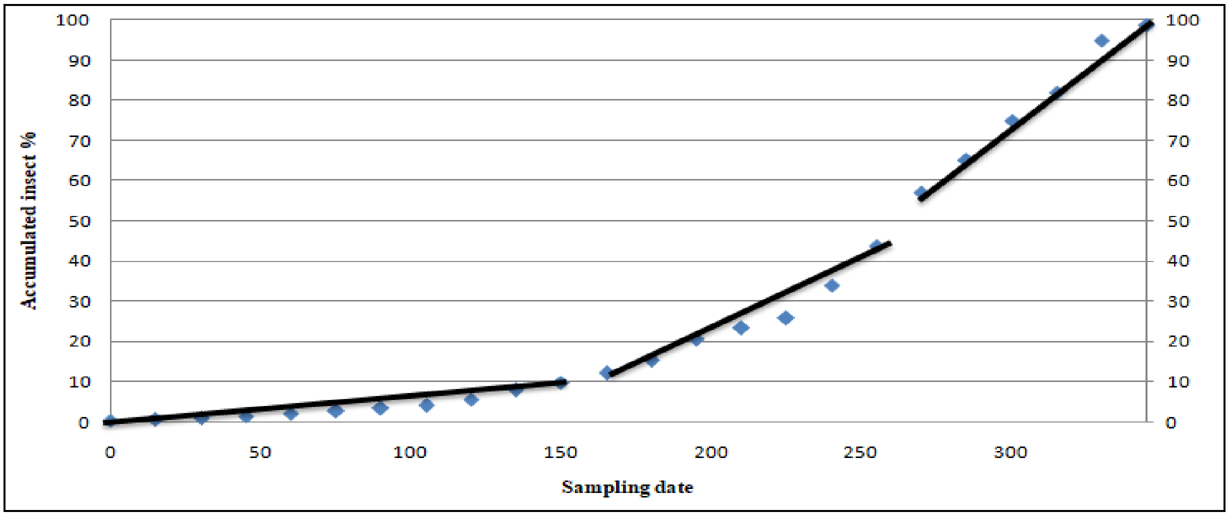

Figure 4. Generations of *M. hirsutus* on Sapota, *M. zapota* (L.) during first season2020-2021.

As shown in Fig. (5). Also, there were three generations during the second seasons 2021-2022. The first generation was the longest (180 days) but, second and third generations were shortest (90 and 90 days). However, the first was during Early January to until Mid-June (about 576 individuals/100 leaves). The second generation extended from Early- July to Mid-September (about 3433 individual's individuals/100). The last generation appeared from Early-October to Mid-December with 7559 individuals/100 leaves. These results were agreed with (Manjunath, 1985) who mentioned *M. hirsutus* (Green) had 2-3 generations/year in India on grapevine. The first one was From February to March and the second was during November to February and (Osman, 2012) mentioned that*M. hirsutus* (Green) had three generations under laboratory condition. The first generation was the biggest one. As well as, (Goolsby *et al*. 2002) mentioned that, the lowest populations densities of *M. hirsutus* (Green) were in rainy winter and the increasing on populations was in summer and autumn seasons. Also, (Angu *et al.*, 2017) indicated that, lowest population of *M. hirsutus* (Green) was in July and mid of January.

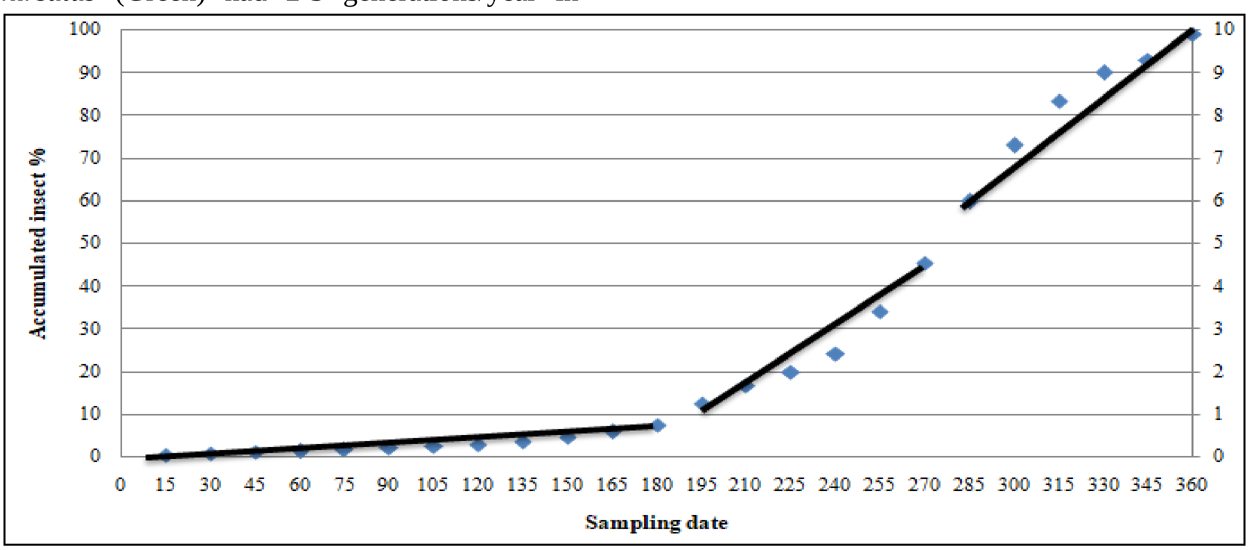

Figure 5. Generations of *M. hirsutus* on Sapota, *M. zapota* (L.) during second season2021-2022.

3.3. Biological aspects of M. hirsutus

Impact of three degrees of temperature (15, 25, and 30˚C) on the development of immature stages of *M. hirsutus* (Green) is presented in Table (3). The longest incubation periods for eggs were 7.87 at 15˚C and 2.11 and 5.90 days at 25 and 30˚C and it increased significantly with decreasing in temperature. Also, the longest duration of 1st, 2nd and 3rd nymphal stages were 10.32, 13.54 and 16.39 days at 15 °C. In contrary, the shortest durations were 4.04, 5.53 and 7.11 days at 30 °C. While the total durations of nymphal stages of *M. hirsutus* (Green) reared under 15˚C was 40.25 and 24.69, 11.68 days at 25 and 30˚C.

Table 3. Developmental durations of *M.hirsutus*immature stages at three constant temperatures and 65 ± 5% RH and a photoperiod 12 hrs reared under laboratory conditions.

Temp.	No. of Rep.	Eggs incubation (Days) Mean ± SE	Nymphal period (days) Mean ± SE			Total nymphal stage Mean ± SE	F
			1st	2nd	3rd		
15°C	10	7.87± 0.57a	10.32± 0.37a	13.54± 0.15a	16.39± 0.19a	40.25± 0.26a	12.34
25°C	10	5.90± 0.46b	7.29± 0.21b	8.12± 0.25b	9.28± 0.24b	24.69± 0.41b	5.02
30°C	10	2.11± 0.38c	4.04± 0.17c	5.53± 0.37c	7.11± 0.18c	11.68± 0.56c	2.72

Values (mean ± SE) followed by different letters within a column are significantly different based on Tukey's test with $p < 0.05$.

Temperature had highly significant effect on incubation period and durations of nymphal stage. Data on Table (4) indicated that, the longest period of Pre-oviposition was 10.98 days at 15˚C and 7.56, 5.03 days at 25 and 30 °C. The ovi-position period was 29.19 days at 15˚C and 18.65 and 11.71 days at 25 and 30 °C. Also, the post-oviposition period was 14.49, 11.15 and 6.88 days at 15˚C, 25 ˚C and 30˚C. Whereas the longest Female longevity was 30.54 days at 15˚C and the lowest was at 23.01 and 20.76 days at 25 and 30 °C. As well as, the female fecundity is presented in Table (4). The lowest mean female fecundity was 105.63 eggs at 30 °C, while at 25 °C, the mean female fecundity increased to 53.0 ± 10.17 eggs. On the contrary, the greatest mean female fecundity was 62.0 ± 7.19 168.32 eggs and 207.44 eggs at 30 °C. It was clear that, the greatest mean female fecundity founded at 30 °C. The On the contrary, the lowest sex ratio (females %) was 5 4.57 and 68.09 % at 25 and 30 °C, while at 15 °C, the mean sex ratio was 37.08 %.

Table 4. Developmental durations of *M.hirsutus* females at three constant temperatures and 65 ± 5% RH and a photoperiod 12 hrs reared under laboratory conditions.

Temp.	No. of Rep.	Pre-oviposition period	Ovi position period	Post-oviposition period	Longevity	Fecundity No. of eggs/female	Sex ratio (%) female	F
15°C	10	10.98± 0.21a	29.19± 0.38a	14.49± 0.12a	30.54± 0.92a	105.63± 18.54a	37.08± 0.28a	22.86
25°C	10	7.56± 0.34b	18.65± 0.44b	11.15± 0.28b	23.01± 1.41b	168.32± 27.36b	54.57± 0.67b	9.42
30°C	10	5.03± 0.26b	11.71± 0.17c	6.88± 0.41b	20.76± 1.09b	207.44± 40.11c	68.09± 1.12c	5.79

Values (mean ± SE) followed by different letters within a column are significantly different based on Tukey's test with $p < 0.05$.

There were highly significant effects of the tested temperatures on the longitivity, Fecundity and sex ratio of *M. hirsutus* (Green). On the other hands, Durations of different developmental stages of *Maconellicoccus hirsutus* (Green) males are obtained in Table, (5). The shortest mean of incubation period was 3.69 and 6.07 day at 30 and 25°C. At 15 °C, the mean incubation period was increased to 10.69 days. Therefore, the longest mean incubation period was at 15 °C. It was observable, that the incubation period decreased significantly with increasing of temperature. Also, the longest durations of immature stages (1st, 2nd, and 3rd) were 11.07, 11.87 and 14.28 days at 15°C, respectively. The lowest durations were 7.27, 5.90 and 5.44 days at 30 °C. Whereas, the longest durations of pupal stages were 17.55 °C at 15 and decreased at 30 °C 6.54 days. Also, the longitivity of males was decreased with increasing temperatures. Our findings agree with (Osman, 2012) who mentioned that *M. hirsutus* which reared on pumpkin fruits at different temperatures in the cages, *M. hirsutus* was completed development in 48 days at 25 °C and 29days at 27 °C. With the results of (Chong *et al*. 2008) who mentioned that the longest female longevity of *M. hirsutus* was at 27°C and it were 27 ºC (19.9 day), and 30ºC (19.5 day). They mentioned that, increasing of temperatures had significant effect on development of immature stages, males, and females under laboratory conditions, also, the most suitable temperatures on rearing *M. hirsutus*was 26°C. (Babu and Azam 1987).

Table 5. Developmental durations of *M. hirsutus* males at three constant temperatures and 65 ± 5% RH and a photoperiod 12 hrs reared under laboratory conditions.

Temp.	Durations (days) different developmental stages of *Maconellicoccus hirsutus* (Green) males Mean±SE.						
	Egg	1st	2nd	3rd	Pupae	Longtivity	F
15°C	10.69± 0.43a	11.07± 0.27a	11.87± 0.16a	14.28± 0.35a	17.55± 0.67a	2.55± 0.11a	13.46
25°C	6.07± 0.29b	8.08± 0.43 b	8.56± 0.31b	10.49± 0.51b	10.21± 0.54b	1.58± 0.15b	8.86
30°C	3.69± 0.21c	5.44± 0.51 c	5.90± 0.59c	727± 0.29b	6.54± 0.38c	1.08± 0.08c	7.81

Values (mean ± SE) followed by different letters within a column are significantly different based on Tukey's test with p < 0.05.

4. Conclusion

In this paper, the obtained results showed that Sapota trees were attacked by many species of scale insets and mealybugs. Five species of mealybuhs were recorded, *M. hirsutus*, *Planococcuscitri* (Risso) *Ferrisiavirgata* Cockerell and *Phenacoccus solenopsis* Tinsleywere recorded *Iceryaseychellarum* (Westwood) and two species of (Coccidae) *Milviscutulus mangifera* (Green) and *Coccus viridis* (Green). The most dangerous of these insect pests which attacks Sapota trees during seasons of study was *M. hirsutus*. We found that, the peak of population of *M. hirsutus* that was recorded in early November 1701 individuals/100 leaves during 2020-2021 and 1513 individuals/100 leaves. While the population lowest opoulation density was in December 344 and 285 individuals/100 leaves, respectively during 2020-2021 and 2021-2022. Also, we recorded one species of predators, was *Scymnus syriacus* (Mars.), it was had three peaks were recorded in June, September and October during first season of study and July, October and November during second season of study. Also, recorded two species of parasitoids, the first one is *Leptomastideaabnormis* (Girault) which had three peaks August, October, and November during two seasons of study. As well as Anagyrus kamali Moursi had also, three peaks were early August, mid –September and mid-November during first seasons of study 2020-2021. Also, it had three peaks were mid-July, mid-September, and mid-November during second season 2021-2022. Also, we recorded that, the effects of different temperatures in durations and development of immature stages (eggs and nymphs) and adults (females and males) of *M. hirsutus* was decreased with each increase of temperature. Whereas, durations of eggs, three nymph instars, pre -oviposition period, oviposition period and post- oviposition period were longest at 15° C and on the contrary were lowest at 25 and 30° C. As well as, the longtivity of females and males were lowest at 25 and 30° C and longest at 15°C. Also, the No. of eggs /female was increased with increasing temperatures. Sex ratio also, increased at 25 and 30° C. So, the most suitable temperatures for rearing *M. hirsutus* were 25- 30 °C under laboratory conditions. The previous results will help us how controlling this insect pests on orchards.

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5. References

Abd- Rabou, S. (2000). *'Parasitoids attacking the hibiscus mealybug Maconellicoccus hirsutus (Green) (Homoptera: Pseudococcidae) in Egyp',* Proceedings of the Scientific Conference of Agricultural Sciences, Faculty of Agriculture, Assiut University, Vol. II: 661 – 666.

Abd- Rabou, S. (2008). *'Update list of parasitoids attacking mealybugs (Hemiptera: Pseducoccidae) in Egypt',* Proceedings of the XI International Symposium on Scale Insect Studies (ISSIS XI). September 24-27, 2007. Oeiras, Portugal, pp. 235- 240.

Abd- Rabou, S., Hendawy, A. S. (2005). 'Updating nomination of the parasitoids of pink hibiscus mealybug, *Maconellicoccus hirsutus* (Homoptera: Pseudococcidae), in Egypt', *Egyptian Journal of Agricultural Research,* 83(3), pp. 1135-1139.

Adly, D., Fadl, H. A. A. A., Mousa, S. F. M. (2016). 'Survey and seasonal abundance of mealybug species, their parasitoids and associated predators on guava trees in Egypt', *Egyptian Journal of Biological Pest Control*, 26(3), pp. 567-664.

Attia, A. R. (2012). 'Hymenptrous parasitoids as a bioagents for controlling maybugs (Hemiptera: Pseudococcidae) in Egypt', *Egypt. Acad. J. Biolog. Sci.,* 5(3), pp. 183 - 192.

Angu, A. R., Reddy, C. N., Kumari, D. A., Ramesh, S. (2017). 'Seasonal incidence of mealybug *Maconellicoccus hirsutis* (Green) on grape', *Int. J. Curr. Microbiol. App. Sci.*, 6(2), pp. 1629-1635.

Audemard, H., Milaire, H.G. (1975). 'Le pieeage carpocapse (*Laspeyresia pomonella* L.) avec une pheromone sexuelle de synthese: premiers resultats utilisables pour 1 estimation des populations et laconduite de la lutte', *Ann. Zoll. Ecol. Anim.,* pp. 7 – 61.

Arve, S., Patel, K. G., Chavan, S. (2012). *'Phenacoccus solenopsis: The white menace to global agriculture: Population dynamics, Biology and Chemical control of mealybug, Phenacoccus solenopsis Tinnsley on Hibiscus rosa – sinensis',* LAP LAMBERT Academic puplishing, pp. 156.

Babu, T. R., Azam, K. M. (1987). 'Studies on biology, host spectrum and seasonal population fluctuation of the mealybug, *Maconellicoccus hirsutus* Green on grapevine', *Indian J. Hortic.,* 44, pp. 284-288.

Balerdi, C.F., Crane, J.H., Maguire, I. (2013). *'Sapodilla Growing in the Florida Home Landscape',* University of Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, EDIS. Cited from the Internet, http://edis. ifas.ufl.edu/pdf files/MG/MG05700.

Chong, J. H., Roda, A. L., Mannion, C. M. (2008). 'Life History of the Mealybug, *Maconellicoccus hirsutus* (Hemiptera: Pseudococcidae), at Constant Temperatures', *Environ. Entomol.*, 37(2), pp. 323- 332. Cloyd, R. A. 1999.

Deshmukh, D. V. (2001). *'Varietal screening of sapota against pest complex, comparative biology of Anarsia achrasella Bradley and bio-efficacy of chemical insecticide against bud boring insects of sapota',* M.Sc. (Agri.) Thesis submitted to Gujarat Agricultural University, Navsari, Gujarat.

Dix-Luna, o.j., Montes-Rodríguez, j.m., Kulikowski, J., Takumasa Kondo, T. (2018). '*Alecanochiton marquesi* (Hemiptera: Coccomorpha: Coccidae), a new record for Colombia and Costa Rica, and description of its first-instar nymph', *Caldasia*, 40(2), pp. 246-254.

El-Sherbeni, A. E., El-Hawary, I. S., Farrag, Z. S., Hendawy, A. S., Mashaal, R. E. (2010). 'Ecological studies on insect parasitoids attacking pink hibiscus Mealybug, *Maconellicoccus hirsutus* (Hemiptera: Pseudococcidae) at Kafr- elshikh Governorate', *J. Plant Prot. and Path., Mansoura Univ.*, 1 (11), pp. 909 - 920.

Fayek, N.M., Monem, A.R., Mossa, M.Y., Meselhy, M.R., Shazly, A.H. (2012). 'Chemical and biological study of *Manilkara zapota* (L.) Van Royen leaves (Sapotaceae) cultivated in Egypt', *Pharmacognosy Research*, 4(2), pp. 85-91.

Goolsby, J.A., Kirk, A.A., Meyerdirk, D.E. (2002). 'Seasonal phenology and natural enemies of *Maconellicoccus hirsutus* (Hemiptera: Pseudococcidae)', *Australia Fla. Entomol.,* 85, pp. 494 - 498.

Mani, M., Krishnamoorthy, A. (2008). 'Field efficacy of Australian ladybird beetle *Cryptolaemus montrouzieri* Mulsant in the suppression of *Maconellicoccus hirsutus* (Green) on sapota', *Journal of Biological Control*, 22 (2), pp. 471-473.

Manjunath, T. M. (1985). 'India-*Maconellicoccus hirsutus* on grapevine', *FAO Pl. Protec. Bull.,* 33(2), pp. 74.

Mani, M., Visalakshy, P. N. G., Krishnamoorthy, A., Venugopalan, R. (2008). 'Role of *Coccophagus sp*. in the suppression of the soft green scale *Coccus viridis* (Green) (Hompoptera: Coccidae) on sapota', *Biocontrol Science and Technology*, 18 (7), pp. 721-725.

Mousa, S. F., El-Heneidy, A. H., Hendawy, A. S., Adly, D., Gonzalez, D., Trjaptsyn, S. V. (2001). 'Pink hibiscus mealybug, *Maconelicoccus hirsutus* (Green), parasitoids in Egypt', *1 – Preliminary record Egyptian Journal of Biological Pest Control*, 11 (2), pp. 195-196.

Osman, E. A. (2012). '*Biological studies on the pink- hibiscus Maconellicoccus hirsutus (Green) (HEMIPTERA: PSEUDOCOCCIDAE) reared on potato sprouttubers under laboratory conditions.*

Patel, K. M., Shukla, A., Patel, A. T., Patel, S. R. (2022). 'Survey of Sapota fruit mite, *Tuckerella kumaonensis* Gupta (Tuckerellidae: Acari) and it's predatory mite, Octobdellodes sp. in South Gujarat.', *The Pharma Innovation Journal*, 11(8), pp. 1160-1164

Singh, P., Rathore, M., Prakash, H. G. (2021). 'Studies on Nutritional, Pharmacological and Health Importance of "Chikoo" (*Manilkara Zapota* L.)', *Int. J. of Science and Research*, 10(3), pp. 2319-7064.

Gilly (1943). *'Sapota is a very familiar amazing fruit',* It is also called as Naseberry, Mud Apples, and Sapodilla Plum. A working list of all plant Species.

García Morales, M. D., Miller, D.R., Miller, G.L., Ben-Dov, Y. (2016). '*ScaleNet: A literature-based model of scale insect biology and systematics*', Database. doi: 10.1093/database/bav118. http://scalenet.info.

Jacob, N. (1977). 'Un model matematic pentru stabilirea. Limitelor economice de toloranta a *atacului molilor*. Fructelor in Iupte integrate', *Analele I. C. P. P., Romania*, 15, pp. 179.

Wankhede, S.M, Shinde, V.V., Ghavale, S.L. (2019). 'Assessment of important pests of coconut during roving survey in Konkan region of Maharashtra', *Green Farming*, 10(3), pp. 364-367.