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Study on biology of *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcidae), *Paracoccus marginatus* (Williams and Granara de Willink) (Hemiptera: Pseudococcidae), *Maconellicoccus hirsutus* (green) (Pseudococcidae: Hemiptera) and *Ferrisia virgata* (Cockerell) (Hemiptera: Pseudococcidae) in laboratory conditions

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Abstract

Mealybugs (Hemiptera: Pseudococcidae) are important insect pests in worldwide. The study on biology revealed that there were three distinct nymphal instars in female and four nymphal instars in male mealybug (*Phenacoccus solenopsis* (Tinsley)). The duration of egg, first, second, third instar nymphs and fourth (male) pupae varied from 6.00 to 8.00, 4.00 to 5.00, 5.00 to 7.00, 3.50 to 6.00 and 2.50 to 3.00 days. The adult male longevity ranged from 2.00 to 2.50 days and the adult female longevity ranged from 17.50 to 19.00 days in *P. solenopsis*. In case of *Paracoccus marginatus* (Williams and Granara de Willink), the duration of egg, first, second, third instar nymphs and fourth (male) pupae varied from 5.00 to 6.00, 3.00 to 4.00, 4.00 to 4.50, 3.50 to 5.00 and 3.00 to 3.25 days. The adult male longevity ranged from 1.00 to 2.00 days and the adult female longevity ranged from 17.00 to 18.50 days in *P. marginatus*. The duration of egg, first, second, third instar nymphs and fourth (male) pupae varied from 4.00 to 5.00, 6.00 to 8.00, 5.00 to 7.00, 5.00 to 6.00 and 4.00 to 5.00 days. The adult male longevity ranged from 1.00 to 2.00 days and the adult female longevity ranged from 16.00 to 18.00 days in *Maconellicoccus hirsutus* (Green) and in case of *Ferrisia virgata* (Cockerell), the duration of egg, first, second, third instar nymphs and fourth (male) pupae varied from 3.80 to 5.50, 4.00 to 5.20, 5.00 to 6.00, 5.20 to 7.00 and 2.50 to 3.00 days. The adult male longevity ranged from 1.00 to 2.00 days and the adult female longevity ranged from 15.00 to 19.50 days in *F. virgata*.

Keywords: *Phenacoccus*, *Paracoccus*, *Maconellicoccus* and *Ferrisia*.

Introduction

Mealybugs are small, soft-bodied, plant sucking insects, which embrace the second largest family of scale insects (Pseudococcidae) with approximately 2000 species belonging to 300 genera and common name is due to the waxy material which covers the bodies of adult females (Miller and Williams 1997; Downie and Gullan 2004). The mealy bug, *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcidae) has been observed, damaging cotton crop very seriously from 2004-05 in Gujarat (Jhala *et al.*, 2008). In 2005 and 2006, *P. solenopsis* has caused heavy loss in Gujarat and later in Punjab and Haryana. Being a polyphagous pest, *P. solenopsis* is found to feed on number of cultivated and other crops including weeds and this pest has attained national significance (Patel *et al.*, 2009). The Papaya mealybug, *Paracoccus marginatus* (Williams and Granara de Willink) (Hemiptera: Pseudococcidae) is native to Mexico and Central America (Miller *et al.*, 1999) and was first described in 1992 (Williams and Granara de Willink, 1992). It is a small hemipteran found to attack several genera of host plants. First report of its occurrence was in 1992 and thereafter it has spread to more than 15 countries. It is a polyphagous pest infesting more than 60 species of economically important host plants (Tanwar *et al.*, 2010).

Maconellicoccus hirsutus (Green) (Pseudococcidae: Hemiptera) is a sporadic pest mainly found on hibiscus plant and infests crops such as hibiscus, citrus, coffee, guava, mango, soybean, cotton, maize etc. *M. hirsutus* was recorded on cotton in some parts of India,

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particularly Punjab (Dhawan and Sidhu 1980) and in Gujarat (Muralidharan *et al.*, 2000). *M. hirsutus* was also recorded on cotton from Coimbatore, Salem district and the incidence level varied from 5 to 85 per cent (Nagrare *et al.*, 2014). *Ferrisia virgata* (Cockerell) is highly polyphagous infesting over 150 genera in 68 families (CABI, 2003) and distributed in more than 110 countries around the world (Docs, 2013). *F. virgata* was recorded from Nagpur in traces and infestation ranging from 16-83 per cent was recorded on cotton at Coimbatore (Nagrare *et al.*, 2014).

Materials and methodology

Studies on biology of *P. solenopsis*, *P. marginatus*, *M. hirsutus*, *F. virgata* were carried out in the Insectary at TNAU, Coimbatore using the population collected from unsprayed potted cotton plants of *Gossypium hirsutum* L. (Malvales: Malvaceae) at Insectary. Individual females were separated, and fed on cotton leaves in Petri plates. Individual leaves free from mealybug infestation, were washed with tap water and shade dried and used as food source. Since parthenogenetic reproduction of *P. solenopsis*, *P. marginatus*, *M. hirsutus*, *F. virgata* were observed under field conditions, individual neonate crawlers emerging from females were used to start the biology study. The base of the petiole of individual leaves were covered with a water soaked cotton swab to prevent desiccation of the leaf.

A total of 250 crawlers drawn from different females, laid on the same day were individually transferred to separate glass Petri plates (15 × 2 cm) each containing a leaf. Observations on survival and moult of the crawlers were recorded daily under stereoscopic microscope until they became adults.

Transferring the cut cotton leaf disc along with crawler obviated their direct handling using a camel hair brush. Petri plates with missing crawlers were discarded and excluded from the final data. The developmental time of each instar was recorded based on an observed exuvia. Daily monitoring of crawlers, those that had stopped further moulting and reached adult stage was done to determine the pre reproductive and reproductive periods, fecundity, and longevity. As the eggs or neonate crawlers were counted and discarded, the individual adults were transferred to new Petri plates for further observations. When eggs were observed they were separated along with the leaf disc and observed until they hatched.

Range and mean values for the developmental period of each instar for females and males, pre reproductive and reproductive periods, fecundity, and longevity were calculated for each life stage based on the total number of observations made. The number of observations for each of the life history parameter varied depending upon the progress in development and survival of the crawlers and adults. The number of males out of the total population that survived to adult stage was calculated.

Experimental design

Leaves and Petri-dishes were distributed in a completely randomized design with 30 to 40 replicates per treatment, where each insect represents one replicate. Nymphal development period for each instar was assessed only in those insects reaching the next stage (dead insect were not considered).

Table 1: Biology of mealy bugs under laboratory conditions

Life stage	Duration (Days) (Mean ± SD)			
	<i>Paracoccus marginatus</i>	<i>Maconellicoccus hirsutus</i>	<i>Phenacoccus solenopsis</i>	<i>Ferrisia virgata</i>
Immature stage	5.33 ± 0.58	4.83 ± 0.29	6.67 ± 1.15	4.43 ± 0.93
I instar	3.67 ± 0.58	6.67 ± 0.76	4.50 ± 0.50	4.40 ± 0.69
II instar	4.25 ± 0.25	5.83 ± 0.76	5.67 ± 0.76	5.50 ± 0.50
III instar	4.17 ± 0.76	5.33 ± 0.58	5.00 ± 0.50	6.23 ± 0.93
Pupa or cocoon (Male)	2.92 ± 0.38	4.67 ± 0.58	3.00 ± 0.50	2.83 ± 0.29
Adult longevity				
Male	1.67 ± 0.58	1.33 ± 0.58	2.33 ± 0.29	1.33 ± 0.58
Female	17.83 ± 0.76	17.17 ± 0.86	18.17 ± 0.76	16.70 ± 2.44
Total life cycle				
Male	20.33 ± 1.94	28.83 ± 1.89	22.17 ± 2.47	24.73 ± 3.52
Female	35.25 ± 1.25	40.00 ± 1.32	40.00 ± 2.60	37.27 ± 2.16
(No. of eggs)	314.67 ± 5.51	252.33 ± 8.74	353.33 ± 5.20	260.67 ± 9.50
Oviposition period	9.67 ± 1.15	9.17 ± 1.04	8.50 ± 0.87	7.83 ± 0.76

Results & Discussion

Biology of *Phenacoccus solenopsis*

Eggs: The eggs were observed as small, light yellow in color. The incubation period of eggs varied from 6.00 to 8.00 days with an average of 6.67 ± 1.15.

First Instar Nymph: The neonate larvae were pale yellow in colour, oblong in shape and the duration of first instar stage ranged from 4.00 to 5.00 days with an average of 4.50 ± 0.50 days. The results described herein are in accordance with Singh and Kumar (2012) ^[10] who reported that the development period for first nymphal stage with an average of 4.320 ± 0.8524 days.

Second Instar Nymph: The duration of second instar stage ranged from 5.00 to 7.00 days with an average of 5.67 ± 0.76 days. The results described herein are in accordance with

Singh and Kumar (2012) ^[10] who reported that the development period for second nymphal stage with an average of 4.840 ± 0.8 days.

Third Instar Nymph: The duration of third instar stage ranged from 3.50 to 6.00 days with an average of 5.00 ± 0.50 days. The results described herein are in accordance with Singh and Kumar (2012) ^[10] who reported that the development period for third nymphal stage was an average of 5.12 ± 0.8327 days.

Fourth Instar Nymph (Male): In this stage, male nymph forms a white cocoon of loose filaments around the body. The duration of fourth instar stage ranged from 2.50 to 3.00 days with an average of 3.00 ± 0.50 days.

Adult Male: The adult male longevity ranged from 2.00 to 2.50 days with an average of 2.33 ± 0.29 days. Singh and

Kumar (2012) ^[10] stated that, male was short lived with an adult life of 1.960 ± 0.8406 days.

Adult Female: An adult female was larger in size, oblong in shape with soft segmented body clearly divisible in three thoracic and ten abdominal segments. The body consists of a pair of dark spots on the thorax and three pairs on the abdomen forming longitudinal stripes are noticed. The adult female longevity ranged from 17.50 to 19.00 days with an average of 18.17 ± 0.76 days. Similar findings of female adults lived longer (19.10 ± 1.49 days) as compared to male adults (Kedar *et al.*, 2013).

Oviposition Period: The ovipositional period ranged from 7.50 to 9.00 days with an average of 8.50 ± 0.87 days.

Fecundity: The mature female laid eggs in clusters in ovisac and the egg laying capacity of single female varied from 345 to 365 eggs with an average of 353.33 ± 10.41 per female. Vennila *et al.* (2010) reported that females showed dynamic patterns of fecundity with the number of crawlers produced per female ranging between 128 and 812, with a mean of 344 ± 82 . Kedar *et al.* (2013) also reported that *P. solenopsis* female laid an average of 373.24 ± 36.7 eggs during its life period. From the above observations it can be concluded that the incubation period for female had been 6.67 ± 1.15 , nymphal stages had a duration of 15.17 ± 0.95 and adult life span of 18.17 ± 0.76 days. Similarly the incubation period, nymphal period and adult life span of male had been 6.67 ± 1.15 , 18.17 ± 1.25 and 2.33 ± 0.29 days, respectively. Singh and Kumar (2012) ^[10] reported that total nymphal stage had a duration of 14.28 ± 0.812 days and the fecundity rate of female ranged from 300 to 750 which increased its survival rate. The longevity of female was higher (24.44 ± 2.329 days) than male (1.960 ± 0.8406 days).

Biology of *Paracoccus marginatus*

Egg: Eggs were greenish yellow in color and enclosed in elongated loose, cottony egg sac on the ventral side of abdomen of female called ovisac. The incubation period of eggs varied from 5.000 to 6.00 days with an average of 5.33 ± 0.58 . Kumar *et al.* (2014) ^[4] revealed that eggs are greenish yellow and are laid in an egg sac which is 3-4 times the body length and entirely covered with white wax. The incubation period varied from 3 to 9 days in female and 3 to 10 days in male. Similar biology observations were recorded by Miller and Miller (2002), Walker *et al.* (2008), Muniappan *et al.* (2008) and Singh and Beera (2010) ^[10] who reported that the egg-laying of *P. marginatus* was usually in a small white ovisac and egg hatching occurred in about 10 days.

Nymph: The neonate larvae were oval in shape and highly mobile and settled on the host immediately and started developing into crawlers without any white waxy coating. At this stage, males and females were not distinguishable. The duration of first instar stage ranged from 3.00 to 4.00 days with an average of 3.67 ± 0.58 days. The nymphs did not show any sexual differentiation. The duration of second instar stage ranged from 4.00 to 4.50 days with an average of 4.25 ± 0.25 days. The results are in accordance with the results obtained by Chellapan *et al.* (2013) ^[1] who reported that, first instar nymphs duration was seen on potato (3.56 ± 0.53 days) and duration of second instar female nymphs on papaya (4.2 ± 0.63 days)

There was no change in the morphological characters of third instar nymph except amount of white mealy wax was more

and size of the body increased. After this stage, female instar developed into an adult; however, males entered as fourth nymph instar and the duration of third instar stage ranged from 3.50 to 5.00 days with an average of 4.17 ± 0.76 days. Total nymphal stages had a duration of 12.09 ± 0.56 days.

Fourth Instar Nymph (Male): In this stage, male nymph forms a white cocoon of loose filaments around the body. The duration of fourth instar stage ranged from 3.00 to 3.25 days with an average of 2.92 ± 0.38 days.

Adult Male: The adult male longevity ranged from 1.00 to 2.00 days with an average of 1.67 ± 0.58 days. Adult male were smaller in size than female.

Adult Female: The adult female was yellow in colour, wingless and covered with a white waxy coating therefore gave a neotenic appearance. There was a series of short waxy caudal filaments, less than 1/4th the length of the body existed around the margin of the female body. When squashed the body, fluid of yellow colour came out. The adult female longevity ranged from 17.00 to 18.50 days with an average of 17.83 ± 0.76 days. Entire colony becoming covered by white, waxy ovisac material (OEPP / EPPO, 2006).

Oviposition period: The ovipositional period ranged from 9.00 to 11.00 days with an average of 9.67 ± 1.15 days

Fecundity: The mature female laid eggs in clusters in the form of ovisac and the egg laying capacity of single female varied from 309 to 320 eggs with an average of 314.67 ± 5.51 per female). The fecundity of *P. marginatus* was similar to the observations made by Walker *et al.* (2008) and Singh and Beera (2010) ^[10], who reported that females of *P. marginatus* usually lay 100 to 600 eggs in an ovisac, in a span of one to two weeks. From the above observations it can be concluded that the incubation period for female had been 5.33 ± 0.58 , nymphal stages had a duration of 12.09 ± 0.56 and adult life span of 17.83 ± 0.76 days. Similarly the incubation period, nymphal period and adult life span of male had been 5.33 ± 0.58 , 15.01 ± 0.71 and 1.67 ± 0.58 days, respectively.

Biology of *Maconellicoccus hirsutus*

Egg: The fresh laid eggs were translucent and pink or light orange in colour, elongated and oval in shape with shiny and smooth chorion with little tapering ends. With lapse of incubation period, the translucent yellowish egg became pinkish brown before hatching. The incubation period of eggs varied from 4.00 to 5.00 days with an average of 4.83 ± 0.29 . Egg colour is pink, pink; immature females and newly matured females greyish-pink, dusted with mealy white wax (OEPP/EPPO, 2006). The results were corroborated with similar findings of Katke and Balikai (2009) ^[4] who reported that the incubation period varied from 3 to 5 days with an average of 4.7 ± 0.47 days for female of *M. hirsutus*.

First Instar Nymph: The nymphs were usually yellow or orange colour with reddish compound eyes. The duration of first instar stage ranged from 6.00 to 8.00 days with an average of 6.67 ± 0.76 days. Katke and Balikai (2009) ^[4] reported that as incubation period advanced the translucent eggs became pinkish in colour towards hatching. The study results herein accordance with Mani (1986), reported that the duration of first nymphal instar with an average of 6.60 ± 0.50 days.

Second Instar Nymph: The second instar nymphs were soft, oval and flat showing large body size than first instar nymphs. The six segmented antennae were clearly seen. The nymphs

did not show any sexual differentiation. The duration of second instar stage ranged from 5.00 to 7.00 days with an average of 5.83 ± 0.76 days. Similar findings were reported by Mani (1986), that the mean duration of second nymphal instar occupied by female was 6.55 ± 0.52 days.

Third Instar Nymph: There was no change in the morphological characters of third instar nymph except amount of white mealy wax was more and size of the body increased. After this stage, female instar developed into an adult; however, males entered as fourth instar and the duration of third instar stage ranged from 5.00 to 6.00 days with an average of 5.33 ± 0.58 days.

Fourth Instar Nymph (Male): In this stage, male nymph forms a white cocoon of loose filaments around the body. The duration of fourth instar stage ranged from 4.00 to 5.00 days with an average of 4.67 ± 0.58 days.

Adult Male: The male adults were active, orange in colour. Specifically the head was dark brown and wings were thin, iridescent and transparent. The adult male longevity ranged from 1.00 to 2.00 days with an average of 1.33 ± 0.58 days. Adult male were smaller in size than female.

Adult Female: An adult female was larger in size, oval in shape with soft segmented body clearly divisible in three thoracic and ten abdominal segments. Antennae were 9 segmented. When squashed, a pink to red fluid was discharged. No lateral wax fringe and caudal filaments. Adult female with an average of 2.77 ± 0.09 mm in length and with an average of 1.73 ± 0.07 mm in width and the adult female longevity ranged from 16.00 to 18.00 days, soft-bodied, elongate oval and slightly flattened. Entire colony becoming covered by white, waxy ovisac material (OEPP / EPPO, 2006). Shelke (2001)^[9] reported that, longevity of female was 17-20 days with a mean of 18.00 days.

Oviposition period: The ovipositional period ranged from 8 to 10 days with an average of 9.17 ± 1.04 days. Katke and Balikai (2009)^[4] recorded the ovipositional period of *M. hirsutus*, ranged from 7 to 9 days with an average of 8.7 ± 0.72 days.

Fecundity: The mature female laid eggs in clusters in ovisac and the egg laying capacity of single female varied from 245 to 262 eggs with an average of 252.33 ± 8.74 per female. Each adult female lays 150–600 eggs over a period of about one week, and these hatch in

6-9 days (Bartlett *et al.*, 1978; Mani, 1989). From the above observations it can be concluded that the incubation period for female had been 4.83 ± 0.29 , nymphal stages had a duration of 17.83 ± 0.96 and adult life span of 17.17 ± 0.76 days. Similarly the incubation period, nymphal period and adult life span of male had been 4.83 ± 0.58 , 22.50 ± 0.90 and 1.33 ± 0.58 days, respectively.

Biology of *Ferrisia virgata*

Egg: The average length of eggs were 0.32 ± 0.04 mm and diameter 0.12 ± 0.01 mm. The incubation period of eggs varied from 3.80 to 5.50 days with an average of 4.43 ± 0.93 days. This results were corroborated with similar findings of Katke and Balikai (2009)^[4] who reported that the incubation period varied from 3 to 5 days with an average of 4.7 ± 0.47 days for female of *M. hirsutus*.

First Instar Nymph: The neonate larvae were oval in shape and highly mobile and settled on the host immediately and started developing into crawlers without any white waxy coating.

At this stage, males and females were not distinguishable. The duration of first instar stage ranged from 4.00 to 5.20 days with an average of 4.40 ± 0.69 days.

Second Instar Nymph: The second instar nymphs showing large body size than first instar nymphs. The nymphs did not show any sexual differentiation. The duration of second instar stage ranged from 5.00 to 6.00 days with an average of 5.50 ± 0.50 days.

Third Instar Nymph: There was no change in the morphological characters of third instar nymph except amount of white mealy wax was more and size of the body increased. After this stage, female instar developed into adult; however, males entered as fourth instar and the duration of third instar stage ranged from 5.20 to 7.00 days with an average of 6.23 ± 0.93 days.

Fourth Instar Nymph (Male): In this stage, male nymph forms a white cocoon of loose filaments around the body. The duration of fourth instar stage ranged from 2.50 to 3.00 days with an average of 2.83 ± 0.29 days.

Adult Male: The adult male longevity ranged from 1.00 to 2.00 days with an average of 1.33 ± 0.58 . Adult male were smaller in size than female.

Adult Female: Females were wingless and bigger than the males and consists of two long prominent waxy filaments at the posterior end and lot of waxy or glassy hair over the body. Adult female has piercing and sucking mouth parts and have fairly long, dorsal stripes on the dorsum of the posterior end of the body. The adult female longevity ranged from 15.00 to 19.50 days with an average of 16.70 ± 2.44 days. Adult female are oval, yellow/green in colour and 4-4.5 mm long. When viewed dorsally, there are two dark stripes down their length. These show through the waxy secretion that covers their body (CABI, 2002). Lapis (1970)^[6] reported that life-span of the adult female was 12-31 (with a mean of 16) days.

Oviposition period: The ovipositional period ranged from 7.00 to 8.50 days with an average of 7.83 ± 0.76 days when reared on red pumpkin.

Fecundity: The mature female laid eggs in clusters in ovisac and the egg laying capacity of single female varied from 251 to 270 eggs with an average of 260.67 ± 9.50 per female. A mated female usually will lay eggs in a waxy ovisac containing 100 - 500 eggs (McKenzie 1967, Chong *et al.* 2003, Daane *et al.* 2006)^[7]. From the above observations it can be concluded that the incubation period for female had been 4.43 ± 0.93 , nymphal stages had a duration of 16.13 ± 0.101 and adult life span of 16.70 ± 2.44 days. Similarly the incubation period, nymphal period and adult life span of male had been 4.43 ± 0.93 , 18.96 ± 1.44 and 1.33 ± 0.58 days, respectively.

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