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Biology and Population Dynamics of Mealybug, *Phenacoccus solenopsis* Tinsley on *Hibiscus rosa-sinensis* L. in Southern Gujarat Conditions

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Studies on biology of *Phenacoccus solenopsis* on leaves of *Hibiscus rosa-sinensis* L. were carried out in P.G. Laboratory, Department of Entomology, Navsari Agricultural University, Navsari (India) during the year 2006-07 revealed that the females laid 256.16 ± 133.64 eggs in group within cottony ovi sac. The average length, breadth, incubation and hatching percentage of eggs were 0.35 ± 0.02 mm, 0.20 ± 0.01 mm, 42.32 ± 8.41 minutes and 84.66 ± 11.05%, respectively. The average total nymphal periods of male and female were 19.8 ± 1.54 days and 21.28 ± 2.29 days, respectively. Adult male was delicate, slender, elongate and smoky brown with a single pair of wings, measured 1.18 ± 0.06 mm in length with wing expansion of 2.33 ± 0.06 mm. While female adult was elongate oval, flattened dorso-ventrally and measured 2.23 ± 0.26 mm in length and 0.87 ± 0.07 mm in breadth. The longevity of the male and female adult was 2.6 ± 0.59 and 28.8 ± 2.60 days, respectively. The pre-oviposition, oviposition and post-oviposition periods recorded 8.1 ± 1.44, 13.26 ± 2.40 and 4.43 ± 3.03 days, respectively. The sex ratio of male to female was 1: 1.72. The total life span of both male and female from egg stage to death of an adult averaged 22.4 ± 1.63 and 50.06 ± 3.12 days, respectively. The highest population of mealybugs per plant were found in first fortnight of November (93.68) and showed significant positive correlation with maximum temperature and negative significant correlation with average relative humidity. Under field condition, the nymphs and adult females were preyed upon by two predators *Spalgis epius* (Westwood) and *Scymnus coccivora* (Aiyar).

Key words : Biology, *Phenacoccus solenopsis* Tinsley, *Hibiscus rosa-sinensis* L**.** Population dynamics

Mealybugs (Hemiptera: Pseudococcidae) are important plant pests worldwide. About 5000 species of mealybugs have been recorded from 246 families of plants throughout the world. Among these, 56 species have been reported from 15 genera of family Malvaceae, including hibiscus, cotton and many other crops of economic importance (Ben- Dov, 1994). The mealybug *Phenacoccus solenopsis* Tinsley has a wide geographical distribution with its origin in Central America (Fuchs *et al.,* 1991; Williams and Granara de Willink, 1992) followed by reports in the Caribbean and Ecuador (Ben-Dov, 1994), Argentina (Granara de Willink, 2003) and Brazil (Mark and Gullan, 2005). Arif *et al.* (2009) recorded 154 plant species from 53 families comprising 20 field and horticultural crops, 45 ornamentals, 64 weeds and 25 bushes and trees as hosts of *P. solenopsis* in Pakistan. It was found on *Hibiscus rosa-sinensis* plant where they aggregated on the stem of the plant (Akintola and Ande, 2008).

P. solenopsis has been the current topic of research for insect taxonomists and applied entomologists in India due to its invasiveness, rapid spread, morphological and biological variations and the need for establishing an effective control strategy. A detailed comparative study of few species of *Phenacoccus* including the Indian and Pakistan species, and details on the existence of seasonal morphological variations were given by Hodgson *et al.* (2008) which provides strong support for its presence in India. Recently, from Gujarat, *P. solenopsis* has been observed damaging cotton crop very seriously (Jhala *et al*., 2008). *P. solenopsis* is commonly described as cotton mealybug, due to its large scale occurrence on cotton. In spite of its occurrence as a pest since last few years, the information on its biology is scanty. Therefore, the present study on biology of *P. solenopsis* was carried out in the laboratory, so that the information generated may be used to formulate management strategy of the pest.

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Materials and Methods

The biology of *P. solenopsis* was studied in Post Graduate Laboratory, Department of Entomology, Navsari Agricultural University, Navsari, Gujarat (India) during the year 2006-07 where temperature and relative humidity ranged from 24.2- 30.5^{o}C and 70.5- 80.5%, respectively. Initial culture of *P.*

solenopsis, was started from heavily mealy bug infested hibiscus twigs collected from fields and reared in the laboratory. Sprouted potatoes were used for rearing of mealy bugs in the laboratory for further studies as described by Mani (1988). Healthy potatoes were washed with water and allowed to soak in shade. Whole potatoes were placed in plastic trays (30 × 25 × 5 cm) about ½" apart on a ½" layer of soil in the tray and covered with slightly moist soil for sprouting. The tray along with potatoes was kept in wooden cage (60 × 60 × 75 cm) on glass jar (20 x15 cm). Then the glass jar along with tray was again kept in another plastic tray (30 × 25 × 5 cm) inside the wooden cage. The tray was filled with water at about one cm level to prevent the attack from ant. When the sprouts developed to a height of 3 to 5 cm, the ovisacs of *P. solenopsis* were introduced into the green sprout with the help of fine camel hair brush. The collected nymphs and adult females were also released on sprouted potato. About three days after release, the female mealy bugs settled on sprouted potato and started egg laying. The crawlers emerged out and started feeding on sprouted potatoes. The freshly laid eggs in the ovisac were used for further study on biology. Subsequently, specimens of mealybugs were identified as *P. solenopsis* by the Insect Identification Service of Indian Agricultural Research Institute, New Delhi.

Biology of *P. solenopsis* was studied on leaves of *Hibiscus rosa-sinensis* which were individually kept in Petri plate. The leaf petiole of the hibiscus leaves were wrapped with absorbent cotton wool dipped in water to keep the leaves turgid and such leaves were placed in glass Petri dish (9 × 1 cm). The eggs laid by females of *P. solenopsis* were examined under binocular microscope for colour, shape and size. The adult females were picked up and placed individually on tender hibiscus leaf with the help of fine camel hair brush. The leaves were kept turgid for longer period as described earlier. Individual leaf was kept in glass Petridish (9 × 1 cm) and observed daily under microscope till egg laying. The time of egg laying was noted. Freshly laid eggs were counted and transferred to fresh tender hibiscus leaves. The length and breadth of the eggs were measured with the help of occular and stage micrometer. Time taken for egg hatching was recorded to compute incubation period. Hatching of eggs was calculated from the number of eggs hatched out of total number of eggs kept under observation.

To study the number and duration of different nymphal instars, freshly hatched fifty nymphs were marked individually and observed daily in the morning under microscope, to note moulting process. Moulting as confirmed by presence of caste off skin on the posterior end of nymph of subsequent instar. The shape, size and colour of each nymphal instar of male and female were also studied. The length and breadth of third and fourth instars of male were measured by removing silken cocoon, which was made by male nymph wrapping its body with glossy thread.

Adult females that emerged after last moult were observed for colour and shape. Measurements of the females were made by using measuring scale. Similarly, adult males from the silken cocoons were observed under microscope for their colour, shape and size. Freshly emerged females were reared separately on tender hibiscus leaves to study their pre-oviposition, oviposition and post-oviposition periods. Since the females laid their eggs in cottony sac located at posterior end of its abdomen, the ovisacs were collected during oviposition period and the number of eggs in each ovisac was enumerated for assessing fecundity. Longevity of male and female was assessed separately i.e. days of survival from emergence to the death of adults. The third instar, forming cocoons were separated as male and female and sex ratio was worked out. Total life cycle of female and male was calculated from the egg laying to the death of adult stage.

For population assessment, observations were recorded by counting the number of nymphs and adult females on twigs of three portion viz., top, middle and bottom of each randomly selected plant at fortnightly interval throughout the year. In order to study the influence of weather parameters viz., maximum temperature, minimum temperature, average temperature, morning relative humidity, evening relative humidity, average relative humidity, rainy days, sunshine hours, wind velocity and rainfall on population of mealybug, *P. solenopsis* the simple correlation coefficient was worked out. Fortnightly meteorological data recorded at the meteorological observatory, N.M. College of Agriculture, Navsari Agricultural University, Navsari were used for this purpose. Simultaneously, regular survey was undertaken to study the existence of natural enemies on *P. solenopsis*.

Results and Discussion

Life cycle of P. solenopsis

Egg: The adult female laid eggs in mass in a loose cottony ovisac (Plate 2) at the posterior end of the body. The eggs of *P. solenopsis* were smooth, translucent, light yellow and oval to cylindrical with round ends (Plate 1). The length of egg was 0.35 ± 0.02 mm and breadth was 0.20 ± 0.01 mm. Similar observations was reported by Tanwar *et al*. (2008) with varying length from 0.3 to 0.4 mm in *P. solenopsis*. It was observed that the embryonic development was very quick. It is clear from Table 1 that the incubation period was varied from 28 to 59 minutes with on an average of 42.32 ± 8.41 minutes. All these findings were identical to the results obtained by Nikam *et al*. (2010) who studied the detailed biology on cotton leaves. He observed the average length, breadth and incubation period were

0.37 ± 0.01, 0.19 ± 0.01 mm and 39.00 ± 7.57 minutes respectively. However, the present findings were disagreeing with the result of Akintola and Ande (2008) wherein they reported that the eggs of *P. solenopsis* were not observable.

Nymphs: *P. solenopsis* exhibited variation in males and females at immature stages itself on hibiscus leaves. The female nymph was found passing through three nymphal instars, while male was found passing through four nymphal instars. In the first and early second instar, both sexes were indistinguishable. The differentiation became apparent towards the end of second instar, when the male nymph started wrapping its body with glossy thread and resembled a white silken cocoon. It was observed that total nymphal period of female varied from 16 to 27 days and of male it varied from 17 to 23 days (Table 1). Akintola and Ande (2008) reported that the female nymph completed its development within 24 days, whereas, Tanwar *et al*.

Table 1. Developmental characteristics of *P. solenopsis* on hibiscus

Particulars	Period (days)			Length (mm)			Breadth (mm)		
	Min.	Max.	Av. + SD	Min.	Max.	Av. + SD	Min.	Max.	Av. + SD
Egg	28	59	42.32 + 8.41	0.28	0.38	0.35 + 0.02	0.18	0.22	0.20 + 0.01
Nymphal Period									
Male									
I instar	4	8	6 + 1.12	0.40	0.47	0.43 + 0.0.1	0.13	0.17	0.14 + 0.01
II instar	7	9	8.2 + 0.83	0.68	0.78	0.73 + 0.01	0.30	0.35	0.32 + 0.01
III instar	1	3	2.1 + 0.64	1.1	1.35	1.23 + 0.08	0.42	0.57	0.50 + 0.05
IV instar	2	5	3.5 + 0.76	1.25	1.41	1.32 + 0.05	0.39	0.57	0.50 + 0.05
Total nymphal period	17	23	19.8 + 1.54	-	-	-	-	-	-
Female									
I instar	4	9	6.28 + 1.01	0.40	0.47	0.43 + 0.01	0.13	0.17	0.14 + 0.01
II instar	7	9	8.13 + 0.85	0.68	0.78	0.73 + 0.01	0.30	0.35	0.32 + 0.01
III instar	9	13	6.93 + 1.83	0.97	1.17	1.11 + 0.05	0.48	0.55	0.52 + 0.03
Total nymphal period	22	29	21.28 + 2.29	-	-	-	-	-	-
Pre- oviposition period	6	12	8.1 + 1.44	-	-	-	-	-	-
Oviposition period	9	17	13.26 + 2.40	-	-	-	-	-	-
Post-oviposition period	3	16	4.43 + 3.03	-	-	-	-	-	-
Fecundity (number)	87	548	256.16 + 133.64	-	-	-	-	-	-
Adult									
Male	2	4	2.6 + 0.59	1.1	1.32	1.18 + 0.06	2.16	2.43	2.33 + 0.06
Female	22	34	28.8 + 2.60	2.23	1.92	2.23 + 0.26	0.75	0.98	0.87 + 0.07
Female (at time of egg laying)	-	-	-	3.1	4.37	3.58 + 0.36	1.25	1.92	1.59 + 0.24
Total life period (days)									
Male	20	26	22.4 + 1.63	-	-	-	-	-	-
Female	45	58	50.06 + 3.12	-	-	-	-	-	-

SD- Standard deviation

(2008) observed that it lasted for 22 to 25 days. Recently, Nikam *et al*. (2010) observed the total nymphal period of *P. solenopsis* as 14-20 days on cotton leaves. According to Vennila *et al.* (2010) the mean total developmental period for crawlers with three instars, and four instars that developed into females and males, was 13.2 ± 1.8 and 18.7 ± 0.9, respectively on cotton at CICR, Nagpur.

I instar: The freshly hatched nymphs always remained underneath the mother for some time before crawling out. They were very active, searching for suitable food and later settled on succulent parts of plant. First instar nymph was oval, flattened dorso-ventrally, pale yellow with a three pairs of well developed legs (Plate 3). It measured on an average of 0.43 ± 0.01 mm in length and 0.14 ± 0.01 mm in breadth (Table 1) which was contradictory to Akintola and Ande (2008) who reported that the average body length of 12.27 ± 1.20mm and breadth of 0.74 ± 0.63 mm. The duration of female instar varied from 4 to 9 days with an average of 6.28 ± 1.01 days while those of male instar ranged from 4 to 8 days with on an average of 6 ± 1.12 days (Table 1). These reports on sex wise duration of first and second instar nymphs were not reported earlier. The findings are more or less similar with those of Akintola and Ande (2008) who reported the duration of 6 days, while Mishra *et al*. (2004) reported that the first instar nymph of *P. bengalensis* completed its development within 5 to 14 days.

II instar: The freshly moulted second instar nymphs were pale yellow and oval in shape (Plate 4). The second instar nymphs were similar to that of first instar nymphs in general appearance and morphological features, except in size. Later, secretion of white mealy scale on body surface was observed and it was found to be settled down on lower side of leaves near the midrib. The male nymph stopped feeding for about one to two days prior to second moult and started secreting hairs profusely. The body becomes slightly cylindrical. The average length and breadth of II instar nymph was 0.73 ± 0.01 mm 0.32 ± 0.01 mm, respectively. The average duration of second instar female was 8.13 ± 0.85 days while, that of male was 8.2 ± 0.83 days (Table 1). As reported by Akintola and Ande (2008) the second instar nymph completed its development within 8 days, while *P. bengalensis* took 8 to 19 days

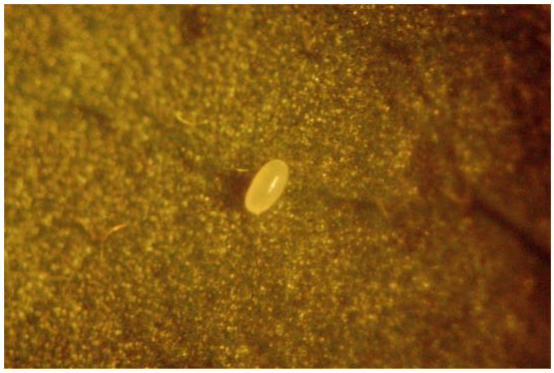

Plate 1. Singly laid Egg

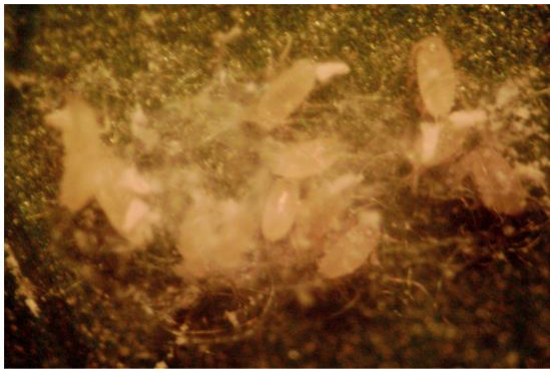

Plate 2. Egg mass in ovisac

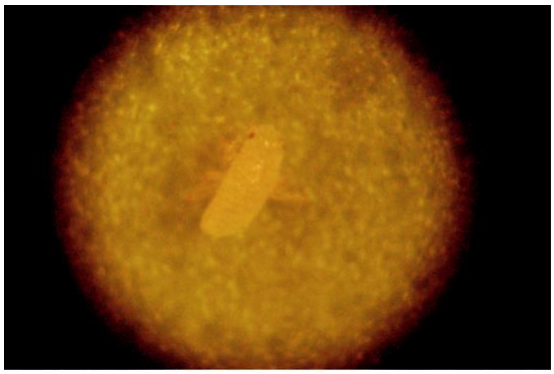

Plate 3. instar nymph

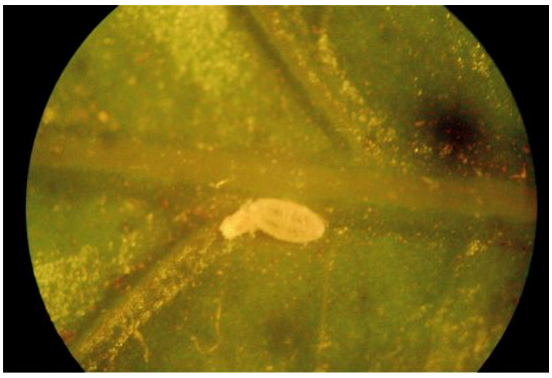

Plate 4. instar nymph

Plate 5. instar female nymph

Plate 6. Male cocoon

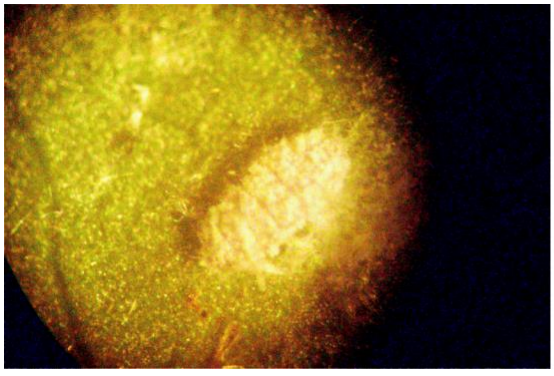

Plate 7. instar male nymph

Plate 8. instar male nymph

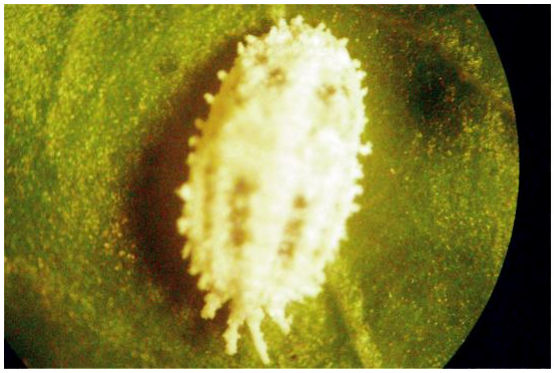

Plate 9. Adult female

Plate 10. Adult male

Plate 11. Copulation

Plate 12. Ovipositing Female

Plate 14. Pupa of *S. epius*

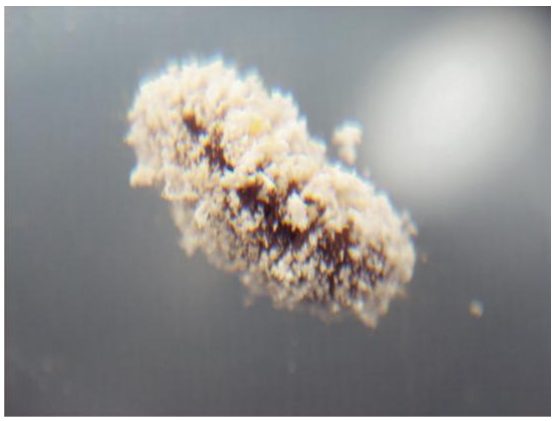

Plate 13. Larva of *S. epius*

(Mishra *et al*., 2004). Body dimension of 0.79 ± 0.08 length and 0.35 ± 0.04 mm width and 4.70 ± 0.77 days duration was reported by Nikam *et al*. (2010) on cotton leaves, respectively.

III instar: Male and females of *P. solenopsis* nymphs can be distinguished from third instar onwards. The newly moulted third instar nymphs of female were white and oval with distinct segmentation (Plate 5). It measured with on an average of 1.11 ± 0.05 mm in length and 0.52 ± 0.02 mm in breadth. The duration varied from 4 to 11 days with a mean of 6.93 ± 1.83 days (Table 1). The male nymphs formed a white silken cocoon after their third moult, which was absent in females. The cocoons were whitish to reddish brown and elongated in shape and they were distinct in general appearance from that of previous nymphal instars having begun to assume form of the adult (Plate 6). The caudal filaments were absent. The average length of third instar male was 1.23 ± 0.08 mm and breadth was 0.50 ± 0.05 mm. The duration ranged from 1 to 3 days with an average of 2.1 ± 0.64 days (Table 1). Agrawal (1953) and Mishra *et al.* (2004) observed that the third instar female nymph completed it development within 7 to 8 days for *P. insolitus* and *P. bengalensis* respectively, whereas in case of *P. solenopsis* on cotton it required 4 to 6 days for female and 6 to 7 days for male (Nikam *et al*., 2010) and 8.30 days for *P. citri* (Malleshaiah *et al*., 2000). Thus present findings are more or less

Table 2. Correlation matrix between weather parameters and number of mealybugs on hibiscus and its predators *Spalgis epius* and *Scymnus coccivora* during 2007-08

Weather parameter	Correlation coefficient (r)		
	Mealybug	*S. epius*	*S.coccivora*
Max. Temperature ^{o}C (x_1)	0.4142*	0.3510	0.3106
Min. Temperature ^{o}C (x_2)	0.0102	-0.0932	-0.1125
Av. Temperature ^{o}C (x_3)	0.1932	0.0464	0.0464
Morning RH (%) (x_4)	-0.2728	-0.3258	-0.3077
Evening RH (%) (x_5)	-0.3224	-0.3430	-0.3652
Average RH(%) (x_6)	-0.4444*	-0.4060*	-0.4230*
Wind Velocity (km/hr) (x_7)	-0.3656	-0.3832	-0.3947
Sunshine Hours (hr/day) (x_8)	0.2009	0.1390	0.1323
Rain-fall (mm) (x_9)	-0.2497	-0.1906	-0.2114
Rainy Days (x_{10})	-0.2166	-0.1715	-0.2151
Evaporation (mm) (x_{11})	-0.0657	-0.1719	-0.1687
Mealybugs per plant (x_{12})	-	0.9245*	0.8698*

* Significant at 5% level (r = ± 0.4034)

in conformity with the findings of above workers. However, Akintola and Ande (2008) reported that the third instar female nymph required 10 days to complete its development.

IV male instar: The male had an additional fourth instar. The fourth instar male emerged out after third moulting within cocoon, was whitish yellow and distinctly different in general appearance (Plate 8). It measured an average of 1.23 ± 0.08 mm in length and 0.50 ± 0.05 mm in breadth. The duration varied from 2 to 5 days with an average of 3.5 ± 0.76 days (Table 1).

Adult: Adult male was delicate, slender, elongate in shape and smoky brown with a single pair of well developed mesothoracic wings and three pairs of well developed legs with no mouthparts (Plate 10). Two pairs of long waxy filaments were present at the anal end which extended beyond the wing tips in fully grown male. The average length of 1.18 ± 0.06 mm with wing expansion of 2.33 ± 0.06 mm was observed (Table 1).

The body of newly emerged adult female was elongated oval, soft with distinct segmentation and flattened dorso-ventrally. It was light to dark whitish yellow in colour which subsequently changed to white colour due to covering of mealy scale within few hours (Plate 9). After few days, paired dark stripes developed dorsally. Females were apterous, soft bodied, well distinguished segmented. Antennae were filiform. The body possessed short lateral wax filaments and slightly longer terminal wax filaments (less than half as long as the body). The newly emerged adult female measured on an average of 2.23 ± 0.26 mm in length and 0.87 ± 0.07 mm in breadth. However, the average length of female at the time of egg laying was 3.58 ± 0.36 mm in length and 1.59 ± 0.24 mm in breadth (Table 1). More or less similar characters of adult female were described by Culik and Gullan (2005), Gautam (2007), Akintola and Ande (2008), Tanwar *et al*. (2008), Jhala *et al*. (2008) and Nikam *et al*. (2010).

Oviposition: The pre-oviposition, oviposition and post oviposition period varied from 9 to 17 days, 6 to 12 days and 3 to 16 days with an average of 8.1 ± 1.44 days, 13.26 ± 2.40 days and 4.43 ± 3.03 days respectively (Table 1). The fecundity of the gravid female varied from 87 to 548 eggs with an average of 256.16 ± 133.64 eggs. Earlier, Agrawal (1953) reported that single female of *P. insolitus* laid 2 to 3 loose cottony egg sacs and each sac consist of 100 to 200 eggs. Nikam *et al.* (2010) observed that 400 to 700 eggs were laid by a female with an average of 572 ± 102 eggs on cotton leaves.

Table 3. Regression coefficients of hibiscus mealybug population and its predators with weather parameters

Weather parameter	Regression coefficient ('r')		
	Mealybug	*Spalgius epius*	*Scymnus coccivora*
	(Y_1)	(Y_2)	(Y_3)
Max Temp (X_1)	2.7059	-	-
Avg. RH (X_2)	-0.5608	-0.0029	-0.0086
A value (constant)	-28.2355	0.2518	0.7264
R_2	0.2770	0.1729	0.1790
Variation explained (%)	27.70	17.29	17.90
R	0.5263	0.4158	0.4230

Longevity: It was observed that the longevity of female varied from 22 to 34 days with on an average of 28.8 ± 2.60 days, while longevity of male varied from 2 to 4 days with an average of 2.6 ± 0.59 days (Table 1). Akintola and Ande (2008) reported that the longevity was about 37 days, in female while, Mishra *et al*. (2004) observed that the average longevity of *P. bengalensis* was 50 ± 2.94 days. Similarly, Nikam *et al*. (2010) reported 8.70 ± 0.79 days and 33.67 ± 1.19 days of average male and female longevity on cotton.

Life cycle: The life cycle (egg to the first oviposition) of female ranged from 23 to 36 days with an average of 29.96 ± 2.89 days while, the life cycle of male (egg to adult emergence) varied from 17 to 23 days with an average of 19.8 ± 1.54 days. The total life span from egg to death of adults varied from 45 to 58 days with an average of 50.06 ± 3.12 days in female and from 20 to 26 with on an average of 22.4 ± 1.63 in male (Table 1). Recently, Nikam *et al*. (2010) reported that the average life cycle of male and female was 26.73 ± 2.20 days and 58.00 ± 3.72 days, respectively on cotton.

Sex ratio: During the course of study, the first instar nymphs of mealybugs were reared upto third instar. On the basis of character of cocoon formation the third instar males were identified and observed that the sex ratio male: female was 1: 1.72.

Population fluctuations and its correlation with biotic and abiotic factors

Data collected during the year 2007-08 revealed that the mealybug population was observed throughout the year with its peak activity from first fortnight of October to first fortnight of December

(Fig. 1). The highest population of mealybugs per plant was found in first fortnight of November (93.68). The mealybug population decreased during January to March. There was significant positive correlation with maximum temperature and negative significant correlation with average relative humidity. Further, the minimum temperature, average temperature and sunshine hours showed positive correlation but non-significant. Similarly, morning relative humidity, evening relative humidity, rainfall, rainy days, wind velocity and evaporation showed non-significant negative correlation with the mealybug population (Table 2).

The regular survey on existence of natural enemies on *P. solenopsis* indicated that two different predators were observed. One was lepidopteran predator, *Spalgis epius* (Westwood) was (Lepidoptera: Lycaenidae) and another was *Scymnus coccivora* Aiyar (Coleoptera: Coccinellidae) collected from field and reared out during present study, however detailed identification remained incomplete. Earlier, Venkatesha *et al.* (2004) reported that *S. epius* larva was predator of various species of pseudococcids and coccids. From the data presented in Table 2 it is evident that both predators *S. epius* and *S. coccivora* showed significant positive relationship with mealybug population (x_{12}) whereas, with weather parameters it showed significant negative relationship with average relative humidity (x_6). The regression analysis (Table 3) revealed that total impact of weather parameters on population of mealybug was 27.70 per cent (R_2 = 0.2770), on population of *S. epius* it was 17.29 per cent (R_2 = 0.1729) and in case of *S. coccivora* it was 17.90 per cent (R_2 = 0.1790).

The present study is the first report on detailed biology of *P. solenopsis* and population dynamics on hibiscus from Southern Gujarat, India. The information on various life stages and activity of different stages can help in planning the strategy of management under practice of plant protection.

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