



Full Length Article

Studies on Cotton Mealybug, *Phenacoccus solenopsis* (Pseudococcidae: Homoptera), and its Natural Enemies in Punjab, Pakistan

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ABSTRACT

The biological studies on cotton mealybug *Phenacoccus solenopsis* Tinsley, were undertaken to explore the role of its natural biocontrol agents. Cotton mealybug was active throughout the year on various crops, ornamental plants and weeds with two population peaks in Multan and nearby districts. Females reached adult stage after three nymphal moults whereas, male nymphs shed two moults before pupation. Reproduction was only sexual. Promising natural enemies such as parasitoid, *Aenasius bambawalei* and predators, *Brumoides suturalis*, *Scymnus coccivora*, *Menochilus sexmaculatus* and spiders were found associated with mealybug in large numbers round the year. Some other species, *Coccinella undecimpunctata*, *C. septempunctata*, *Hyperaspis maindroni*, *Chrysoperla carnea*, *Diadiplosis* sp. and *Geocoris* sp. were relatively less abundant, while *Orius* sp. and *Campylomma* sp. were incidentally recorded on the mealybug. Population dynamics and feeding efficiency tests for natural enemies indicated their significance as bio-control agents in integrated management of mealybug if allowed to act in congenial conditions. © 2012 Friends Science Publishers

Key Words: Cotton; Mealybug; Parasitoid; Predators; Phenology; Incidence

INTRODUCTION

Among crops, cotton stays on the top for its unique position in Pakistan's economy, as it contributes 8.5% of GDP in agriculture sector, about 60% of foreign exchange earnings and fulfills 64% of our edible oil requirements (Arshad, 2011). Cotton crop is attacked by many chewing and sucking insects (Saeed *et al.*, 2007) that cause about 20-40% loss annually (Ahmad, 1999).

In 2005, a new pest, *Phenacoccus solenopsis* Tinsley appeared on cotton crop in Punjab and Sindh provinces, and subsequently spread over to many crops, vegetables, ornamental plants and weeds (Arif *et al.*, 2009, Abbas *et al.*, 2010a & b). As a result of survey across 47 locations predominance of *P. solenopsis* has been established in India (Nagrare *et al.*, 2009). Yield losses of 34.9% in Indian Central Zone (Vennila *et al.*, 2010) and a loss of about 3.1 million bales of cotton in 2006-2007 in Punjab, Pakistan (Mahmood *et al.*, 2011) have been reported.

Although efforts of researchers and extension workers enabled the farmers to cope with this pest, its infestation level increased with poor plant protection especially later in the crop season. Mealybug perpetuated on ornamental plants in offices, parks and residential areas in addition to weeds on waste lands and road sides, from where it shifted to cotton and other crops.

Keeping the importance of cotton mealybug in view, its damage, phenology and biology were investigated along

with recording its natural enemies on different host plants in Multan and surrounding districts. Studies on population dynamics, biology and effectiveness of natural enemies against mealybug were also undertaken that could be effectively incorporated in the integrated management of this pest.

MATERIALS AND METHODS

Field samples were taken monthly during 2008-2010 from mealybug infested plants as mentioned in Table I. A sample consisted of two randomly collected 30 cm long branches bearing 3-4 leaves each in Multan district and surrounding areas. Mealybug and its natural enemies (parasites & predators) in each sample were recorded. The samples were then kept in the laboratory (26^o±1^oC) separately in plastic jars (5 L capacity) covered with muslin cloth, secured with rubber bands.

Samples were examined and number of natural enemies was recorded and removed daily for two weeks. Population percentage of the parasitoid, *Aenasius bambawalei* was calculated based on total number of mealybugs collected in each sample, whereas, number of different predators was recorded from each sample of all plant categories. The data presented is based on three years mean. Studies on biology and feeding efficiency of natural enemies were also carried out in the laboratory.

Newly hatched crawlers were kept individually in 50 glass tubes with cotton leaf as food. Open end of each tube was covered tightly with the help of polythene sheet and rubber band and placed in the laboratory. Their development was observed daily and nymphal moults were recorded. Provision of fresh leaves was maintained throughout the study. Male mealybugs were isolated on cocoon formation/pupation and further studies were conducted on the adults, thus, emerged. Females were kept to note life span, fecundity and mode of reproduction.

To record mating behaviour a gravid mealybug female was exposed to 2-3 randomly selected males in a glass tube. After first successful attempt other males were removed and mating duration was recorded. The female was then allowed to feed on cotton leaves in a glass jar (1 lb capacity) without male. After 24 h the female was again offered to males in the glass tube to record mating as before. The procedure was continued until the female declined to mate in its life span. It was replicated five times.

RESULTS

Cotton Mealybug (*P. solenopsis* Tinsley) Damage: Cotton mealybug is a sap sucking insect that attacked all plant parts. It secreted honey dew which caused stickiness in fibre and served as a medium for sooty molds to grow and hinder plant photosynthesis. Leaf shedding and plant death occurred in 8-10 weeks if infested in early stage of about 8" height of cotton plant.

Identification: Females are wingless, flat and oval measuring 4-5 mm when full-grown. Body colour is greenish yellow and covered with white waxy powder. There are two parallel rows of dark spots on dorsal side (thorax & abdomen) and numerous short white waxy filaments on outer margin of the body. Anal filaments are a bit longer.

Males are light smoky brown in colour with two grayish white transparent wings and four white waxy caudal filaments (inner pair a bit longer). They had blackish eyes, long antennae and resembled cotton whitefly adults in shape and size with rudimentary mouth-parts.

Biology: Under laboratory conditions ($26^{\circ}\pm 1^{\circ}\text{C}$), females mated repeatedly lasting for 10-45 (\bar{X} = 23.9) minutes. They laid 310-625 (\bar{X} = 470.3) creamy white oblong eggs in 3-5 white waxy ovisacs produced under the abdomen at different time intervals during oviposition period. Incubation period of eggs lasted 4-6 h in the laboratory. They passed through three nymphal instars before entering into adult stage. First to third instar nymphs lasted, respectively, for 5-7 (\bar{X} = 5.96), 4-7 (\bar{X} = 4.64) and 6-9 (\bar{X} = 6.75) days. Adult females lived for 15-27 (\bar{X} = 23.7) days with total life span (nymph + adult) of 30-48 (\bar{X} = 40.7) days indicated more or less 10 overlapping generations in a year. Eggs of the mealybug were also found naked in clusters on ratoon cotton in the field in winter

months of January and February with mean maximum and minimum temperatures of 17.4 and 4.9°C, and 21 and 7.8°C, respectively.

Male nymphs moulted first in 5-6 (\bar{X} = 5.67) days and after further 4-6 (\bar{X} = 5.0) days, they spun silken cocoons around them and pupated. Before pupation they shed second moult found attached to the cocoon. Male adults emerged in 5-7 (\bar{X} = 5.8) days from the pupae. They had short life span of 2-3 days in the laboratory.

Reproduction: To determine whether cotton mealybug reproduces parthenogenetically, its 25 newly hatched nymphs were reared individually in glass tubes in the laboratory. Fresh cotton leaves were provided for food daily. Out of these, 9 died within 20 days. The remaining 16 lived for 31-49 (\bar{X} = 40.22) days. During their life span they neither laid eggs nor produced ovisacs, indicating no parthenogenetic reproduction in mealybug.

Dispersal: Winglessness was no hindrance in the spread of this pest. It was easily flown by wind on infested dry and dropped plant foliage. Water courses, field workers, animals and farm machinery played significant role in its dispersal. Transportation of infested agricultural produce, ornamentals and other plants also contributed in this direction.

Phenology: After winter, population build-up of mealybug took place and its number was high in March on weeds and in April on crops, respectively being 328 and 434 per sample. Its number remained low in mid cotton season followed by a second peak of 320 mealybugs per sample on weeds and 474 on crops in November. Population declined in December. On ornamental plants, incidence of mealybug started increasing in May. Its highest number of 432 mealybugs per sample was recorded in July followed by a decline. Second peak of 304 mealybugs per sample was observed in November followed by a gradual fall (Fig. 1).

Natural Enemies

A. Most Common Natural Enemies

1. *Aenasius bambawalei* Hayat (Encyrtidae: Hymenoptera) Population dynamics: *A. bambawalei* remained active throughout the year with fluctuating population densities in different months. On crops listed in Table I, its mean parasitism on the mealybug was quite low in February (6.2%) and March (2.2%) but higher in May (35.5%). Thereafter, the incidence fluctuated at low levels from June to August and started increasing in September. It was most common during winter, being highest (58.3%) in December followed by January (44.1%). Population level on weeds was low but trend was almost the same as for crops. On ornamental plants, parasitism was high during summer months of May-September, being highest (75.3%) in July (Fig. 2). A hyperparasite (*Promuscidea unfauciiventris*) was recorded from the mummies of *A. bambawalei* with highest incidence of 26.7% in October.

Biology: Mated females of *A. bambawalei* parasitized 9-31 (\bar{X} = 15.6) mealybugs of suitable stage (18-20 days-old) in

Fig. 1: Population of cotton mealybug on different host plants

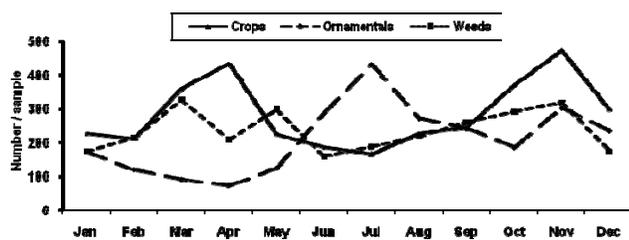


Fig. 2: Incidence of *Aenasius bambawalei* on cotton mealybug

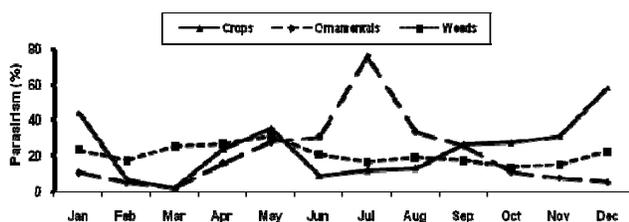


Fig. 3: Population of *Brumoides suturalis* on cotton mealybug

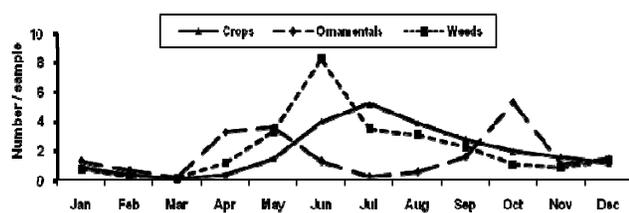
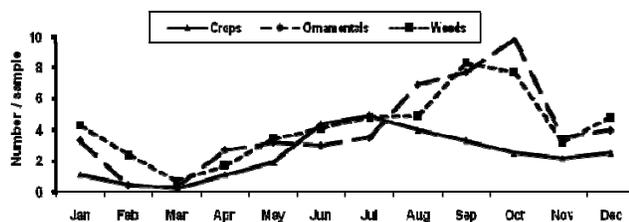


Fig. 4: Population of *Scymnus coccivora* on cotton mealybug



their total life span of 11-25 (\bar{X} =20.0) days. From the parasitized mealybugs over 97% adult emergence was recorded with female to male ratio of 5.3:10 (1:1.9). Mean development period from egg to adult emergence was slightly longer (14.2 days) for females than that of males (13.6 days) (Table II). Only males emerged from the mealybugs exposed to unmated females of the parasitoid. Its development rate reduced to half in older mealybugs parasitized during the ovisac formation period as compared to those in pre-oviposition stage.

***Brumoides suturalis* (Fabricius) (Coccinellidae: Coleoptera)**

Population dynamics: *B. suturalis* was found associated with the mealybug throughout the year on all host plants. Its incidence was about two per sample in winter. Its population started building-up in spring being highest on weeds followed by crops and ornamental plants from April to October (Fig. 3).

Biology: Egg, larval, pupal and adult stages of *B. suturalis* lasted 3, 12.5, 8 and 22.5 days, respectively. Its larvae and adults consumed, on average, 310 crawlers and 237 3-4 day old nymphs of mealybug respectively in the laboratory.

3. *Scymnus coccivora* Ayyar (Coccinellidae: Coleoptera)

Population dynamics: It was found associated with mealybug throughout the year on various host plants. Though small sized, it was more abundant than any other predator. Its number was highest on mealybug infested ornamental plants and weeds as compared to field crops (Fig. 4).

Biology: Eggs, larvae, pupae and adults lived for 4-5, 9-12, 5-8, and 57-67 (\bar{X} =62.33) days, respectively, under laboratory conditions. Larvae and adults consumed 70-100 (\bar{X} =91.6) and 439-474(\bar{X} =453.67) 3-4 day old mealybugs in the laboratory.

4. *Menochilus sexmaculatus* Fabricius. (Coccinellidae: Coleoptera) Zigzag Ladybird Beetle

Population dynamics: It was recorded on mealybug round the year. Its incidence was higher on crops especially during winter followed by that on weeds and ornamental plants during summer (Fig. 5).

Biology: Egg, larval, pupal and adult periods were 3, 12-14, 5-6 and 34-36 days, respectively. Its larvae and adults consumed, on average, 410 and 2967 3-4 day old nymphs of mealybug, respectively in the laboratory.

5. Spiders (Acarina)

Population dynamics: A few species of spiders were found

Fig. 5: Population of *Menochilus sexmaculatus* on cotton mealybug

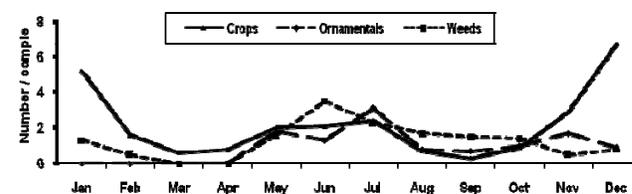
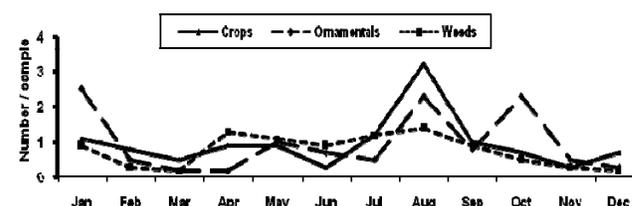


Fig. 6: Population of spiders on cotton mealybug



associated with the mealybug on different host plants round the year. Their populations per sample was generally very low (0.2–1.0) on all the plant groups. Highest number recorded with mealybug infestations, was on crops (3.2) followed by ornamental plants (2.5) and weeds (1.4) (Fig. 6).

B. Less Common Natural Enemies

1. *Coccinella undecimpunctata* Linnaeus (Coccinellidae: Coleoptera) 11-Spotted Ladybird Beetle

Population dynamics: Both adults and nymphs were found predated on mealybug on crops, ornamentals and weeds. Its population fluctuated in low numbers during winter and mid-summer (Table III).

Biology: Its eggs, larvae, pupae and adults lived for 3, 9-10, 4-5 and 38 days, respectively. Larvae and adults, on average, consumed 391 and 3160 3-4 day old mealybug nymphs in the laboratory.

2. *C. septempunctata* Linnaeus (Coccinellidae: Coleoptera) 7-Spotted Ladybird Beetle

Population dynamics: This predatory coccinellid persisted in very low numbers on the mealybug infesting various crops,

ornamentals and weeds mainly in winter and mid-summer (Table III).

Biology: Eggs, larvae, pupae and adults lived for 3-4, 7-9, 4-6 and 41-48 days, respectively in the laboratory.

3. *Hyperaspis maindroni* Sicard (Coccinellidae: Coleoptera)

Population dynamics: It was found with mealybug infestations on various plant species in summer months from April to September. Highest mean population was recorded in May (6.3) followed by other months (Table III).

Biology: Adults lived for 14-16 days and consumed 125-141 3-4 day old nymphs of cotton mealybug in the laboratory.

4. *Chrysoperla carnea* (Stephens) (Chrysopidae: Neuroptera) Green Lacewing

Population dynamics: Its population persisted at low level on mealybug infested plants of various categories round the year except March and April (Table III).

Biology: On cotton mealybug nymphs, larval life of *C. carnea* was prolonged to 22-30(\bar{X} =25.3). It consumed

Table I: Host plants examined for cotton mealybug and its natural enemies

Host Plants Category	Botanical Name	English/Vernacular Name
Field crops	<i>Gossypium hirsutum</i> Linn.	Cotton
	<i>Solanum melongena</i> Linn.	Egg plant, Brinjal
	<i>Abelmoschus esculentus</i> Linn.	Okra, <i>Bhindi</i>
Ornamentals	<i>Hibiscus rosa-sinensis</i> Linn.	China rose, <i>Gurhal</i>
	<i>Cestrum nocturnum</i> Linn.	Night Jasmine, <i>Raat Ki Rani</i>
	<i>Lantana camara</i> Linn.	Tickberry, Surinum tea plant
Weeds	<i>Abutilon indicum</i> Sweet	Mallow, <i>Kanghi</i>
	<i>Chenopodium album</i> Linn.	White goosefoot, <i>Bathoo</i>
	<i>Withania somnifera</i> Dunal	Winter cherry, <i>Aksen</i>

Table II: Development of *Aenasius bambawalei* on cotton mealybug under laboratory condition

Sl. No	Female life (days)	No. of mealy-bugs offered (@ 4-5/day)	No. of mummies formed	No. of adult parasitoid emerged	Sex ratio		Mean of egg to adult emergence period (days)	
					Female	Male	Female	Male
1	22	108	12	11	4	7	15.3	14.6
2	25	123	15	14	5	9	15.3	14.9
3	14	70	9	9	3	6	14.3	13.5
4	24	118	31	31	7	24	14.7	14.3
5	20	100	21	20	5	16	14.6	13.9
6	19	95	10	10	6	4	13.7	13.3
7	20	100	14	14	4	10	13.0	12.6
8	19	95	14	14	6	8	14.1	13.1
9	11	55	12	11	4	7	12.7	12.4
10	21	105	16	16	6	10	14.2	14.3
11	23	113	18	17	7	10	15.1	13.2
12	22	110	15	15	6	9	13.8	12.8
Mean	20.0	99.3	15.6	15.2	5.3	10.0	14.2	13.6

Table III: Mean number of less common natural enemies of cotton mealybug on various host plants

Natural Enemies	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<i>Coccinella undecimpunctata</i>	0.4	0.2	0.5	0.6	0.4	1.1	1.6	0.0	0.0	0.0	0.1	0.3
<i>Coccinella septempunctata</i>	0.3	0.2	0.4	0.3	0.1	0.5	0.0	0.0	0.0	0.2	0.1	1.0
<i>Hyperaspis maindroni</i>	0.0	0.0	0.0	2.2	6.3	2.0	1.6	0.4	0.1	0.0	0.0	0.0
<i>Chrysoperla carnea</i>	0.5	0.3	0.0	0.0	0.5	1.0	2.3	1.1	1.8	1.1	0.6	2.7
<i>Diadiplosis</i> sp	0.4	1.4	3.7	2.8	1.2	3.0	0.7	4.7	5.4	8.7	5.0	1.6
<i>Geocoris</i> sp	0.4	0.3	0.0	0.0	0.2	2.5	0.4	0.3	0.5	1.6	0.4	0.7

218-310 (\bar{X} =273.3) 3-4 day old nymphs of mealybug in its larval life in the laboratory.

5. *Diadiplosis* sp. (Cecidomyiidae: Diptera)

Population dynamics: It was found scattered on mealybug infestations on different plant groups throughout the year. Its infestation levels were higher from August to October (Table III).

Biology: Egg, larval, pupal and adult stages of this predatory midge lasted 3, 10-12, 5-6 and 2-3 days, respectively, in the laboratory.

6. *Geocoris* sp. (Geocoridae: Hemiptera) Big-eyed Bug

Population dynamics: It was active round the year except March and April. Its population was generally very low with highest number being 2.5 per sample in June (Table III).

C. Incidental natural enemies: Two predatory bugs including an Anthocorid minute pirate bug (*Orius* sp.) and a Mirid (*Campylomma* sp.) were found from the field collections of mealybug. Both the species fed on mealybug crawlers in the laboratory but quantitative feeding efficiency was not recorded.

DISCUSSION

Being polyphagous and capable to withstand food-shortage and adverse weather conditions, the cotton mealybug can be considered as an all-time pest on most of our economic crops, vegetables and other plants. In addition to direct losses by sucking plant sap, its body secretions caused pre- and post- harvest qualitative losses to the agricultural produce.

Our findings on biology of *P. solenopsis* were generally similar to those of Vennila *et al.* (2010) with slight differences due to rearing environments. However, some characteristics like mode of reproduction (asexual) and the number of males caudal filaments (2) clearly differed with our studies. These differences suggest further investigations for specific/sub-specific identity of *P. solenopsis* in India.

Population peaks of mealybug on vegetables (okra, brinjal etc.) in March/April and other crops (cotton etc.) in October/November were observed near their maturity/termination. At this stage, pesticides applications were either reduced or were less effective due to plant canopy formation resulting in high densities of mealybug population. Trend of mealybug population was almost the same on weeds. On ornamental plants, population of mealybug started increasing in spring and was highest in July followed by a decline and another peak in November showing its natural trend of population growth on this category of plants not being normally sprayed with pesticides.

Quite a large number of natural enemies of the mealybug were found playing active role in suppressing its population in the field. Of these, *A. bambawalei* was most effective endo-parasitoid. Its incidence on mealybug was

higher on the ornamental plants that were least sprayed against insect pests. Its parasitism was also high on mealybug on crops (cotton etc) when insecticidal applications were reduced/stopped prior to their termination. Most probably, that was the reason population of mealybug remained moderate on weeds which were not directly sprayed for insect pests. Some weeds, however, received some quantities of insecticides indirectly in the field or by drifts around the field. Currently observed promising performance of *A. bambawalei* may be adversely affected by high population of the hyperparasite *Promuscidea unfasciatiiventris* (Arif *et al.*, 2011).

Among predators of mealybug found throughout the year, *S. coccivora* was most abundant followed by *B. suturalis*, *M. sexmaculatus* and spiders. Like *A. bambawalei*, all the predators showed higher incidence on ornamental plants and weeds as compared to crops for deleterious effects on natural enemies due to insecticidal application on crops.

Some other natural enemies of the mealybug, found intermittently during the year included *C. undecimpunctata*, *C. septempunctata*, *H. maindroni*, *Chrysoperla carnea*, *Diadiplosis* sp. and *Geocoris* sp. Their population was generally very low except that of *Diadiplosis* sp. which showed comparatively higher incidence due to its gregarious nature in feeding stage.

High incidence of natural enemies on unsprayed plants (weeds & ornamentals) and wider host range available for most of them provide sufficient reason to rely on their performance. Therefore, despite the successful survival of mealybug on large number of host plants round the year, it can be managed adequately if its natural enemies are provided fair chance to play their role. Application of chemical pesticides can only be allowed if pest infestation level goes beyond control with natural enemies. Observations recorded in this study about phenology of mealybug, its parasitoids and predators had more or less the same trend as reported by Solongi and Mahmood (2011) and Mahmood *et al.* (2011).

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