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Research Article

Spatio-temporal dynamics of the parasitoid, *Aenasius bambawalei* Hayat (Hymenoptera: Encyrtidae) on mealybug, *Phenacoccus solenopsis* Tinsley in cotton based cropping systems and associated weed flora

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ABSTRACT: The mealybug, *Phenacoccus solenopsis* Tinsley, a polyphagous pest with a wide host range is of recent occurrence on Bt cotton in all the three major cotton growing zones in India. The first perceptible appearance of the pest on cotton in Warangal district of Andhra Pradesh was noticed in *Kharif* 2008. *P. solenopsis* was recorded on several plants other than cotton which include cultivated crops and weed hosts. The mealybug population is naturally regulated by *Aenasius bambawalei* Hayat (Hymenoptera: Encyrtidae). This paper reports the dynamics of this key parasitoid in a spatio-temporal perspective. Monitoring of the parasitoid on *P. solenopsis* occurring on weed hosts found on field bunds, crop fallows, barren lands, roadsides and village backyards indicated its activity on eight weed hosts late in the cotton growing season of 2009. During the year 2010, its activity started early in the season on few weed hosts while many more supported parasitization late in the season. Parasitoid activity was higher (11.3 to 15.3%) initially on the key hosts (*Corchorus olitorius* L., *Abutilon indicum* L., and *Sida acuta* Burm. F.) early in the season (August) which later shifted gradually to the main host (cotton) during the later part of the season. Cropping system and spatial perspective indicated that cotton fields adjacent to roadside and crop fallows supported higher parasitization during September (8.3 – 9.1%) and cotton fields adjacent to barren lands in December (13.3%). These findings have implications for the management of *P. solenopsis* mealybug on cotton from an agro eco-system perspective.

KEY WORDS: *Phenacoccus solenopsis, Aenasius bambawalei*, *Gossypium hirsutum*, cotton, mealybug, parasitoid, alternate hosts, weed flora, cropping systems, diversity

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INTRODUCTION

The solenopsis mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) is a polyphagous pest, with a wide host range. It establishes and spreads easily causing damage to a wide range of vegetable, horticultural and field crops. It has a wide range of variation in morphological characters, biological adaptations and ecological adjustability (Hodgson *et al*., 2008). *P. solenopsis* was initially reported as a pest of cotton in Texas, USA (Fuchs *et al.*, 1991). In 2005, it has been regarded as a new invasive species and a potential threat to cotton in Pakistan (Hodgson *et al.,* 2008), and a year later in India. The mealybug was noticed in 2006 in the north zone of India comprising of Punjab, Haryana, Rajasthan and Gujarat (Nagrare *et al*., 2009). Its occurrence has been reported from the central cotton growing zone and was observed at a perceptible level during 2008 in Andhra Pradesh. *P. solenopsis* feeds on phloem and excretes honey dew, which encourages the development of sooty mould that reduces plant photosynthetic activity. The pest attacks growing parts and results in bunchy and stunted growth of the affected plants which produce small sized bolls with bad opening. Estimated reduction in seed cotton yield due to the pest is about 44 percent (Dhawan *et al*., 2007). The pest carryover and its spread to cotton may be possible through several alternate hosts.

Aenasius bambawalei Hayat (Hymenoptera: Encyrtidae), has been reported as a solitary endoparasitoid on *P. solenopsis* (Hayat, 2009). It is the only dominant and aggressive parasitoid reported so far, responsible for the decline of mealybug in the north zone after its initial unabated establishment (Rishi Kumar *et al*., 2009). The parasitoid is active in all the cotton growing zones of the country. Adult females parasitize third instar nymphs of *P. solenopsis* (Ashfaq *et al*., 2010) and kill the

host before its maturity. Mealybug mummies formed due to parasitization are reddish brown and can easily be distinguished from the healthy colony. Though, the earlier studies established the potential of *A. bambawalei* as a parasitoid on *P. solenopsis* on cotton, the information on its parasitizing ability when *P. solenopsis* is on other alternate hosts is not available. In view of the wide host range of *P. solenopsis*, the role of these host plants in the carryover of pest and its natural enemy, *A. bambawalei* assumes greater significance. Hence, a study was carried out to know the incidence of *P. solenopsis* and its parasitization by *A. bambawalei* in a cropping system perspective. The paper reports the spatio-temporal dynamics of the parasitoid and brings to light the tri-trophic interactions in an agro-ecosystem perspective.

MATERIAL AND METHODS

Recording of mealybug infestation

Field surveys were conducted during *kharif*, 2009 and 2010 in Shayampet mandal of Warangal district, Andhra Pradesh, India. Mealybug infestation on cotton was recorded at fortnightly intervals in seven selected fields based on prevailing cropping systems along with the pesticide use over time. Individual cotton plants (200-300 plants) in 10 border rows in all four directions of the field were inspected for infestation. Mealybug samples were collected from all the fields at fortnightly intervals and kept in laboratory at 27±1°C, 65% RH for parasitoid emergence. Observations for *P. solenopsis* was carried out at periodic intervals on weed flora found on roadsides, crop fallows, barren lands (uncultivated fallows), cultivated fields and backyards which were largely free from pesticide sprays. Percent plant infestation was computed for all the identified weed hosts by pooling data across the fields. These weed flora were preserved in the form of herbarium for future reference. Identification of weeds was done with the help of scientists from Department of Agronomy, College of Agriculture, Rajendranagar, Hyderabad.

Recording of parasitization levels

Mealybug colonies along with infested plant parts on cotton and weed hosts measuring at least 10 cm in length were cut, kept in individual jars and covered with *kora* cloth. These infested plant samples were brought to the laboratory for enumeration of third instar nymphs and adult mealybugs. Samples were returned to jars and observed daily for parasitoid emergence till 15 days after collection. Parasitoid counts were converted to percent parasitization with reference to the initial count of mealybugs.

Statistical analysis

The main and interactive effects of plant species and month of observation (as fixed effects) were analyzed using independent two-way analysis of variance (ANOVA) models for CRD factorial for the response variables: plant infestation by *P. solenopsis* and parasitization by *A. bambawalei* on different plant hosts. Only percent plant infestation data were arcsine transformed before statistical analysis to normalize the data (but un-transformed values are presented in Table 1). Monthly mean parasitization levels of *A. bambawalei* on *P. solenopsis* on different plant species were compared with cotton by using Tukey's studentized range (HSD) post-hoc test. All analyses were carried out using PROC GLM procedure for unbalanced data in SAS 9.2.

RESULTS AND DISCUSSION

Field surveys were undertaken to assess the spatio-temporal dynamics of mealybug, *P. solenopsis* and its parasitoid, *A. bambawalei* occurring on cotton and associated weed flora over two seasons (2009 and 2010). The diversity of host plants observed during the surveys reflected the host preferences of the mealybug under natural conditions. In 2009, the focus was on weed hosts that harboured the mealybug in uncultivated areas mostly free from pesticide sprays. Eight weed hosts were found to support parasitization by *A. bambawalei* (Table 1) in different months (September to November). Weed hosts were observed at different densities during the season and accordingly percent plant infestation of the mealybug varied. Mean infestation was significantly high during October (43.8%) and September (32.7%) while mean parastitisation was non-significant across weed hosts. Among the six weed hosts observed in September, *Abutilon indicum* L. showed the highest plant infestation (48.4%) followed by *Acalypha indica* L. (30.0%), *Sida acuta* Burm F. (27.7%) and *Aerva lanata* L. (25.0%). Host plant species heavily infested have been regarded as most preferred to the pest (Abbas *et al*., 2010). Percent parastization by *A. bambawalei* in September was in the range of 5.3-12.5% at an average of 7.9%. Among the weeds during October, *Abutilon indicum* L. was the most preferred host for *P. solenopsis* (58.7% plant infestation) followed by *Parthenium hysterophorus* L. (55.0), *A. lanata* (50.0%), *Euphorbia geniculata* L. (48.1%) and *S. acuta* (36.7%). However, maximum parasitization was observed on *Hibiscus rosa-sinensis* L. (11.1%) followed by *A. indicum* and *S. acuta* with an average parasitization of 5.0% on all the weed hosts observed in October. Two weed hosts supported parasitization during November with the highest observed on *A. indicum* (8.3%). Although *P. hysterophorus* was also abundant in November, less

than 1.0% plants had mealybug infestation and these did not show parasitization by *A. bambawalei* (Table 1).

In 2009, activity of *A. bambawalei* on mealybug populations in protected cotton fields was surveyed in a cropping system perspective (Fig. 1). Effects of adjacency factor, month of occurrence and their interaction were non-significant. However, in September highest parasitization was observed on mealybugs collected from cotton fields adjacent to roadsides (9.1%) followed by cotton fields adjacent to crop fallows (8.3%). In October, highest parasitization (9%) was observed from cotton fields adjacent to solanaceous vegetables. In November and December, cotton fields adjacent to barren lands, vegetables, roadsides and crop fallows supported higher parasitization by *A. bambawalei*. In January, mealybug infestation and parasitization was observed mostly in irrigated cotton fields. Based on mean parasitization over the entire season, higher mealybug infestation and its parasitization was observed in cotton fields adjacent to barren lands, followed by cotton fields adjacent to roadside and alternate host crops such as vegetables (brinjal, okra and chillies). Lower parasitization levels were observed in cotton fields adjacent to non-host crops such as groundnut and sesamum (Fig. 1). *P. solenopsis* has, however, been recorded on sesame in Pakistan (Arif *et al*., 2009).

Table 1. Activity of *Phenacoccus solenopsis* and its parasitoid, *Aenasius bambawalei* on different weed hosts during 2009

Weed species	% plant infestation by *P. solenopsis*			% parasitization by *A. bambawalei*		
	Sep	Oct	Nov	Sep	Oct	Nov
Abutilon indicum L.	48.4 (22)	58.7 (240)	11.5 (214)	7.9 (285)	6.1 (404)	8.3 (94)
Acalypha indica L.	30.0 (22)	16.6 (48)	5.7 (70)	6.1 (110)	3.1 (28)	5.6 (18)
Parthenium hysterophorus L.	18.8 (16)	55.0 (588)	0.7 (134)	10.5 (19)	1.8 (74)	0.0 (5)
Sida accuta Burm.F.	27.7 (48)	36.7 (275)	–	5.3 (81)	3.3 (239)	–
Aerva lanata L.	25.0 (200)	50.0 (80)	–	12.5 (200)	2.0 (95)	–
Euphorbia geniculata L.	–	48.1 (21)	–	–	1.8 (48)	–
Hibiscus rosa sinensis L.	10.0(40)	–	–	–	11.1 (18)	–
Malvastrum coramandelianum L.	–	32.5 (78)	–	–	0.6 (141)	–
Mean*	32.7ab	43.8b	8.3a	7.9	5.0	6.1
SEM±	18.4	25.6	8.1	5.7	3.5	9.1

Figures in parentheses represent sample size; *means followed by the same letters in a row are not significantly different at p=0.05

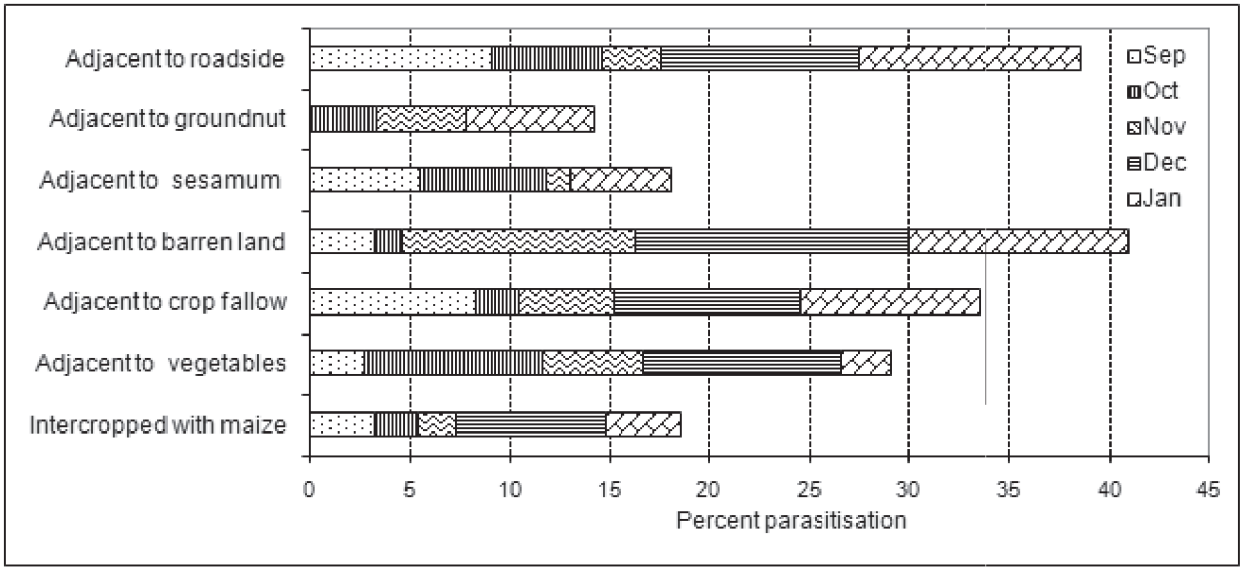

Fig. 1. Parasitism by *Aenasius bambawalei* on *Phenacoccus solenopsis* observed in cotton fields adjacent to different crops, roadsides, fallow and barren lands during 2009

In 2010, ten weed hosts on field bunds around cotton fields infested by *P. solenopsis* also supported parasitization by *A. bambawalei* despite exposure to direct pesticide sprays or spray drift. Effect of plant species, month of observation and their interaction effect were all significant (Table 2). Early in the season, parasitization was higher on weed hosts (7.1 to 15.3%) on field bunds compared to cotton plants (5.3%). Unlike on cotton, parasitization was not evident on all the weed hosts throughout the season. For most part of the season, parasitization was observed on mealybugs collected from *A. lanata* (5.3-11.8%), *Achyranthus aspera* L. (7.6-11.8%) and *A. indicum* (7.3-14.8%). Interaction between plant species and month of occurrence was significant. Predominant early season weed hosts that supported parasitization during August – September were *P. hysterophorus* (12.2%), *S. acuta* (2.4–11.3%), *Phyllanthus reticulatus* Poir (6.5–7.7%), *Corchorus olitorius* L. (15.3%), *Commelina bengalensis* L. (8.4-9.8) and *Xanthium strumarium* L. (6.9%). *Malvastrum coramandelianum* L. supported parasitization during the later part of the season during November – December (3.5–13.3%) (Table 2).

Field surveys to record host range of *P. solenopsis* on flora associated with cotton agro-ecosystem were carried out during 2006 and 2007 in Pakistan wherein 154 plant species were recorded including 64 weed species as hosts which were categorized as year round hosts, summer (early season) and winter (late season) hosts (Arif *et al.,* 2009). Six of the reported weed hosts *viz., A. indicum*, *A. aspera*, *Corchorus* sp., *H. rosa sinensis*, *M. coramandelianum* and *X. strumarium* are common to Warangal. Five of the weed host species viz., *A. aspera, P. hysterophorus, X. strumarium, A. indicum* and *H. rosa sinensis* reported in the present study to harbour both the mealybug and its parasitoid figure in the top 10 ranked weed host species in Pakistan, based on intensity of mealybug infestation and generally in agreement with the month of observed population intensity (Abbas *et al.,* 2010). However, these two host range determination surveys for *P. solenopsis* undertaken in Pakistan do not cover the dynamics of parasitization as reported in the present study. *S. acuta* and *A. lanata* appear to be unique to Warangal location. *H. rosa sinensis* is a preferred, regular and an important summer host for *P. solenopsis* (Aheer

Table 2. Percent parasitization of mealybug by *Aenasius bambawalei* on cotton and key weed hosts during 2010

Plant species	Percent parasitization during					*Mean*	*SEM±*
	Aug	Sep	Oct	Nov	Dec		
A. indicum	14.8*	7.3	10.6	–	–	12.9*	4.8
A. lanata	7.1	5.6	5.3	11.8	–	7.1	2.7
P. hysterophorus	–	12.2	–	5.4	–	7.7	5.3
S. acuta	11.3	2.4	–	–	–	5.4	5.1
A. aspera	–	11.8	7.6	–	–	9.0	5.5
C. olitorius	15.3*	–	–	–	–	15.3*	2.6
M. coramandelianum	–	–	–	13.3	3.5*	8.4	7.0
P. reticulatus	7.7	6.5	–	–	–	7.1	0.9
C. bengalensis	9.8	8.4	3.5	–	–	8.3	2.7
X. strumarium	–	6.9	–	–	–	6.9	4.3
Cotton	5.3	9.1	8.3	7.4	7.6	7.9	3.2
Mean	9.7	7.7	7.9	8.2	3.5		
SEM±	4.9	2.9	3.4	4.2	4.9		
Factor (F)	DF	SS	F Value	P > F			
Plant species (F1)	10	217.49	2.12	0.0365*			
Month (F2)	4	163.60	3.99	0.0062*			
F1 x F2	11	301.80	2.68	0.0074*			

*Significant at p=0.05

et al., 2009) even at Warangal and is mostly prevalent in backyards of many village households. However, parasitization on mealybugs on this key host plant was recorded only in the month of October which needs to be further investigated in future surveys.

Several insecticide molecules have been recommended for the control of *P. solenopsis* on cotton (Saeed *et al*., 2007, Joshi *et al*., 2010). However, the diversity of its hosts suggests that infestations on cotton cannot be managed by insecticide sprays alone. This study clearly establishes that these diverse hosts support activity of the parasitoid at different times of the year in the cotton agro-ecosystem under unprotected conditions. In this study, consistent parasitization levels hovering around 5-10% on *P. solenopsis* inhabiting weed hosts in uncultivated areas and field bunds throughout the season suggests pursuing biological control of this pest involving the dominant parasitoid, *A. bambawalei* as a key option for formulating an integrated pest management strategy.

For the first time, the study has identified and brought out the importance of weed hosts in the population dynamics of *P. solenopsis* and its dominant parasitoid, *A. bambawalei* in a spatio-temporal perspective in the cotton agro-ecosystem. The survey results support a generalization that the host plant species found to be the most severely infested with the pest are also the most conducive to its parasitoid. The findings suggest further exploration and assessment of biological control with *A. bambawalei* as augmentative and conservation approaches to control solenopsis mealybug menace on cotton. The results of the present study also enable devising an integrated pest management strategy for this pest that can prevent serious future outbreaks that often lead to increased protection costs and reduced seed cotton yields.

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