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Research Article

Biological control of solenopsis mealybug, *Phenacoccus solenopsis* Tinsley on cotton: a typical example of fortuitous biological control

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ABSTRACT: Observations on field incidence of solenopsis mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) attacking cotton and the predators and parasitoids associated with it were recorded in the cotton growing belt of Haryana state by conducting monthly surveys during 2008 and 2009. To assess the impact of primary and secondary parasitoids on the population of the solenopsis mealybug, parameters like severity of pest incidence, abundance of predators and parasitoids and parasitism / hyperparasitism by various parasitoids were taken into consideration. One primary parasitoid, *Aenasius bambawalei* Hayat, and four hyperparasitoids were recovered. The most abundant and dominant hyperparasitoid was *Myiocnema comperei* Ashmead, while the other three were of lesser importance. Similarly, out of six predators recovered from mealybug colonies, *Brumoides suturalis* (Fabricius) and *Nephus regularis* Sicard were more abundant. During 2008, in the absence of the primary parasitoid, *A. bambawalei*, mealybug incidence was quite high on cotton. However, during 2009, as the activity of the primary parasitoid increased, the pest population reduced significantly and its incidence was confined to only 18% of the fields and 1.6% of the plants by August. During mid-season (July-August), *A. bambawalei* was attacked by several species of hyperparasitoids, particularly *M. comperei*, which caused considerable reduction in its population during August. This resulted in the resurgence of solenopsis mealybug, though on a lower scale, during September-October.

KEY WORDS: *Aenasius bambawalei*, cotton, parasitoids, predators, *Phenacoccus solenopsis*, *Myiocnema comperei*, biological control

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INTRODUCTION

The solenopsis mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) is a polyphagous pest reported to invade 154 plant species belonging to 53 families (Arif *et al.*, 2009). It was originally described from USA in 1898 (Tinsley, 1898) where it was widespread infesting cultivated cotton and 29 other plant species belonging to 13 families (Fuchs *et al*., 1991). Subsequently, the species was also reported to occur in Central America, the Caribbean, Ecuador (Williams and Granara de Willink, 1992), Chile (Larrain, 2002), Argentina (Granara de Willink, 2003), Brazil (Culik and Gullan, 2005), Pakistan (Zaka *et al*., 2006), India (Suresh and Kavitha, 2008), Nigeria (Akintola and Ande, 2008), Colombia (Kondo *et al*., 2008), Sri Lanka (Vinobaba and Prishanthini, 2009), China (Wu and Zhang**,** 2009) and Australia (Charleston and Murray, 2010*).* It was earlier thought to be a new and undescribed species in the Indian subcontinent and was named as *Phenacoccus gossypiphilus* Abbas, Arif and Saeed (Abbas *et al*., 2005). However, as no type specimens or depositories were designated, the name is now considered as *nomen nudum*. Similarly, Gautam *et al*. (2007) probably incorrectly identified it as *Phenacoccus solani* (Ferris). The confusion regarding the identity of the species was later cleared based on the specimens collected from several locations in the Indian subcontinent (Hodgson *et al*., 2008; Thomas and Ramamurthy, 2008; Nagrare *et al*., 2009).

In the Indian subcontinent, the pest has caused widespread and serious damage to cotton crop (Abbas *et al*., 2005; Dhawan *et al.*, 2007; Mahmood, 2008; Dharajyoti *et al*., 2008; Saini and Ram, 2008; Saini *et al*., 2009). It can damage buds, flowers, bolls, main stem, branches, foliage, *etc*. and if left unchecked can cause complete drying of the plants and forced opening of immature bolls. Early symptoms of attack include white, cottony appearance on the top portion of the main stem or branches, stunted growth, and usually increased activity of ants on honey dew secreted by the pest (Saini and Ram, 2008). In Haryana, the pest was first recorded in

2006 in some villages of Sirsa district, an area adjoining Punjab. Monthly surveys of the cotton growing belt for pest incidence showed that the mealybug had spread to more areas during 2007, showing its impact in the form of patches of dried cotton plants here and there (Anonymous, 2009). A number of other host plants were also found to be infested by this pest. During the course of surveys, in some fields *P. solenopsis* was found to be heavily attacked by a nymphal endoparasitoid, *Aenasius bambawalei* Hayat (Hymenoptera: Encyrtidae) in 2008 (Ram *et al*., 2009). High levels of parasitism of the pest were observed on some other host plants too. As studies on field incidence of solenopsis mealybug in the cotton belt of the state were in progress, it was considered worthwhile to have detailed information on the predators and parasitoids associated with it and to assess the impact of prominent parasitoids on its population during different months.

MATERIALS AND METHODS

Solenopsis mealybug incidence in cotton was recorded during 2008 and 2009 from 20 fields during each survey by examining 25 randomly selected plants from a field selected after every 5-10 km on specified routes. Per cent fields and plants infested with mealybug were worked out. Samples of mealybug infested twigs collected from such fields were examined in the laboratory under a stereo zoom binocular microscope to isolate larval and pupal stages of predators, if any. The predator larvae were reared on mealybugs at room temperature (23.2-33.3°C) under natural light conditions to obtain adults. Per cent relative abundance of a predator species was calculated as:

$$\frac{\text{Total number of adults of a predator species}}{\text{Total number of adults of all species of predators recorded}} \times 100$$

For recording parasitism, the number of mealybugs on the twigs was counted and the twigs were confined in glass jars (20 x 15 cm) and kept under observation. The mealybugs parasitised by *A. bambawalei* transformed into reddish brown mummies. Such mummies were counted, removed from the twigs and transferred to glass vials (7.5 x 1 cm) for obtaining adult parasitoids. The rate of parasitism was determined from the total number of mummies and surviving mealybugs in a sample. Per cent parasitism by the primary parasitoid per sample was calculated as:

$$\frac{\text{Total number of mummies}}{\text{Total number of mummies and surviving mealybugs}} \times 100$$

Each species of natural enemy obtained was recorded and the specimens were sent to appropriate authorities for identification. For assessing the impact of parasitoids on mealybug population, the following parameters were taken into consideration: i) per cent cotton fields and plants infested with the pest, iii) per cent fields with mummies (parasitised mealybugs), iii) extent of mealybug parasitism, and iv) extent of hyperparasitism of the primary parasitoid (*A. bambawalei*).

RESULTS AND DISCUSSION

Solenopsis mealybug incidence

The data on solenopsis mealybug infestation on cotton during 2008 and 2009 are presented in Table 1. During 2008, per cent fields infested with mealybug during different months was very high. From 75 per cent fields infested during June, the figure rose to 100 per cent during August and September. On the other hand, it was quite variable in 2009. Whereas 70-90 per cent fields were found infested with mealybug during June-July, the pest incidence during August was noticed in 18 per cent of the fields only. Similarly, during 2008, per cent plants infested with mealybug during different months was very high. From 11.6 per cent plants infested during June, the pest spread to 82.5 per cent plants during September. On the other hand, the number of mealybug infested plants remained quite low in 2009, being minimum (i.e. 1.6-5.6) during June – August but rose to 16.4 per cent in October.

Relative abundance of natural enemies

Aenasius bambawalei was the only primary parasitoid recorded from *P. solenopsis* on cotton in Haryana (Table 2). During 2008, 47.2 per cent parasitism was recorded in September and 40 per cent of the cotton fields had mealybug mummies. During 2009, parasitism by *A. bambawalei* was observed on cotton throughout the crop growing season. Per cent cotton fields with mealybug mummies ranged from 50 in June to 100 in August. The mealybug parasitism was minimum in June (23.7%) and maximum in September (76.6%). Similarly, different workers have reported more than 50 per cent (Mahmood, 2008), 20-70 per cent (Tanwar *et al*., 2008) and 37.6-72.3 per cent (Ram *et al*., 2009) parasitism of *P. solenopsis* by *Aenasius* sp. on cotton and other host plants. The other primary parasitoids of *P. solenopsis* reported from other countries in the literature are *Chalcaspis arizonensis* Girault (Gordh, 1979) and *Chalcaspis* sp. (Fuchs *et al*., 1991).

Per cent hyperparasitism in a sample was calculated as:

$$\frac{\text{Total number of mummies from which hyperparasitoid emerged}}{\text{Total number of mummies from which primary parasitoid and hyperparasitoids emerged}} \times 100$$

Table 1. Incidence of *Phenacoccus solenopsis* on cotton in Haryana

Month	Number of fields observed		Per cent fields infested with mealybug		Per cent plants infested with mealybug	
	2008	2009	2008	2009	2008	2009
June	20	12	75	70	11.6	3.4
July	22	20	82	90	40.2	5.6
August	16	39	100	18	66.8	1.6
September	11	20	100	55	82.5	11.5
October	–	11	–	67	–	16.4

Table 2. Parasitism of *Phenacoccus solenopsis* on cotton in Haryana

Month	Per cent fields with parasitised mealybug (mummies)		Per cent mealybug parasitism by *A. bambawalei*		Per cent hyperparasitism of *A. bambawalei*	
	2008	2009	2008	2009	2008	2009
June	0	50	0	23.7	0	0.0
July	0	90	0	39.8	0	3.3
August	0	100	0	54.5	0	78.9
September	40	55	47.2	76.6	3.6	38.8
October	–	90	–	47.8	–	55.4

Different hyperparasitoids of *A. bambawalei* recorded were *Promuscidea unfasciativentris* Girault, *Myiocnema comperei* Ashmead, *Prochiloneurus albifuniculus* (Hayat, Alam and Agarwal) and *Marietta leopardina* Motschulsky (Table 3). The predominant hyperparasitoid attacking the primary parasitoid was *M. comperei* whose abundance gradually increased from 80.6 per cent during July to 100 per cent during August, and remained above 90 per cent up to October. The abundance of other hyperparasitoids was quite low (0-14.3%), indicating their very limited role in influencing the population of *A. bambawalei*. *P. unfasciativentris* had earlier been reported as a hyperparasitoid from *P. solenopsis* (Anonymous, 2009; Hayat, 2009; Ram *et al*., 2009). Several other studies have also reported *P. unfasciativentris* as a hyperparasitoid from various mealybug species through their primary encyrtid parasitoids (Hayat *et al*., 2007; Sureshan and Narendran, 2005). Therefore, the status of *P. unfasciativentris* as a primary parasitoid of *P. solenopsis*, as reported by Tanwar *et al*. (2008) and Jhala *et al*. (2009), seems to be erroneous.

Predators were observed to be active throughout the cotton crop season (Table 4). Different predators recorded from mealybug colonies on cotton included *Brumoides suturalis* (Fabricius), *Nephus regularis* Sicard, *Cheilomenes sexmaculata* (Fabricius), *Coccinella septempunctata* L., *Hippodamia variegata* (Goeze), *Scymnus coccivora* Ayyar and an unidentified neuropteran. Among these, *B. suturalis* was the most abundant. Its highest abundance was recorded during June (72.7%) and July (38.5%). *N. regularis* was the second most abundant predator with 18.2 to 28.6 per cent abundance, followed by *C. sexmaculata* with 7.7 to 23.8 per cent abundance, during different months. The abundance of other predators was below 15 per cent. Gautam *et al*. (2007) also reported five predators, *viz*., *B. lineatus* (Weise), *B. suturalis*, *C. sexmaculata*, *N. regularis* and *S. coccivora* feeding on *P. solani* Ferris (probably *P. solenopsis*) infesting *Parthenium hysterophorus* L. from Delhi.

Resurgence of solenopsis mealybug

Mealybug population during 2009 was found to be correlated with the activity of the primary parasitoid (*A. bambawalei*) (Table 2). For example, in comparison to the presence of mummies of the mealybug in 50 per cent of the fields during June, 100 per cent of the fields had mummies by August. Similarly, as the parasitism of the mealybug increased from 23.7 per cent in June to 54.5 per cent in August, the percentage of fields infested with the pest declined drastically from 90 per cent to 18 per cent by August (Table 1). Per cent plants infested with the mealybugs also declined from 5.6 per cent to 1.6 per cent. During 2008, per cent plants infested with the pest

Table 3. Relative abundance of hyperparasitoids associated with *A. bambawalei* on cotton during 2009

Hyperparasitoid species	Relative abundance in different months (%)				
	June	July	August	September	October
Myiocnema comperei	0.0	80.6	100.0	97.1	92.1
Promuscidea unfasciativentris	0.0	14.3	0.0	0.0	7.9
Prochiloneurus albifuniculus	0.0	4.1	0.0	0.0	0.0
Marietta leopardina	0.0	1.0	0.0	2.9	0.0

Table 4. Relative abundance of predators associated with *P. solenopsis* on cotton during 2009

Predator species	Relative abundance of predator species in different months (%)				
	June	July	August	September	October
Brumoides suturalis	72.7	38.5	28.6	23.8	14.3
Cheilomenes sexmaculata	9.1	7.7	14.3	23.8	19.0
Hippodamia variegata	0.0	7.7	7.1	9.5	14.3
Coccinella septempunctata	0.0	7.7	7.1	9.5	14.3
Nephus regularis	18.2	23.0	28.6	23.8	28.6
Scymnus coccivora	0.0	7.7	14.3	4.8	9.5
Unidentified neuropteran	0.0	7.7	0.0	4.8	0.0

ranged from 11.6 to 82.5 as compared to 1.6 to 16.4 during 2009. Thus, in the absence of *A. bambawalei* (during 2008 or before), the mealybug flourished well on cotton and other plants causing widespread damage to cotton crop (Saini and Ram, 2008). However, with the large scale multiplication of *A. bambawalei* in nature, the pest population was drastically reduced during 2009, qualifying it to be a fit case of fortuitous biological control.

The mealybug incidence flared up during September and October, 2009 engulfing 55 and 67 per cent of cotton fields, respectively, with plant infestation rising to 11.5 and 16.4 per cent, respectively. The resurgence of the mealybug during September-October might have been due to the high level of hyperparasitism (38.8–78.9%) of *A. bambawalei*, during August-October, resulting in a decline in its parasitism from 76.6 per cent in September to 47.8 per cent in October. Thus, *A. bambawalei* proved to be a key biotic factor in regulating the mealybug populations under Haryana conditions, though increased activity of hyperparasitoids may adversely affect its efficiency late in the season.

Exotic origin of the pest and the parasitoid

Phenacoccus solenopsis is an exotic species which originated from USA (Nagrare *et al*., 2009). Evidence also suggests that *A. bambawalei* could also be exotic and could have been introduced into the Indian subcontinent simultaneously along with the host. *P. solenopsis* was reported for the first time from Pakistan in 2005 (Abbas *et al*., 2005) and from India in 2006 (Suresh and Kavitha, 2008). Large scale parasitism of *P. solenopsis* by *A. bambawalei* was reported for the first time in August, 2008 simultaneously from four distant places – Hisar, New Delhi and Parbhani in India (Tanwar *et al*., 2008; Hayat, 2009; Anonymous, 2009) and Tando Jam in Pakistan (Mahmood, 2008) within three years of its probable introduction, which is typical of an exotic parasitoid. Moreover, *A. bambawalei* is quite different from the four species of *Aenasius* reported from India (Hayat, 2006) and runs near to *A. longiscapus* Compere in the most recent key to species of *Aenasius* from Costa Rica (Noyes, 2000). The major hyperparasitoid, *M. comperei* also could be exotic as prior to 2007, this hyperparasitoid was never reported from the Indian subcontinent (Hayat *et al.*, 2007).

Thus, it can be concluded that the primary parasitoid (*A. bambawalei*) might have got introduced into the Indian subcontinent alongwith *P. solenopsis*. This probably represents a classic example of fortuitous biological control, which involves the regulation of a pest population by a natural enemy without deliberate introduction or

without any manipulation by man wherein the pest and/or natural enemy or both are exotic. Therefore, *A. bambawalei* needs to be conserved not only on cotton but on other host plants of the solenopsis mealybug also so that the pest population is kept at low levels.

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