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Research Article

Natural enemy complex associated with the mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) infesting different host plants in India

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ABSTRACT: Recently, Indian cotton belt experienced a devastating outbreak of *Phenacoccus solenopsis* Tinsley. Natural enemy complex associated with *P. solenopsis* was explored by conducting extensive field surveys coupled with laboratory screening of samples collected from various localities across the country. A total of seventeen parasitoids inclusive of hyperparasitoids were identified. An encyrtid, *Aenasius bambawalei* Hayat, was found predominantly on *P. solenopsis*. *Promuscidea unfasciativentris* Girault predominated the hyperparasitic fauna. Interestingly, *Aphanogmus* sp. and *Anastatus* sp. were recorded for the first time on *P. solenopsis*. Additionally, eight species of Coccinellidae and two species of Chrysopidae were recovered as important predators.

KEY WORDS: *Aenasius bambawalei*, hyper-parasitoid, *Phenacoccus solenopsis*, parasitoid, predator, survey

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INTRODUCTION

The solenopsis mealybug, *Phenacoccus solenopsis* Tinsley (Pseudococcidae) has recently emerged as a serious insect pest of cotton growing belts in India (Dhawan *et al.*, 2007; Tanwar *et al.*, 2007; Jhala *et al.*, 2008). The *P. solenopsis* was reported damaging more than 194 plant species belonging to 52 families across the globe and in India, *P. solenopsis* has spread throughout the country causing devastation (Gautam, 2007; Tanwar *et al.*, 2007; Jhala *et al.*, 2008; Ananthakrishnan and Alexsander Jesudasan, 2009; Suresh *et al.*, 2010; Pala and Saini, 2010). Considering the economic importance of newly emerged pest and scanty information on its regulation by natural enemies (Tanwar *et al*., 2007; 2008; Fand *et al.*, 2010b, c; 2011), present investigations were carried out on exploration of potential natural enemy complexes and the possibility of their utilization in biological suppression programme.

MATERIALS AND METHODS

Field survey

The samples of mealybugs were collected from different infested plants in the field from three different localities *viz*., Delhi, Maharashtra and Andhra Pradesh. The severity of mealybug incidence and intensity of plant damage was assessed by using four point scale suggested by Nagrare *et al*. (2009). This scale describes the pest infestation as: I = scattered appearance of few mealybugs on plant, II = one branch severely infested, III = more than one branch or half portion of host plant severely infested and IV = whole plant severely infested. About 4-5 branches heavily infested with *P. solenopsis* were removed gently from each host plant using secateur and brought to the laboratory for rearing on sprouted potato tubers at 27+2°C temperature, 60+5% relative humidity and 16 h L: 8 h D photoperiod (Gautam, 2008b). The cultures kept in plastic jars (10 cm diameter), separately for each host plant were examined daily for the emergence of parasitoids. Predators associated with mealybugs were noted down in field itself, during the course of survey.

In-situ host plant survey

Survey of natural enemies of *P. solenopsis* was carried out on four different host plants *viz*., brinjal (*Solanum melongena* L.), china rose (*Hibiscus rosa-sinensis* L.), sorrel (*Hibiscus sabdarifa* L.) and okra (*Abelmoschus esculentum* L.) planted in the experimental field of Division of Entomology, IARI, New Delhi. Total of 5 plants each of brinjal and sorrel, 20 plants of okra and 22 plants of china rose were randomly surveyed at weekly interval.

Table 1. Parasitic fauna associated with the field population of *P. solenopsis*, on different host plants

Host plant/ Family/ Botanical name	Utility	Parasitoids					Hyperparasitoids											
		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
		A.bamba-walei	*Leptomas-tix* sp	*P. tachikawa*	*Anagyrus* sp.	*P. unfascia-tiventris*	*M. leopardina*	*M. comperei*	*A. purpureus*	*P. albifuni-culus*	*P. testaceus*	*P. pulchellus*	*Cheilo-neurus* sp.	*C.walkeri*	*Aphanog-mus* sp	*Anastatus sp*	*Unknown Encyrtidae*	*Unknown Pteroma-lidae*
Amaranthaceae																		
Achyranthes aspera L.	Weed	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Amaranthus viridis L.	Weed	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Annonaceae																		
Polyalthia longifolia var. *pendula* L.	Ornamental	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apiaceae/ Umbelliferae																		
Daucus carota L.	Vegetable	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Asteraceae																		
Chrysanthemum sp.	Ornamental	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Helianthus annuus L.	Ornamental	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parthenium hyterophorus L.	Weed	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tagetes erecta L	Ornamental	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Xanthium strumarium L	Weed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chenopodiaceae																		
Chenopodium leptophyllum (Moq.)	Weed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kochia indica Wight	Weed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cucurbitaceae																		
Momordica charantia L.	Vegetable	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Malvaceae																		
Abelmoschus esculentus L.	Vegetable	+	-	-	+	+	-	+	-	+	-	-	+	-	-	-	+	-
Abutilon indicum Sweet	Weed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gossypium hirsutum L.	Cash crop	+	-	-	-	+	-	-	-	-	+	-	-	+	-	-	-	-
Hibiscus rosa-sinensis L.	Ornamental	+	-	-	-	+	+	+	+	+				+				+
H. subdariffa vr. *sabdariffa* L.	Vegetable	+	-	-	-	+	-	-	-	-	+	+	+	-	+	-	-	-
Moraceae																		
Morus alba L.	Fruit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Punicaceae																		
Punica granatum L.	Fruit	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Solanaceae																		
Capsicum annuum L.	Vegetable	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Datura metel L.	Weed	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Lycopersicum esculentum (L.) Mill.	Vegetable	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Solanum melongena L.	Vegetable	+	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-
Withania somnifera Dunal	Medicinal	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Verbanaceae																		
Lantana camara L.	Weed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

+ = presence – = absence

Mummies of *P. solenopsis* were collected with the help of camel hairbrush and forceps, brought to the laboratory and kept individually in the numbered homeopathic vials till the emergence of parasitoids. Observations on the number of mummies collected, numbers kept for emergence and number of parasitoids emerged, per cent mortality and type of parasitoid emerged were recorded.

Identification and preservation of specimens

The predators collected and parasitoids emerged were examined under stereomicroscope (Leica EZ-4) for observing their body parts and important identification characters. Finally, the specimens were stored in 90 per cent ethyl alcohol for future reference.

The specimens were identified at Aligarh Muslim University, Aligarh, Uttar Pradesh; Insect Identification Service, Indian Agricultural Research Institute, New Delhi and Prof. T. C. Narendran Trust for Animal Taxonomy, Calicut, Kerala. Status of the parasitoids was checked with the help of Chalcidoidea Database, 2011 (*www.nhm.ac.uk/entomology/chalcidoids*) and as per, Noyes and Hayat (1994). The predators collected from field as well as emerged from maintained culture of *P. solenopsis* brought from different host plants during survey were identified based on the literature and, Coccinellidae of the Indian subcontinent (2011).

RESULTS AND DISCUSSION

Diversity of parasitoid fauna associated with *P. solenopsis*

Field survey

The field survey of different host plants from three different localities across India revealed that 17 parasitoids belonging to seven different families were associated with the field population of *P. solenopsis* (Table 1). Amongst them, four species of Encyrtidae *viz.*, *Aenasius bambawalei* Hayat, *Leptomastix* sp., *Paranathrix tachikawai* (Shafee, Alam and Agarwal) and *Anagyrus* sp. were supposed to be the primary parasitoids of *P. solenopsis* whereas, remaining 13 species were found to be hyperparasitoids which included *Promuscidea unfasciativentris* Girault (Aphelinidae), *Marietta leopardina* Motschulsky (Aphelinidae), *Myiocnema comperei* Ashmead (Aphelinidae), *Aprostocetus purpureus* Girault (Eulophidae), *Prochiloneurus albifuniculus* (Hayat, Alam & Agarwal) (Encyrtidae), *Prochiloneurus testaceus* (Agarwal) (Encyrtidae), *Prochiloneurus pulchellus* Silvestri (Encyrtidae), *Cheiloneurus* sp. (Encyrtidae), *Chartocerus walkeri* Hayat (Signiphoridae), *Aphanogmus* sp. (Ceraphronidae) and *Anastatus* sp. (Eupelmidae) and two unidentified species each from Encyrtidae and Pteromalidae.

Among the parasitoids, the solitary endoparasitoid *A. bambawalei* was predominant and has also been reported as key mortality factor causing 30-70% natural parasitism in *P. solenopsis* under field conditions (Gautam *et al.*, 2009; Vennila *et al.*, 2010; Fand *et al*., 2011 and Prasad *et al*., 2011). The parasitoid was neither imported purposefully nor released artificially and thus reported to establish fortuitously (Gautam *et al*. 2009; Pala and Saini, 2010), giving satisfactory control of P. solenopsis that has devastated Indian agriculture. Thus, there is a great potential for implementation of environment friendly biological control programme for this invasive and polyphagous insect pest. *P. unfasciativentris* found as dominant hyperparasitoid on *P. solenopsis* is also reported by earlier workers (Shankar *et al*., 2011, anwar *et al*., 2011). Gregarious nature observed in the case of *P. tachikawai*, is in conformity with Noyes and Hayat (1994). Species of *Leptomastix* and *Anagyrus* are already reported as a primary parasitoids of many Hemipteran pests especially the mealybugs (Abd Rabou and Hendawy, 2005; Chalcidoidea, 2011). Hyperparasitic nature of *P. unfasciativentris, M. leopardina, M. comperei, A. purpureus, P. albifuniculus, P. testaceus, P. pulchellus, Cheiloneurus* sp. and *C. walkeri* has been widely reported (Noyes and Hayat, 1994; Abd Rabou and Hendawy, 2005; Das and Sahoo, 2005; Hayat *et al.*, 2007; Vennila *et al.*, 2010; Pala and Saini, 2010; Chalcidoidea, 2011). *Aphanogmus* sp. and *Anastatus* sp. are reported for the first time on *P. solenopsis* from India and both are presumed to be hyperparasitoids (Gregory *et al.*, 2005).

In-situ host plant survey

The seasonal dynamics of parasitoid population associated with *P. solenopsis* on four different host plants is shown in Table 2. The samples collected from *Hibiscus rosa sinensis* (L.) revealed maximum density and diversity of the parasitoids. It was the only host, the samples collected from which a parasitoid species *M. leopardina* was recovered as previously reported by Abd Rabou and Hendawy (2005). . *Solanum melongena* L., being the less favoured host of *P. solenopsis*, revealed less parasitic diversity hosting only *A. bambawalei* and its hyper-parasitoid, *P. unfasciativentris.* Samples collected from plants of *Abelmoschus esculentum* recorded highest population of *A. bambawalei* and very little population of hyperparasitoids.

Highest density of *A. bambawalei* than its hyperparasitoids revealed from okra (*Abelmoschus esculentum)* samples indicates that the okra ecosystem is an ideal habitat for natural biological control of *P. solenopsis.* The incidence of mealybug on different host plants was found negatively correlated with the

Table 3. Diversity of *P. solenopsis* predators surveyed on different hosts

Host plant/ Family/ Botanical name	Utility	Coccinellidae								Chrysopidae	
		1	2	3	4	5	6	7	8	9	10
		C. septempunctata	*H. maindroni*	*N. regularis*	*C. sexmaculata*	*S. coccivora*	*B. suturalis*	*A. variegata*	*Illeis* sp.	*Mallada* sp.	*C. carnea*
Amaranthaceae											
Achyranthes aspera L.	Weed	+	+	+	-	-	-	-	-	-	-
Amaranthus viridis L.	Weed	+	+	+	-	-	-	-	-	-	-
Annonaceae											
Polyalthia longifolia var. *pendula* L.	Ornamental	-	-	+	-	-	-	-	-	-	-
Apiaceae/ Umbelliferae											
Daucus carota L.	Vegetable	+	-	-	+	-	-	-	-	-	-
Asteraceae											
Chrysanthemum sp.	Ornamental	-	+	+	-	-	-	-	-	-	-
Helianthus annus L.	Ornamental	-	+	+	-	+	-	-	-	-	-
Parthenium hyterophorus L.	Weed	-	+	+	-	+	-	-	-	-	-
Tagetes erecta L	Ornamental	+	-	+	-	-	-	-	-	-	-
Xanthium strumarium L	Weed	-	-	+	-	+	+	-	-	-	-
Chenopodiaceae											
Chenopodium leptophyllum (Moq.)	Weed	-	+	+	-	+	-	+	-	-	-
Kochia indica Wight	Weed	+	+	+	+	-	-	-	-	-	-
Cucurbitaceae											
Momordica charantia L.	Vegetable	+	-	-	+	-	-	-	-	-	-
Abelmoschus esculentus L.	Vegetable	+	+	+	+	-	-	-	-	+	-
Abutilon indicum Sweet	Weed	-	-	+	-	-	-	-	-	-	-
Gossypium hirsutum L.	Cash crop	+	+	+	+	-	-	-	-	-	+
Hibiscus rosa-sinensis L.	Ornamental	+	+	+	+	+	+	-	-	-	-
H. subdariffa vr. *sabdariffa* L.	Vegetable	+	+	+	+	-	+	-	-	-	-
Moraceae											
Morus alba L.	Fruit	-	-	+	-	-	-	-	-	-	-
Punicaceae											
Punica granatum L.	Fruit	-	-	+	-	+	-	-	-	-	-
Solanaceae											
Capsicum annuum L.	Vegetable	+	-	-	+	-	-	-	-	-	-
Datura metel L.	Weed	-	-	+	-	+	-	-	-	-	-
Lycopersicum esculentum (L.) Mill.	Vegetable	+	-	-	+	-	-	-	-	-	-
Solanum melongena L.	Vegetable	+	-	+	+	+	+	+	+	-	-
Withania somnifera Dunal	Medicinal	-	-	+	-	+	-	-	-	-	+
Verbanaceae											
Lantana camara L.	Weed	-	-	+	-	-	+	-	-	-	-

+ = presence – = absence

Table 2. Diversity of parasitoids as revealed in *in-situ* host plant survey on four different hosts during 2008

Host plant	Number of mummies collected	Number of parasitoids. emerged	Mortality (%)	Species of parasitoids emerged
Brinjal (*Solanum melongena* L.)	36	17	52.78	*AB* (3), *PU* (14)
China rose (*Hibiscus rosa-sinensis* L.)	330	197	40.31	*AB* (16), *PU* (151), *AP* (20), *ML* (3), *UP* (1), *CW* (3), *PA* (3)
Okra (*Abelmoschus esculentum* L.)	98	86	12.15	AB (47), PU (28), CW (8), PA (2), Un. Ency. (1)
Sorrel (*Hibiscus sabdarifa* L.)	144	129	10.42	*AB* (6), *PU* (122), *CH* (1)

Where, AB = *Aenasius bambawalei* PA = *Prochiloneurus albifuniculus*
PU = *Promuscidea unfasciativentris* CH. = *Cheiloneurus* sp.
AP. = *Aprostocetus purpureus* UE = Unknown Encyrtid
UP = Unknown Pteromalid ML = *Marietta leopardina*
CW = *Chartocerus walkeri*

amount of rainfall received during the periods of survey. This is in conformity with the reports of earlier workers (Jeyakumar *et al.*, 2009; Saroja *et al.*, 2009).

Predators associated with P. solenopsis

Eight species of coccinellids and two species of chysopids were found as important natural enemies predacious on *P. solenopsis* field population. The ladybird beetles collected were *Hyperaspis maindroni* Sicard, *Brumoides suturalis* (Fabricius), *Scymnus coccivora* Ramakrishna Ayyar, *Nephus regularis* (Sicard), *Coccinella septempunctata* Linnaeus, *Cheilomenes sexmaculata* (Fabricius), *Adonia variegata* (Goeze) and *Illeis* sp. *Chrysoperla* sp. and *Mallada* sp. were the species of Chrysopidae (Table 3).

The species of Coccinellidae were the predominant predators followed by the species of Chrysopidae. Unlike parasitoids, predators were reported from all the surveyed hosts of *P. solenopsis*. Role of Coccinellidae and Chrysopidae in natural biological control of *P. solenopsis* has been widely recognised (Gautam *et al.*, 2007; Fand *et al.*, 2010a,b; Joshi *et al.*, 2010; Pala and Saini 2010; Vennilla *et al.*, 2010; Kedar *et al*., 2011 and Shankar *et al*., 2011). Fand *et al*. (2010 a,b) reported that, the coccinellid grubs feed voraciously and preferably on second instar mealybugs than on third instar and adult mealybugs, and the fecundity of coccinellids is numerically affected by the increasing prey density. The study reports some species of Coccinellidae such as *Coccinella septempunctata* F. and *Cheilomenes sexmaculata* F., predacious on Pseudococcidae which are not mentioned in earlier review on Homopterans as prey for ladybird beetles (Hodek and Honek, 2009).

Substantially, good deal of natural enemies, both the predators and parasitoids were found associated with the field population of mealybug *P. solenopsis*, indicating great potential for environment friendly natural biological control. The solitary endoparasitoid, *A. bambawalei* was found as one of the key regulating factor for the mealybug, despite harbouring about 11 different hyperparasitoids. On a good part, not a single hyper-parasitoid was found gregarious; otherwise successful fortuitous biological control of *P. solenopsis* by *A. bambawalei* would have not been possible. Keeping in view the diversity of natural enemy fauna of newly flared up mealybug under Indian conditions, it is imperative to conserve it for effective suppression of the pest.

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