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Spatio-temporal diversity of natural enemies of mealybugs infesting cotton in central India

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Abstract

Mealybugs are worldwide indoor and outdoor pests of agricultural and horticultural crops. In India, nine species of mealybugs have been recorded infesting cotton with varying degrees of infestation ranging from low to severe reducing seed cotton yield up to 50 % failing management. In this study an attempt was made to document spatio-temporal diversity of natural enemies of mealybugs infesting cotton in central India. Surveys were carried out during 2009 to 2016 in 22 districts of central India which revealed a wide diversity of natural enemies viz., 16 species of parasitoids *Aenasius aerizonensis* (Girault), *Acerophagous papayae* Noyes & Schauff, *Metaphycus* sp., *Aprostocetus bangaloricus* Narendran, *Encyrtus aurantii* (Geoffroy), *Aprostocetus* sp., *Anagyrus dactylopii* (Howard), *Anagyrus mirzai* Agarwal and Alam, *Homalotylus albiclavatus* (Agarwal), *Homalotylus* sp., *Anagyrus kamali* Moursi, *Chartocerus kerrichi* (Agarwal), *Pachyneuron leucopiscida* Mani and 8 species of predators viz., *Brumus* sp., *Cheilomenes sexmaculata* (Fabricius), *Cryptolaemus montrouzieri* (Mulsant), *Chrysoperla carnea* (Stephans), *Nephus regularis* (Sicard), *Rodolia fumida* Mulsant, *Scymnus coccivora* Ayyar on five species of mealybugs viz., *Phenacoccus solenopsis* Tinsley, *Nipaeococcus viridis* (Newstead), *Paracoccus marginatus* Williams and Granara de Willink, *Rastrococcus iceryodes* and *Maconellicoccus hirsutus* (Green). *Pachyneuron leucopiscida* Mani, *Promuscidea un fasciiventris* (Girault), *Prochiloneurus pulchellus* Silvestri and *Prochiloneurus aegypticus* (Mercet) are termed as hyperparasitoids. *A. arizonensis* was the most dominant parasitoid of *P. solenopsis* recorded every year starting from 2009 to 2016 in most the locations surveyed with average parasitization 14.1% (9-27%) over these years. Maximum parasitization (37%) of *P. solenopsis* by *A. arizonensis* was found in the month of September coinciding with boll development stage of the crop and thereafter recedes in subsequent months.

Keywords: Spatio-temporal diversity, natural enemies, cotton mealybugs

1. Introduction

Mealybugs are worldwide indoor and outdoor pests of agricultural and horticultural crops. In India, since 2007, nine species of mealybugs viz., cotton mealybug *Phenacoccus solenopsis* Tinsley, papaya mealybug *Paracoccus marginatus* Williams and Granara de Willink, Pink hibiscus mealybug *Maconellicoccus hirsutus* (Green), spherical mealybug *Nipaeococcus viridis* (Newstead), striped mealybug *Ferrisia virgata* Cockrell, mango mealybug *Rastrococcus iceryoides* (Green), Malvastrum mealybug *Ferrisia malvastra* (McDaniel), ber mealybug *Perissopneumon tamarindus* (Green) and Madeira mealybug, *Phenacoccus madeirensis* Green have been recorded infesting cotton with varying degrees of infestation ranging from low to severe^[1, 2]. Among these mealybug species *P. solenopsis* is highly destructive invasive insect and pest reduces seed cotton yield up to 50 % on failing management actions^[3, 4]. Mealybugs infest all plants parts, suck the plant juices that results in weakening of plant and in severe cases death of plant. Some species of mealybugs are also vectors of plant viruses^[5]. Mealybugs are difficult to manage as they have wide host range, bears waxy coating on the body, have high reproductive potential and ability to disperse in shorter time. Several control methods such as cultural, mechanical, biological, chemical etc are being employed to check the population of mealybugs however; farmers prefer chemical insecticides as a handy way of controlling this pest^[6]. It is an established fact that insecticides application not only incurs heavy expenditure but also affect the natural enemy fauna present in the agro-ecosystem. Injudicious usage of insecticides can advance to intimidation such as resurgence and resistance development in pests besides causing environmental pollution^[7, 8, 9, 10]. Hence, use of natural enemies such as predators and parasitoids as a natural biological control is of great importance

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Because they play vital role in checking several pests including mealybugs [11]. Reports are available on natural enemies especially on *Aenasius arizonensis* (=bambawalei) as a dominant parasitoid of *P. solenopsis* and few other natural enemies [12, 13, 14, 15, 16, 17].

2. Materials and Methods

2.1 Field survey

Random field surveys were conducted during cotton growing seasons of 2009-2016 in 22 districts of three states in central India viz., Maharashtra (16 districts- Akola, Amravati, Aurangabad, Beed, Buldana, Chandrapur, Dhule, Hingoli, Jalgaon, Jalna, Nagpur, Nanded, Osmanabad, Parbhani, Yavatmal, Wardha), Gujarat (4 districts- Amreli, Bharuch, Bhavnagar, Junagadh, Vadodara) and Madhya Pradesh (1 district- Chhindwara). In total 468 samples of mealybugs colonies were collected from these 22 districts.

2.2 Diversity of predators and parasitoids

Diversity of predators was recorded *in situ* while mealybugs colonies were collected and brought to the laboratory of ICAR-Central Institute for Cotton Research, Nagpur for recording diversity of parasitoids. From the collected colonies, for each location about 100 third instar nymph of mealybugs were separated and kept in plastic container (10 cm diameter) containing potato sprouts [13]. These mealybugs were replicated thrice and kept at room temperature. Mouth of the plastic container was secured with muslin cloth to prevent escape of mealybugs and parasitoids. Emergence of parasitoid was recorded daily up to 20 days. Emerged parasitoids were carefully collected in small glass bottles. Each parasitoid was observed under Stereo microscope (Leica, Model S8 APO) and grouped according to identical parasitoids. The recovered parasitoids were then dry mounted on rectangles and labelled according to the standard procedure [18]. Emerged parasitoids were preserved in 70 % ethyl alcohol. Predators were identified with the help of literature while parasitoids were

identified from National Pusa Collection, Insect Identification Service, Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi. Per cent parasitization was calculated based on emerged parasitoid and total number of 3rd instar mealybug nymphs that were kept for observations.

3. Results

3.1 Diversity of natural enemies

Six species of mealybugs viz., *P. solenopsis*, *N. viridis*, *P. marginatus*, *R. iceryodes*, *M. hirsutus* and *F. virgata* were observed infesting cotton in central India. Parasitization by one or more parasitoids was recorded in all mealybug species except *Ferrisia virgata*. A diversity of natural enemies viz., 16 species of parasitoids viz., *Aenasius aerezonensis* (=bambawalei), *Acerophagous papaya* Noyes & Schauff, *Metaphycus* sp., *Aprostocetus bangaloricus* Narendran, *Encyrtus aurantii* (Geoffroy), *Aprostocetus* sp., *Anagyrus dactylopii* (Howard), *Anagyrus mirzai* Agarwal & Alam, *Homalotylus albiclavatus* (Agarwal), *Homalotylus* sp., *Anagyrus kamali* Moursi, *Chartocerus kerrichi* (Agarwal), *Pachyneuron leucopiscida* Mani has been recorded. Out of these *Pachyneuron leucopiscida* Mani, *Promuscidea unifasciiventris* (Girault), *Prochiloneurus pulchellus* Silvestri and *Prochiloneurus aegypticus* (Mercet) are termed as hyperparasitoids. *Anagyrus kamali* Moursi was the common parasitoid of *N. viridis*, *R. iceryodes* and *M. hirsutus*. Number of parasitoids recorded in *P. solenopsis*, *N. viridis*, *P. marginatus*, *R. iceryodes* and *M. hirsutus* were 14, 5, 4, 3 and 1, respectively. (Table 1). Eight species of predators have been recorded on *P. solenopsis* and *N. viridis*, out of these *Brumus* sp., *Cheilomenes sexmaculata* (Fabricius), *Cryptolaemus montrouzieri* (Mulsant), *Chrysoperla carnea* (Stephans), *Nephus regularis* (Sicard), *Rodolia fumida* Mulsant, *Scymnus coccivora* Ayyar were recorded on *P. solenopsis* while only one species of predator *Cacoxenus perspicax* (Knab) on *N. viridis* (Table 2).

Table 1: Parasitoid diversity on cotton infesting mealybugs during 2009-2016 in central India

Name of mealybug and associated parasitoids	Family	Order
<i>Phenacoccus solenopsis</i> Tinsley		
1. <i>Aenasius arizonensis</i> (=bambawalei)	Encyrtidae	Hymenoptera
2. <i>Anagyrus kamali</i> Moursi	Encyrtidae	Hymenoptera
3. <i>Anagyrus dactylopii</i> (Howard)	Encyrtidae	Hymenoptera
4. <i>Anagyrus mirzai</i> Agarwal and Alam	Encyrtidae	Hymenoptera
5. <i>Aprostocetus bangaloricus</i> Narendran	Eulophidae	Hymenoptera
6. <i>Aprostocetus</i> sp.	Eulophidae	Hymenoptera
7. <i>Chartocerus kerrichi</i> (Agarwal)	Thysanidae	Hymenoptera
8. <i>Encyrtus aurantii</i> (Geoffroy)	Encyrtidae	Hymenoptera
9. <i>Homalotylus albiclavatus</i> (Agarwal)	Encyrtidae	Hymenoptera
10. <i>Metaphycus</i> sp.	Encyrtidae	Hymenoptera
11. * <i>Prochiloneurus albifuniculus</i> (Hayat et al.)	Encyrtidae	Hymenoptera
12. * <i>Promuscidea unifasciiventris</i> Girault	Aphelinidae	Hymenoptera
13. <i>Pachyneuron leucopiscida</i> Mani.	Pteromalidae	Hymenoptera
14. * <i>Prochiloneurus pulchellus</i> Silvestri	Encyrtidae	Hymenoptera
<i>Nipaecoccus viridis</i> (Newstead)		
1. <i>Aprostocetus</i> spp.	Eulophidae	Hymenoptera
2. <i>Anagyrus kamali</i> Moursi	Encyrtidae	Hymenoptera
3. * <i>Prochiloneurus albifuniculus</i> (Hayat et al.)	Encyrtidae	Hymenoptera
4. <i>Pseudleptomastix mexicana</i> Noyes and Schauff	Encyrtidae	Hymenoptera
5. * <i>Promuscidea unifasciiventris</i> Girault	Aphelinidae	Hymenoptera
<i>Paracoccus marginatus</i> Williams and Granara de Willink		
1. <i>Acerophagus papayae</i> Noyes & Schauff	Encyrtidae	Hymenoptera
2. <i>Aprostocetus</i> sp.	Eulophidae	Hymenoptera
3. <i>Pseudleptomastix mexicana</i> Noyes and Schauff	Encyrtidae	Hymenoptera

4. <i>*Promuscidea unifasciiventris</i> Girault	Aphelinidae	Hymenoptera
<i>Rastrococcus iceryoides</i> (Green)		
1. <i>Anagyrus kamali</i> Moursi	Encyrtidae	Hymenoptera
2. <i>Pseudleptomastix mexicana</i> Noyes and Schauff	Encyrtidae	Hymenoptera
3. <i>*Promuscidea unifasciiventris</i> Girault	Aphelinidae	Hymenoptera
<i>Maconellicoccus hirsutus</i> (Green)		
1. <i>Anagyrus kamali</i> Moursi	Encyrtidae	Hymenoptera

*Hyperparasitoids

Table 2: Predator diversity on cotton infesting mealybugs during 2009-2016 in central India

Name of mealybug and associated predators	Family	Order
<i>Phenacoccus solenopsis</i> Tinsley (Hemiptera: Pseudococcidae)		
1. <i>Brunus</i> sp.	Coccinellidae	Coleoptera:
2. <i>Cheilomenes sexmaculata</i> (Fabricius)	Coccinellidae	Coleoptera
3. <i>Cryptolaemus montrouzieri</i> (Mulsant)	Coccinellidae	Coleoptera
4. <i>Chrysoperla carnea</i> (Stephans)	Crysopidae	Neuroptera
5. <i>Nephus regularis</i> (Sicard)	Coccinellidae	Coleoptera
6. <i>Rodolia fumida</i> Mulsant	Coccinellidae	Coleoptera
7. <i>Scymnus coccivora</i> Ayyar	Coccinellidae	Coleoptera
<i>Nipaeococcus viridis</i> (Newstead), (Hemiptera: Pseudococcidae)		
1. <i>Cacoxenus perspicax</i> (Knab)	Drosophilidae	Diptera

Percent parasitization of mealybugs

Among 16 parasitoids recorded, *A. arizonensis* was the dominant parasitoid of *P. solenopsis* recorded every year starting from 2009 to 2016 in most the locations surveyed and over the years average parasitization recorded was 14.1% (range 9-27%) (Fig 1). Average parasitization by other parasitoids of *P. solenopsis* was recorded as *A. kamali* (3.0), *A. dactylopii* (7.0%), *A. mirzai* (6.0%), *A. bangaloricus* (4.0%), *Aprostocetus* spp (3.7%), *C. kerriichi* (5.0%), *E. aurantii* (8.0%), *H. albiclavatus* (4.0%), *Metaphycus* sp. (4.0%), *P. albiculus* (1.0%), *P. unifasciiventris* (6.4%), *P.*

leucopiscida (2.0%) and *P. pulchellus* (9.0%). *Aprostocetus* sp. (6.0%), *A.kamali* (8.5%), *P. albiculus* (8%) and *P.mexicana* (7%) and *P. unifasciiventris* (7%) were found to parasitize *N. viridis* while *A. papayae* (6%), *Aprostocetus* sp. (2.0%), *P.mexicana* (13.5%), and *P.unifasciiventris* (8%) were recorded on *P. marginatus*. *A.kamali*, *P.mexicana* and *P.unifasciiventris* were recorded on *R. icerod*s with corresponding parasitization at 5, 12 and 9%, respectively. *A.kamali* was also found to parasitize *M.hirsutus* at (9%) (Fig 2).

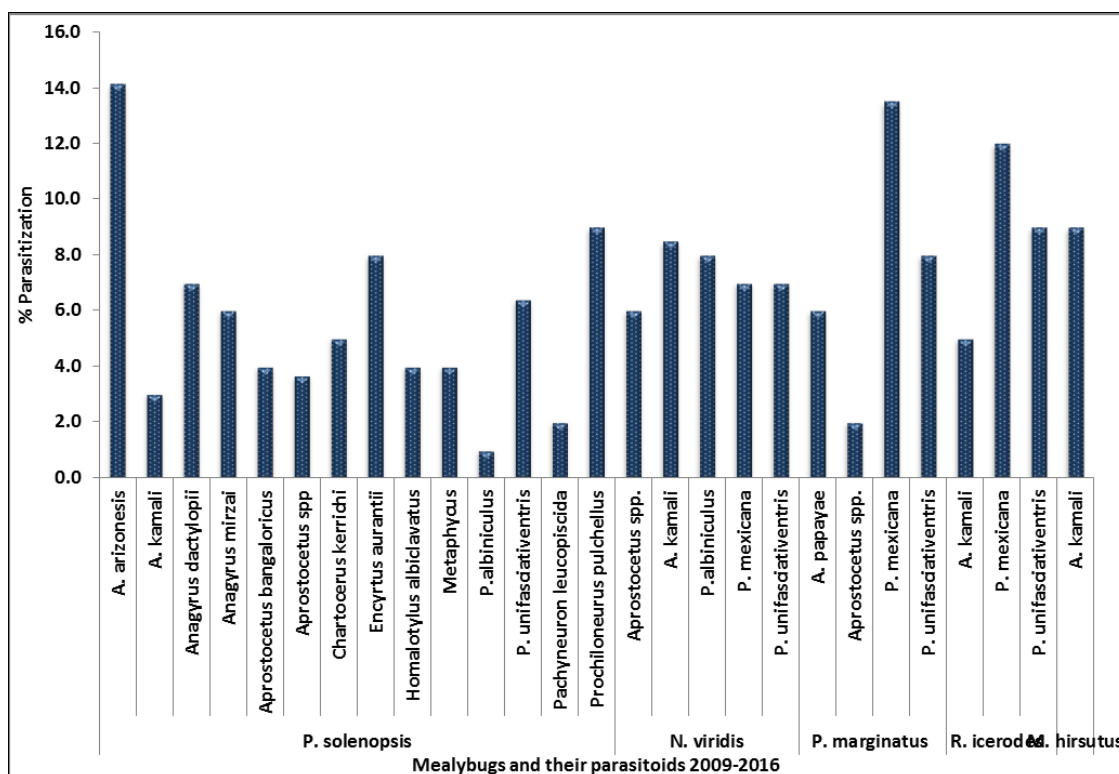


Fig 1: Cotton infesting mealybugs and their parasitoids 2009-2016

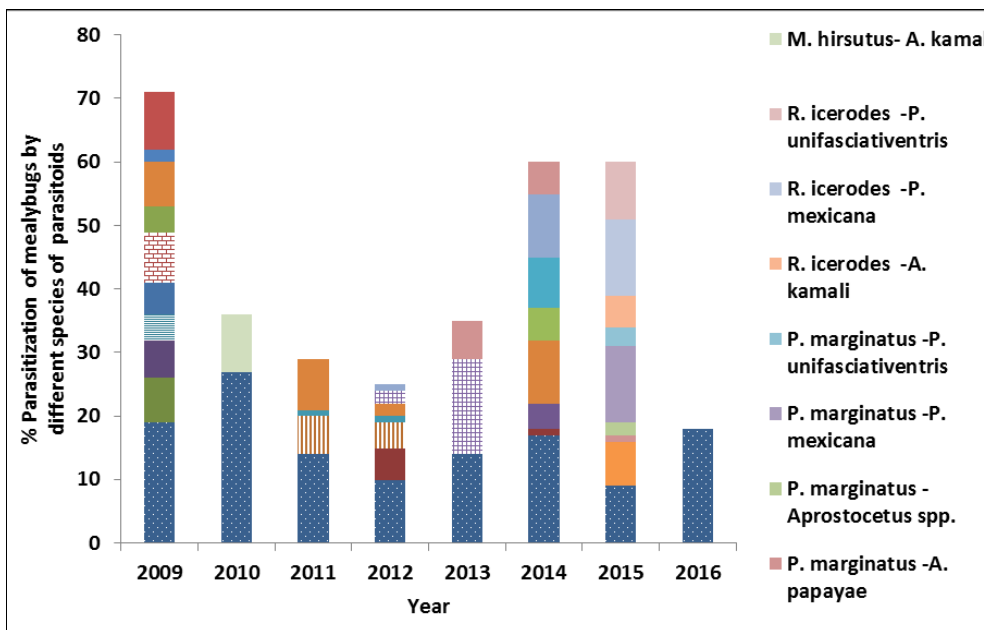


Fig 2: Parasitoid diversity during 2009 to 2016

Spatio-temporal Diversity

Over the years (2009-16) highest number of parasitoids (10) was recorded during 2009 followed by 2014 and 2015. Maximum parasitization (37%) of *P. solenopsis* by *A. arizonensis* was found in the month of September coinciding with boll development stage of the crop and thereafter recedes in subsequent months (Fig 3). During that period highest population of mealybugs was recorded on cotton. Greater diversity of parasitoids (12 numbers) was recorded during

December followed by August (12 numbers). In the months of October and January similar kind of parasitoid diversity was recorded while least diversity was recorded in the month of November (Fig 4). In all the 22 locations, maximum diversity of parasitoids (16 species) was recorded at Nagpur as frequent surveys were conducted at this location (Fig 5). Chhindwada recorded second highest parasitoids (4) among the selected location surveyed.

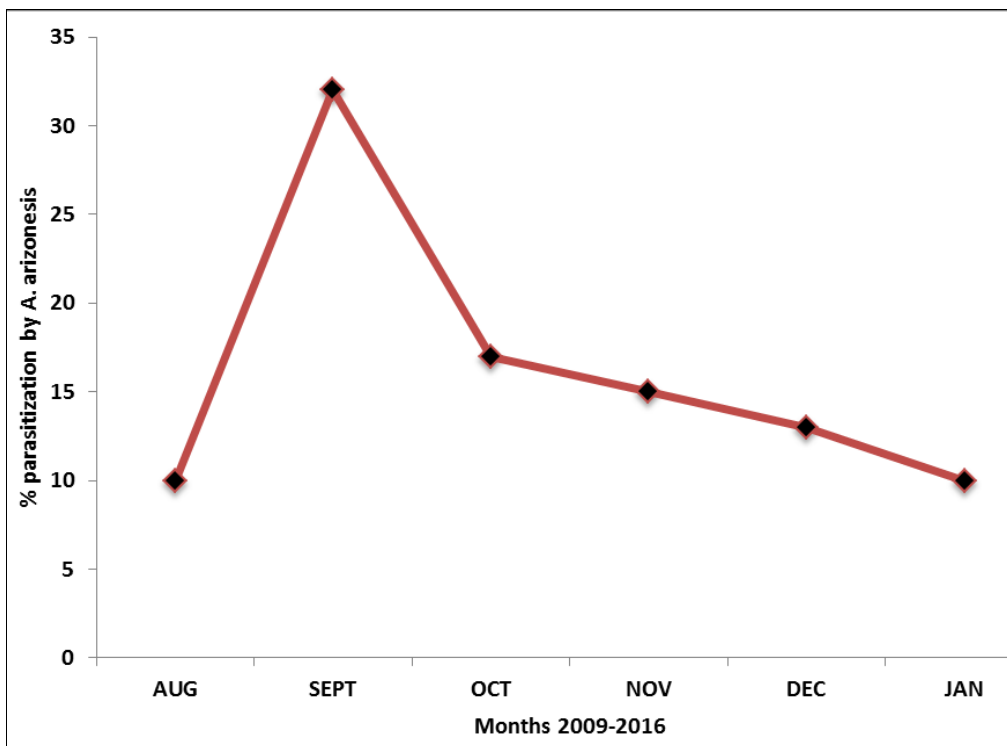


Fig 3: Parasitization of *P. solenopsis* by *A. arizonensis* during crops seasons 2009 to 2016

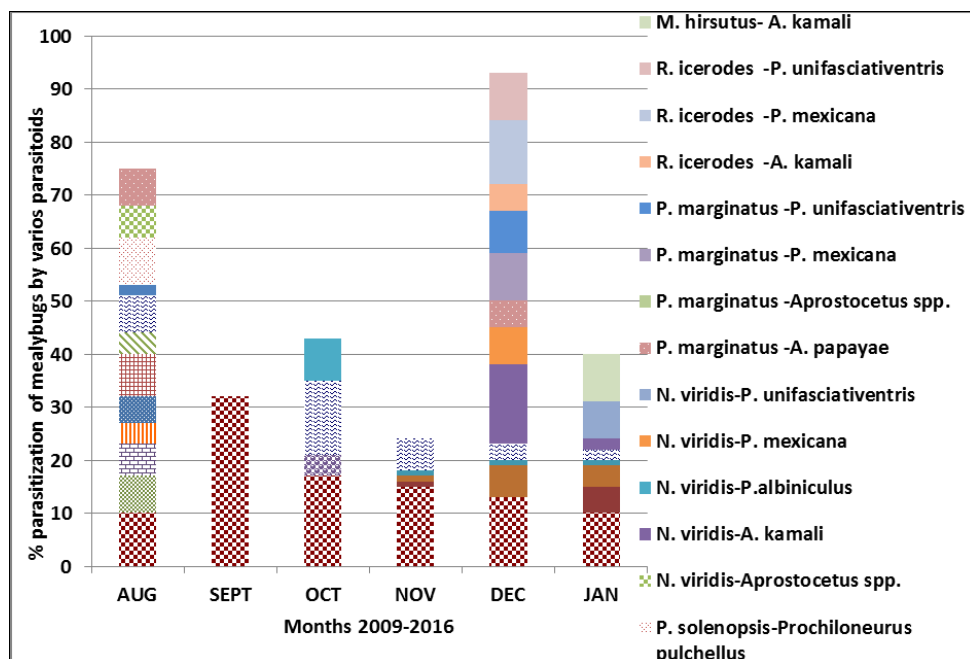


Fig 4: Diversity of parasitoids during months (2009-16)

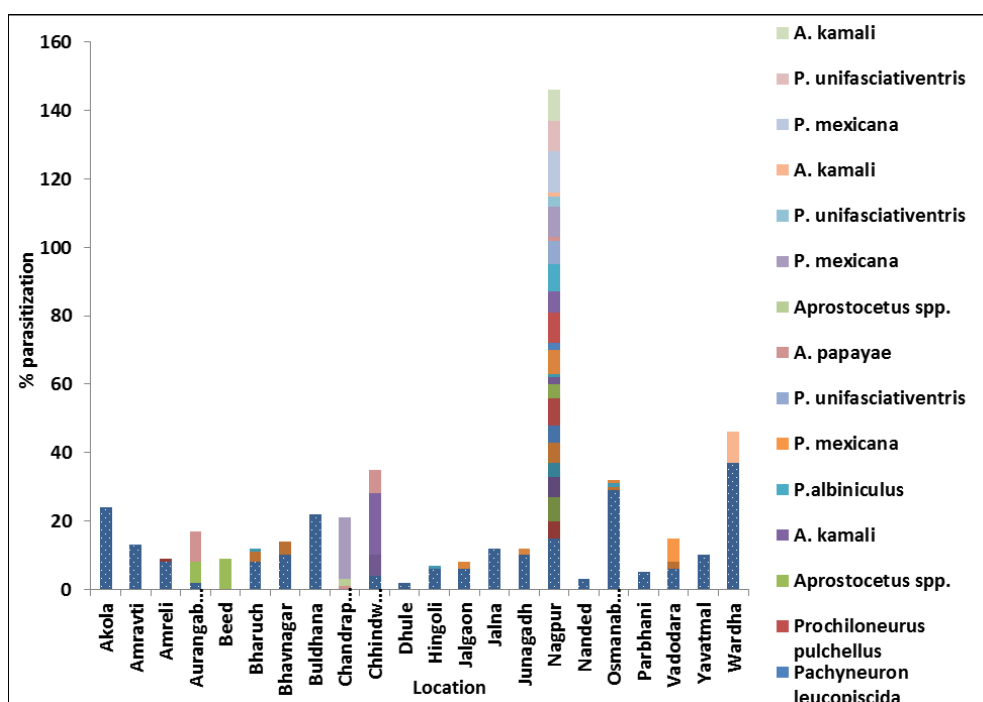


Fig 5: Location wise mealybug parasitoid diversity in central India

4. Discussion

During growth and development processes, the population density of each organism is regulated by abiotic and biotic factors. Fluctuation and outbreak may occur in some species due to these factors^[19]. Biotic factors such as natural enemies have great potential to check the population of pests. In this study we have reported spatio-temporal diversity of natural enemies 16 species of parasitoids and 8 species of predators on 5 species of mealybugs infesting cotton in central India. A wide diversity of 14 parasitoids and 7 predators have been reported on *P. solenopsis* however, earlier reported¹⁵ 17 parasitoids out of which 4 were common, 11 parasitoids were not found in central India while 10 are new in our study. Similarly out of 10 predators reported on *P. solenopsis* 3 were common, 7 were not recorded while 4 are new in this study.

Tanwar^[20] reported scanty diversity of only two parasitoids viz. *A. arizonensis* and *P. unifasciiventris* during 2009-10. Sankar^[17] recorded coccinellids *Scymnus nubilus* Mulsant, *Hyperaspis maindroni* Sicard, green lacewing, spiders, *Aenasius bambawalei* Hayat, *Homalotylus eytelwenii* Ratzeburg, *P. unifasciiventris* and *Coccophagus* sp. on *P. solenopsis* in Perambalur district of Tamil Nadu during 2008-10 of which only *A. arizonensis* is common with our study. Singh and Kumar^[21] reported five natural enemies *Sympherobius fallax* (Navas), *Chrysoperla zastrowi* Arabica (Henry), *Cheilomenes sexmaculata* (Fab.), *Scymnobioides sordidus* (Horn), parasitoids *A. arizonensis* on *P. solenopsis* from Vadodara. In Guangdong and Hainan Provinces of China, four species of ladybirds, viz., *C. montrouzieri* Mulsant, *Lemnia biplagiata*(Swartz), *C. sexmaculatus*

(Fabricius) and *Nephus quadrimaculatus* (Kamiya) had been found to feed on *P. solenopsis*. In addition, four species of parasitoids viz. *Acerophagus coccois* Smith, *Aenasius arizonensis*, *Prochiloneurus nagasakiensis* (Ishii) and an undescribed species *Allotropa* sp. were documented to attack *P. solenopsis*²². Fourteen species of insect natural enemies have been found in association with *P. solenopsis* in Israel the common ones were: *A. arizonensis*, *Cheilomenes propinqua* (Mulsant), *Hyperaspis vinciguerrae* (Capra); *H. polita* Weise, *Exochomus nigripennis* (Erichson), *Parascymnus varius* Kirsch and *Scymnus flagellisiphonatus* (Fursch) [23]. On reviewing above reports [21, 22, 23], it was observed that *A. arizonensis* was the most common parasitoid wherever *P. solenopsis* infestation reported whereas other natural enemies were found to differ from place to place.

With the widespread infestation of major mealybug *P. solenopsis* on cotton and some other hosts, fortuitous parasitoid *A. aerizonensis* have been reported with varying degree of parasitization 5-100 % in central India [13], 8.3% to 13.3% in Warangal [16], 46-64% in Sirsa Haryana [14], 40.69 to 43.53 in Punjab [24] during 2007-2009. In this study we report average 14% parasitization (range 9-27%) this might be due to the reduction in mealybugs population 2009 onwards.

Considerable diversity of natural enemy is available for regulating mealybug population ecofriendly way and that is the reason why we must wait and watch for the performance of these natural enemies to rely on their performance. Beyond doubt *A. arizonensis* is the most important parasitoid arise in India and elsewhere on widely spread mealybug *P. solenopsis*. To manage pests like mealybugs, chemical control should be the last choice if pest population is unable to be managed with the availability of natural enemies. Considering the utility of natural enemies, attention should be given on conservation of these natural enemies to obtain sustainable regulation of mealybug population.

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Compliance with Ethical Standards

It is declared that there is no conflict of interest of any financial and personal relationships with other people or organizations that could inappropriately influence present work.

The present investigations do not involved Human Participants and/or Animals in the experiments; hence prior consent is not applicable.

7. References

- Shylesha AN, Joshi S. Occurrence of Madeira mealybug, *Phenacoccus madeirensis* Green (Hemiptera: Pseudococcidae) on cotton in India and record of associated parasitoids. Journal of Biological Control. 2012; 26(3):272-273.
- Nagrare VS, Kranthi S, Kranthi KR, Naik V, Chinna Babu, Kumar Rishi. Handbook of Cotton Plant Health, Central Institute for Cotton Research, Nagpur, 2013, 100.
- Hodgson C, Abbas G, Arif MJ, Saeed S, Karar H. *Phenacoccus solenopsis* Tinsley (Sternorrhyncha: Coccoidea: Pseudococcidae), an invasive mealybug damaging cotton in Pakistan and India, with a discussion on seasonal morphological variation. Zootaxa. 2008; 1913:1-35.
- Nagrare VS, Kranthi S, Biradar VK, Zade NN, Sangode V, Kakde G. Widespread infestation of the exotic mealybug species, *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcidae), on cotton in India. Bulletin of Entomological Research. 2009; 99:537-541.
- Tang Y, He M, Lu Y. Acquisition, retention and transmission risk of Cotton leaf curl Multan virus by cotton mealybug *Phenacoccus solenopsis* Tinsley. Journal of Environmental Entomology. 2016; 38(4):736-741.
- Meyerdirk DE, French JV, Hart WG. Effect of pesticide residues on the natural enemies of citrus mealybug. Environmental Entomology. 1982; 11:134-136.
- Kumar R, Swami D, Pal V, Kranthi KR. Insecticide induced resurgence of mealybug, *Phenacoccus solenopsis* Tinsley in cotton. In Book (Edited by Kranthi, K. R.; Venugopalan, M. V.; Balasubramanya, R. H.; Kranthi, S.; Singh, S.; Blaise D.) World Cotton Research Conference-5, Mumbai, India, 2011, 198-202.
- Stoll G. Natural crop protection in the tropics, 3rd Edition. Margraf publishers scientific books, Weikersheim, Federal Republic of Germany, 1988, 188.
- Pillmoor JB, Wright K, Terry AS. Natural products as a source of agrochemical and leads for chemical synthesis. Pesticide Science. 1993; 39:131-140.
- Nas MN. *In vitro* studies on some natural beverages as botanical pesticides against *Erwinia amylovora* and *Curobacterium flaccumfaciensis* subsp. poinsettiae. Turkish Journal of Agriculture and Forestry. 2004; 28:57-61.
- Anil K, Kurtadikar JS, Wadnerkar DW, Nemade PW. Studies on the safety of pesticides to grapevine Predators and parasitoids of *Phenacoccus solenopsis* mealybug predator, *Cryptolaemus montrouzieri* Aiyar. Pestology. 2008; 32(4):17-27.
- Hayat M. Description of a new species of *Aenasius* Walker (Hymenoptera: Encyrtidae), parasitoid of mealybug, *Phenacoccus solenopsis* Tinsley (Homoptera: Pseudococcidae). Biosystematica. 2009; 3:21-25.
- Nagrare VS, Kranthi S, Kumar R, Dharajothi B, Amutha M, Deshmukh AJ. Compendium of Cotton Mealybugs. Technical Bulletin, Central Institute for Cotton Research, Nagpur, 2011, 42.
- Kumar R, Kranthi KR, Monga D, Jat SL. Natural parasitization of *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) on cotton by *Aenasius bambawalei* Hayat (Hymenoptera: Encyrtidae). Journal of Biological Control. 2009; 23:457-460.
- Suroshe SS, Gautam RD, Fand BB. Natural enemy complex associated with the mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) infesting different host plants in India. Journal of Biological Control. 2013; 27(3):204-210.
- Prasad YG, Prabhakar M, Sreedevi G, Thirupathi M. 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. Journal of Biological Control. 2011; 25(3):198-202.
- Sankar C, Marimuthu R, Saravanan P, Jeyakumar P, Tanwar RK, Sathyakumar S. Predators and parasitoids of

- cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) in Perambalur district of Tamil Nadu. Journal of Biological Control. 2011; 25: 242-245.
18. Noyes JS. Collecting and preserving chalcid wasps (Hymenoptera: Chalcidoidea), Journal of Natural History. 1982; 16(3):315-334.
 19. Toshiharu T, Chieka M. Insecticides and Parasitoids, Insecticides - Advances in Integrated Pest Management, Dr. Farzana Perveen (Ed.), ISBN: 978-953-2012, 307-780-2, In Tech, Available from: <http://www.intechopen.com/books/insecticides-advances-in-integrated-pest-management/insecticides-andparasitoids>, 115-140
 20. Tanwar RK, Bhamare VK, Ramamurthy VV, Hayat M, Jeyakumar P, Singh A. Record of new parasitoids on Mealybug, *Phenacoccus solenopsis*. Indian Journal of Entomology. 2008; 70:404-405.
 21. Singh A, Kumar D. Feeding potential of *Scymnobiussordidus* Horn (Family: Coccinellidae) on cotton mealybug, *Phenacoccus solenopsis* (Tinsley). Journal of Entomology and Zoology Studies. 2015; 3(5):235-238.
 22. Chen Hua-Yan, He Lang-Fen, Zheng Chun-Hong, Li Pan, Yi Qing-Hui, Xu Zai-Fu. Survey on the natural enemies of mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) from Guangdong and Hainan, China. Journal of Environmental Entomology. 2011; 33(2):269-272.
 23. Spodek Malkie, Ben-Dov Yair, Mondaca Lily, Protasov Alex, Erel Eyal, Mendel Zvi. The cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) in Israel: pest status, host plants and natural enemies. Phytoparasitica. 2018; 46:45-55.
 24. Dhawan AK, Singh K, Saini S, Aneja A, Singh J. Parasitizing potential of parasitoid (*Aenasius bambawalei*) on mealybug (*Phenacoccus solenopsis*) in cotton (*Gossypium* spp) and weed plants. Indian Journal of Agricultural Sciences. 2011; 81(1):97-99.