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Research Article

Impact of withdrawal of pesticide application against papaya mealybug, *Paracoccus marginatus* Williams and Granara de Willink on the biodiversity of natural enemy complex in small scale papaya farming system in Tamil Nadu

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ABSTRACT: Observations on the incidence of mealybug, *Paracoccus marginatus* Williams and Granara de Willink and spider and ants associated with it were recorded in 10 papaya fields each (total of 30 fields) falling in three categories *viz.* 1) Abandoned and severely infested fields released with parasitoid *Acerophagus papayae*, 2) Infested but yielding fields released with *A. papayae.* and 3) Fields with 2-4 months old crop without parasite release in Tamil Nadu. The *P. marginatus* incidence was reduced to an extent of 7-33 per cent with very low intensity in parasitoid released fields. Six species of spiders *viz. Clubiona* spp. crab spider*, Thomisus* spp., Jumping spider *Phidippus* sp.*, Plexippus* sp.*, Araneus* sp. wolf spider*, Lycosa pseudoannulata* were found and the most predominant one was *Araneus* sp. Nine species of coccinellids, *viz. Brumoides suturalis* (Fabricius)*, Cheilomenes sexmaculata* (Fabricius), *Coccinella septumpunctata* Linnaeus, *Coccinella nigrita* Fabricus*, Cryptolaemus montrouzieri* Mulsant, *Hippodamia variegata* (Goeze), *Hyperaspis maindroni* Sicard, *Nephus regularis* Sicard and *Scymnus coccivora* Ayyar recorded from the fields. Two species of chrysopids, *Chrysoperla zastrowi silemi (carnea)* and *Mallada* sp. were observed. Parasitoids *A. papayae* and *Torymus* sp. (Torymidae) only were found. Four species of ants *viz., Camponotus compressus* (Fabricius*), Camponotus sericeus* (Fabricius*), Camponotus parius* Emery and *Tapinoma melanocephalum* (Fabricius) were found to be associated with mealybug. Avoidance of insecticide spraying resulted in the appearance of notable number of biocontrol organisms in papaya fields in Tamil Nadu.

KEY WORDS: *Paracoccus marginatus***,** natural enemies, insecticides

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INTRODUCTION

Papaya cultivation taken up since 2004 for papain production by about 100 progressive farmers in Tamil Nadu facilitated by Senthil Papain and Food Products Ltd. (SPFP), Coimbatore, India – was affected seriously by the new invasive mealybug, *Paracoccus marginatus* Williams and Granara de Willink (Regupathy and Ayyasamy, 2009) in 2006, necessitating repeated application of insecticides. Some of the farmers could not even maintain the crop after 2006 and has to give up papaya crop altogether (Regupathy and Ayyasamy, 2010a) resulting in reduction on papain production (Regupathy and Ayyasamy, 2010b). *P. marginatus* has never gained status the serious pest in its native Mexico and/or Central of America, probably, due to the presence of an endemic natural enemy complex. But, in places where they got introduced without their native natural enemies, it potentially poses a great threat to numerous agricultural produce/products, if uncontrolled. Classical biological control was identified as an important component in the management of *P. marginatus* (Walker *et al.,* 2006). Biocontrol programme was implemented in Tamil Nadu, thanks to the efforts taken by NBAII through USA consulate at New Delhi and Dr Muniappan. All the three parasitoid species, *Acerophagus papayae* Noyes & Schauff*, Anagyrus loecki* Noyes and *Pseudleptomastix mexicana* Noyes & Schauff were imported from the USDA, APHIS parasitoid rearing facility at Puerto Rico on July, 15, 2010 (Rabindra and Shylesha, 2011). Conservation of the released parasitoids and naturally occurring preadators like *Spalgis* sp. and coccinellids by avoiding the use of chemical pesticides is considered as the important strategy for biological control of *P. marginatus* (Shylesha *et al.,* 2010; Anonymous, 2010). Hence, a survey was made on the revival of various natural enemies and other associated

insects in the farms, where, the farmers were advised to desist from insecticide sprays in parasitoid released fields.

MATERIALS AND METHODS

Diversity studies were carried out in 10 papaya fields each (total of 30 fields) falling in three categories *viz.,* 1. Abandoned and severely infested fields released with *A. papayae*, 2. Infested but yielding fields released with *A. papayae* and 3. Fields with 2-4 months old crop without parasitoid release. Five sites were selected in each field and in each site 20 plants selected at random were observed for the incidence of mealybug as per the method followed by Regupathy and Ayyasamy (2010a). The per cent of incidence was worked out from the number of affected and total plants observed. During sampling, whole plants under observation were examined for occurrence of the bugs, their natural enemies *viz.,* coccinellids, chrysopids, lycaenid predators, spiders and ants. Infestation of the mealybug was categorized based on the following parameters recorded using visual observations.

The identity of coccinellid predators was made by consulting *Coccinellidae of Indian Subcontinent by* J. Poorani *www.angelfire.com/bug2/j_poorani.* The data on plants harbouring mealybug/spiders/coccinellids and chrysopids and populations of these insects were statistically scrutinized by paired t test after transforming the data (x + 0.5).

RESULTS AND DISCUSSION

P. marginatus incidence

The impact of parasitoid was observed in low incidence and reduced intensity of the *P. marginatus*. The *P. marginatus* incidence was as low as 7-33 per cent with very low intensity in parasitoid released fields compared to cent per cent incidence with very high intensity in abandoned fields (Table 1).

Spiders

Six species of spiders *viz., Clubiona* spp. crab spider, *Thomisus* spp., Jumping spider *Phidippus* sp., *Plexippus* sp., *Araneus* sp., wolf spider, *Lycosa pseudoannulata* were found and the most predominant one was *Araneus* sp. Spiders were observed more in fields falling in category 2 (infested but yielding fields released with *A. papayae)* than in fields falling in category 1 (abandoned severely infested fields released with *A. papayae)*. Spiders in the range of 9-102 in all ten fields falling in category 2 (Table 1) and 7-27 numbers/100 plants in eight out of ten fields falling in category1 were observed. Spiders are the abundant natural enemies in any agroecosystem and were found in most terrestrial habitats, often present in large numbers (Mathirajan and Regupathy, 2003 a,b,c; Senthil Kumar and Regupathy, 2003, 2004; Vijayaraghavan and Regupathy, 2006; Vanitha, 2000). Spiders were favoured in ecological studies as indicators of environmental quality (Maelfait *et al.,* 1990) and as biological control agents in agricultural ecosystems (Bishop and Riechert, 1990). Though, insects constitute primary prey and all spiders are predaceous (Turnbull, 1973), predation remains one of the most difficult ecological processes to study, but is critical to understand if we have to use predators more effectively in agricultural pest control (Naranjo and Hagler, 2001). As spiders are generalist predators and tend to be small, cryptic feeders, have extra-oral digestion and sucking mouthparts, and exhibit amorphous gut contents, it is difficult to obtain data on predation rates especially on coccids and mealybugs. There is a need to gather some

Parameters	Infestation levels
Very Low	A few individuals of the *P. marginatus* casually found.
Low	*P. marginatus* found in low numbers. No adverse symptoms like deformation of leaf observed on the plant.
Medium	Almost 75 – 100% coverage of leaves/fruits/inflorescence. Yellowing of leaves. Shedding of infested leaves and fruits.
High	Almost all plant parts (stem, leaves, flowers and fruits) covered with *P. marginatus* showing white appearance. Leaves, fruits and inflorescences covered with honey dew secretion and sooty mould.
Very High	All plant parts (stem leaves, flowers and fruits)covered with *P. marginatus* showing white appearance. Honey dew rain under the tree. Crinkling of leaves. Drying and death of plants

information by direct observation. The gut analysis of field-collected spiders is the least disruptive and the most efficient means to acquire data on predation. Gut content analysis, confirmed the predation of the coffee green scale, *Coccus viridis* (Green) by the foliage dwelling spiders *Dieta virens* (Thorell), *Olios milleti* Pocock, *Telomania dimidata* (Simon), and *Clubiona* sp., and revealed greater possibility of the acridids (*Aularches* sp.) as one of the preys for spiders *Leucauge decorate* (Blackwall), *Hippasa* sp. and *Plexipus* sp. in field margins and strips in coffee ecosystem (Senthilkumar and Regupathy, 2009). Similar studies might be useful in assessing the predatory role of spiders on *P. marginatus* on papaya.

Coccinellids

Nine species of coccinellids, *Brumoides suturalis* (Fabricius), *Cheilomenes sexmaculata* (Fabricius), *Coccinella septumpunctata* Linnaeus, *Coccinella nigrita* Fabricius, *Cryptolaemus montrouzieri* Mulsant, *Hippodamia variegata* (Goeze), *Hyperaspis maindroni* Sicard (earlier reported as *Brumoides lineatus* (Weise)), *Nephus regularis* Sicard and *Scymnus coccivora* Ayyar were encountered in the unsprayed fields. *C. montrouzieri* is the dominant predator in the fields. In contrast to spiders, coccinellids were more in fields falling in category 2 than in fields falling in category 1. Coccinellids in the range of 7-81 in all ten fields falling in category 1 (Table 1) and 1-7 / 100 plants in seven out of ten fields falling in category 2 were observed.

Chrysopids

Two species of chrysopids, *Chrysoperla zastrowi sillemi* and *Mallada* sp. were observed. Chrysopids were less when compared to coccinellids and observed only in three fields each falling in categories 1 and 2 (Table 1). Coccinellid and chrysopid populations were slightly more in fields falling in category 1 than that in category 2.

Lycaenid predator

In one field falling under category 1, lycaenid predator *Spalgis epius* (Westwood) was noticed. In the earlier survey predatory larvae of *S. epius* was not observed on papaya though notable numbers of were found feeding on *P. marginatus* on other hosts like bread fruit, teak, pomegranate, *Tecoma, Thespesia*, hibiscus and nerium, thevetia etc. during the cooler months (Ayyasamy and Regupathy, 2010).

Parasitoids

Though a number of parasitoids like *Torymus* sp. (Torymidae) and *Prochiloneurus aegyptiacus* (Mercet) (Chalcidoidea) had been recorded on *P. marginatus* on cotton with 21 and 7 per cent parasitisation, respectively, on other alternate hosts of *P. marginatus* like *Parthenium hysterophorus*, *Abutilon indicum, Phyllanthus niruri, Commelina benghalensis, Convolvulu sarvensis,* and *C. viscera* (Amutha *et al.,* 2009), no parasitoid on papaya was reported in the earlier survey (Ayyasamy and Regupathy 2010). In the present observation, however, the parasitoids *A. papayae and Torymus* sp. (Torymidae) only were found in fields under category 1 and 2. *Torymus* being hyperparasite might have visited bug infested papaya fields for the honey dew secreted by mealybug.

Ants

Four species of ants *viz., Camponotus compressus* (Fabricius), *Camponotus sericeus* (Fabricius), *Camponotus parius* Emery and *Tapinoma melanocephalu* (Fabricius) were found frequenting mealybug on papaya plants. A number species of ants were found to be associated with *P. marginatus* on Jatropha (Regupathy and Ayyasamy, 2011). They were frequenting mealy bug for feeding honey dew secretion. The most predominant one was *C. compressus.*

Withdrawal of insecticides on natural enemy complex

Bugs, coccinellids and chrysopids were not observed in fields falling in category 3 (fields with 2-4 months old crop without parasite release). The diversity and richness of the predators was more in field severely affected by *P. marginatus* and in abandoned fields as well. Coccinellid and chrysopid populations started declining with effective parasitization of *A. papayae*. However, the richness and diversity of spiders were observed even in fields where effective check of *P. marginatus* was observed. This might be due to the fact that spiders being generalist predators and coccinellids and chrysopids prey dependent.

Before implementing biocontrol programme, coccinellids, chrysopids, and hover flies commonly found feeding on other species of mealybug populations and notable numbers of *S. epius* were found feeding on *P. marginatus* on other hosts like breadfruit, teak, pomegranate, *Tecoma, Thespesia*, hibiscus and nerium, thevetia etc. but were seldom found feeding in papaya fields, prior to release of parasitoids and perhaps due to intense spray schedule (Ayyasamy and Regupathy, 2010). The recent observation of *S. epius* and parasitoids in the present survey might be due to withdrawal of insecticide applications to facilitate parasitoid release. Regular monitoring and educating the farmers almost stopped

Table 1. Incidence of *Paracoccus marginatus* and populations of spiders, coccinellids and chrysopids in papaya fields

Fields		1	2	3	4	5	6	7	8	9	10	Mean
		1. Number Plants with papaya mealybug incidence										
Category. I	Plants*	100	100	100	100	100	100	100	100	100	100	100[a]
	Grade	V.H.	V.H	V.H	V.H	H	V.H	V.H	V.H	V.H	V.H	–
Category II	Plants*	7	16	7	8	10	9	13	8	14	33	12.5[b]
	Grade	V.L.	V.L.	V.L.	V.L.	V.L.	V.L.	V.L.	V.L.	V.L.	L.	–
Category III	Plants*	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0.0[c]
		2. Spider population – number / 100 plants										
Category. I	Plants*	7	12	4	18	Nil	6	Nil	4	15	8	7.4[a]
	Spiders	9	18	7	27	Nil	7	Nil	3	23	9	10.3_a
Category II	Plants*	63	44	26	19	22	64	25	23	26	7	31.9[b]
	Spiders	96	45	32	20	24	102	37	26	28	9	41.9_b
Category III	Plants*	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0.0[c]
		3. Coccinellid population – number 100 plants										
Category. I	Plants*	38	52	8	4	20	14	10	50	5	6	20.7[a]
	Coccinellids	76	81	20	7	32	16	14	62	8	7	32.3_a
Category II	Plants*	1	Nil	4	5	3	Nil	2	4	6	Nil	2.5[b]
	Coccinellids	1	Nil	6	7	4	Nil	3	5	7	Nil	3.3_b
Category III	Plants/	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0.0[c]
		4. Chrysopid population – number / 100 plants										
Category. I	Plants*	Nil	1	Nil	Nil	5	Nil	2	Nil	Nil	Nil	0.8[a]
	Chrysopids	Nil	1 M	Nil	Nil	7 M	Nil	3 C	Nil	Nil	Nil	1.1_a
Category II	Plants*	Nil	Nil	1	Nil	Nil	1	Nil	Nil	1	Nil	0.3[a]
	Chrysopids	Nil	Nil	1 C	Nil	Nil	1 C	Nil	Nil	1 C	Nil	0.3_a
Category III	Plants*	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0.0[a]

Intensity: V.L. : Very low; L. : Low; V.H. : Very high

C: *Chrysoperla* sp.; M: *Mallada* sp.

* Number of plants with mealybug/spiders/coccinellids/chrysopids

Category1. Abandoned severely infested fields released with *A. papayae*; Category 2. Infested but yielding fields released with A. papayae; Category 3. Fields with 2-4 months old crop without parasite.

Means followed by same alphabetical letters in superscript are not significantly different by paired t-test at $P = 0.05$ level; Means followed by same alphabetical letters in subscript are not significantly different. by paired t-test at $P = 0.05$ level

insecticide spraying resulting in the appearance of notable number of biocontrol organisms in papaya fields in Tamil Nadu. The predatory fauna is nil in fields falling in category 3 (2-4 month old crop) (Table 1) indicating that, the establishment of coccinellids, chrysopids and lycaenid predators are dependent on host *P. marginatus* apart from withdrawal insecticide applications on papaya (Table 1). Redistribution of the natural enemies / released parasitoids to new areas of infested by *P. marginatus* infested weeds like parthenium, *Plumeria alba*, *Acalypha indica*, hedge plants and other hosts like – teak, mulberry, silk cotton, notchi, guava, mango, pomegranate maintained in their homestead could serve as reservoirs of parasitoids and other natural enemies (Shylesha *et al.,* 2010) . This could be made possible only by educating the farmers not to spray with chemical pesticides.

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