Biological Control 60 (2012) 290–296

Contents lists available at SciVerse ScienceDirect

Biological Control

journal homepage: www.elsevier.com/locate/ybcon

The passionvine mealybug, *Planococcus minor* (Maskell) (Hemiptera: Pseudococcidae), and its natural enemies in the cocoa agroecosystem in Trinidad

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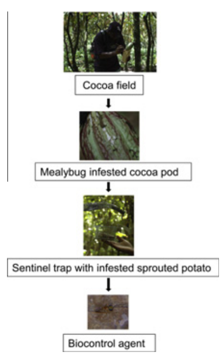
HIGHLIGHTS

- ▶ *Planococcus minor* is found in Trinidad where little was known about the pest.
- ▶ The mealybug was widely distributed on cocoa and infestation levels were low.
- ▶ Cocoa field sites were surveyed for natural enemies.
- ▶ We identified key natural enemies attacking the mealybug.
- ▶ Their identification is a key step in the biological control process.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 11 August 2011
Accepted 2 December 2011
Available online 13 December 2011

Keywords:
Planococcus minor
Biological control
Parasitoids
Parasitism
Hyperparasitoids
Predators

ABSTRACT

Planococcus minor (Maskell) is native to South Asia, but it is also present in several Neotropical locations including the island of Trinidad in the southern Caribbean. The mealybug poses a serious threat to uninfested countries in this region as well as the mainland U.S. As part of an effort to gather much needed information on *P. minor*, 33 cocoa (*Theobroma cacao* L.) field sites on the island were surveyed in 2006 with a view to assess the occurrence and pest status of the mealybug. *P. minor* was identified from 20 field sites, indicating that it was well distributed across the island on this crop, which appeared to be a reliable indicator host plant. Infestation levels were generally low and populations were sparsely distributed across the field sites categorized into three habitat types. The following year, nine field sites were surveyed for natural enemies of *P. minor* using laboratory-infested potatoes in sentinel traps. Species from four insect orders and six families were collected and identified. The major predators belonged to the families Cecidomyiidae and Coccinellidae. Two primary parasitoids, *Leptomastix dactylopii* Howard (Encyrtidae) and *Coccidoxenoides perminutus* (Girault) (=*Pauridia peregrina* Timberlake, =*Coccidoxenoides peregrinus* (Timberlake)) (Encyrtidae), were reared from different mealybug stages, along with several hyperparasitoids. The primary parasitoids were probably introduced fortuitously. These diverse natural enemies were recovered throughout the sampling period from the different habitat types. The identification of key natural enemies associated with *P. minor* has important implications for the implementation of biological control in newly infested areas.

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doi:10.1016/j.biocontrol.2011.12.002

1. Introduction

The passionvine mealybug, *Planococcus minor* (Maskell) (Hemiptera: Pseudococcidae) is a polyphagous pest that can potentially damage many tropical and subtropical plants (Commonwealth Agricultural Bureau, 2003; Venette and Davis, 2004). This mealybug is native to south Asia (Cox, 1989), but is considered a serious pest in countries such as India (Reddy et al., 1997; Tandon and Verghese, 1987) and Taiwan (Ho et al., 2007). In addition to its polyphagous nature, *P. minor* has many other characteristics of a highly invasive species including: ease of spread on traded commodities such as fruit (Venette and Davis, 2004), a relatively short life cycle (Martinez and Suris, 1998) and a high reproductive potential (Maity et al., 1998). Whereas it is not known when *P. minor* first invaded the Neotropics, the insect is now present in at least 21 countries/territories (Williams and Granara de Willink, 1992). As a consequence, and also due to its frequent interception at ports-of-entry in the U.S., *P. minor* has been identified as a serious pest threat (Miller et al., 2002).

Intriguingly, there have been no reports of serious crop losses by *P. minor* in the Neotropics, including Trinidad, and anecdotal evidence suggested that the mealybug was not considered a major pest on the island. Given its broad host range, it is difficult to explain why population levels of *P. minor* have remained low throughout the region. Against this background, and as part of a strategic offshore research initiative targeting high risk pest threats to the U.S., studies were initiated in Trinidad with a view to generate pertinent information on *P. minor* and its natural enemies. Trinidad was selected because of its confirmed populations of the mealybug (Williams and Granara de Willink, 1992) and relative proximity to the U.S.

Specifically, the study set out to: (1) assess the occurrence and pest status of *P. minor* in Trinidad, including its distribution on the island, its host plant range, and its levels of infestation on host plants in different habitats; and (2) determine what, if any, natural enemies were attacking the mealybug, including their identity, relative abundance and occurrence in different habitats, and potential for use in biological control. In order to realize objective 2, it was also essential to develop a reliable method for the survey of natural enemies, especially given the potential co-occurrence of mealybug species that were difficult to distinguish morphologically.

2. Materials and methods

2.1. Maintenance of host material and colony of P. minor

The initial colony of *P. minor* originated from gravid females that were inadvertently collected on cocoa (*Theobroma cacao* L.) pods infested with *Maconellicoccus hirsutus* (Green) and destined for use in a colony of the latter by personnel at the Central Experiment Station, Ministry of Agriculture, Land and Marine Resources (MALMR), Trinidad. The suspect *P. minor* females were isolated and 1st generation offspring (adult females) were sent for expert identification at the USDA-ARS Systematic Entomology Laboratory, Beltsville, MD. The colony of *P. minor* was initiated in May, 2006 on sprouted potatoes, 'Cavendish' variety (*Solanum tuberosum* L.) in a room at 25 ± 2 °C, 60 ± 10% RH, and complete darkness at the experiment station and transferred to laboratory facilities at CABI Caribbean and Latin America Office, Curepe in May, 2007. Rearing methods were similar to those used by Meyerdirk et al. (1998). Each week, 25 potatoes were individually infested with five adult females with ovisacs. These weekly infestations ensured a continuous supply of different mealybug life stages. Infested potatoes were ready for field use after 4–5 weeks.

2.2. Occurrence and pest status of P. minor

Consultations with staff at the Central Experiment Station indicated that *P. minor* could be found on cocoa, but was difficult to find on other plant species. Subsequently, the mealybug was collected at nearby cocoa field sites during a preliminary survey in May 2006. It was therefore decided to use this crop as the primary indicator host plant during the survey. During the preliminary survey, plant parts (pods, flowers, and leaves) on the main trunk of each tree from ground level to 1.5 m were examined for the presence of *P. minor*. All stages from 2nd instar nymphs to adult females were counted with the aid of a 5–10× folding pocket magnifier and a 4-digit tally register. Very low and sparse numbers of mealybugs were found on flowers and leaves as compared to pods; therefore, the latter was chosen as the principal sampling unit on individual trees.

A total of 33 cocoa field sites were surveyed from June 30 to July 27, 2006. Ten trees were randomly selected for visual inspection and estimation of *P. minor* abundance at each field site. Each tree was considered a replicate. A qualitative composite infestation score to estimate mealybug abundance was devised based on the number of mealybugs counted on the pods on each tree *in situ*, and ranged from 0 to 5. No mealybugs were scored as 0, <10 mealybugs were scored as 1, 10 to 100 were scored as 2, >100–200 were scored as 3, >200–500 were scored as 4, and >500 were scored as 5. This score range was based on the range of infestation levels seen for other mealybugs such as *M. hirsutus*, which was observed in very high numbers on some pods. Live mealybug specimens were collected from the pods using a camel hair brush in order to positively confirm their identity as *P. minor*. Other plant species were also visually inspected and scored for *P. minor* at field sites using the same procedure where possible. Most of these plants were listed hosts of *P. minor* and were grown as part of mixed crop systems at 12 field sites. Weed species were identified from Fournet and Hammerton (1991).

Field sites were categorized into three habitat types to determine the influence of existing plant diversity on *P. minor* abundance. Type 1 sites were commercial plots receiving regular crop maintenance and weed management and >2 hectares in size. Type 2 sites were abandoned plots where no crop maintenance or weed management was practiced and ranged from 0.25 to 2 ha in size. Type 3 sites (<0.25 ha) were mixed crop systems with vegetable and root crops planted alongside cocoa trees and receiving regular crop maintenance and weed management. Insecticides were not applied to any of these field sites or known to have been used within the immediate area during the survey period.

2.3. Natural enemies of P. minor

Nine cocoa field sites were surveyed for predators and parasitoids of *P. minor* from June 26 to October 19, 2007. These field sites were used the previous year for surveys of *P. minor* and were selected based on preliminary observations of natural enemy activity. Field sites were grouped into three habitat types as previously outlined. In order to overcome the challenges of finding patchy, low populations of the mealybug at the field sites and to ensure collections of natural enemies were positively associated with *P. minor*, laboratory-infested potatoes were used in sentinel traps. The sentinel trap consisted of a wire cage measuring 12 × 8 × 8 cm in which an infested sprouted potato with 200–300 mealybugs of all life stages was placed (Fig. 1). These cages were securely hung from horizontal branches up to 2.0 m from ground level on randomly chosen trees (1–3 cages/field site) and spaced 10–15 m apart. The number of cages deployed depended on the approximate size of each field site. Field sites less than 0.25 ha were allocated a single cage, 2 cages were placed at sites

Fig. 1. Sentinel trap with infested potato used to collect natural enemies of *P. minor* in Trinidad.

greater than 0.25 ha but less than 1 ha, while sites greater than 1 ha were allocated 3 cages. Because many species of ants negatively affect natural enemies (Buckley and Gullan, 1991), Tangle-Trap® insect trap coating (Tanglefoot Co., Grand Rapids, MI) was applied to the branch on both sides of the cage attachment to prevent ants from entering the cages. Every 10–14 days, newly infested potatoes were taken to the field to replace those in the traps. Exposed potatoes were taken back to the laboratory in individual plastic containers for processing.

Potatoes from the sentinel traps were observed under a dissecting microscope and any adult predators found were immediately collected with a hand-held aspirator. These predators were kept separately based on sentinel trap, field site, and sampling date in small plastic vials filled with 70% alcohol. For collection purposes, any remaining immature larvae and/or nymphs feeding on mealybugs were left to develop to the adult stage in the laboratory at 25 ± 1 °C, 60–70% RH, and a photoperiod 14:10 (L:D).

Methods similar to those utilized for studying parasitism of *M. hirsutus* (Meyerdirk et al., 1998) were followed. Mealybugs in two size classes (2nd instars, and 3rd instars to adult females) were randomly collected from each infested potato and individually placed in gelatin capsules, up to a maximum of 100 individuals per size class. The capsules were held in brown paper bags labeled according to size class and relevant collection data and kept at laboratory conditions. Capsules were inspected after 4–5 weeks for emerged primary parasitoids. Percent parasitism was calculated by dividing the number of parasitized mealybugs by the total number of encapsulated mealybugs from each sentinel trap multiplied by 100. Field-collected mummies from parasitized mealybugs were also placed individually into gelatin capsules to assess hyperparasitism. Percent hyperparasitism was calculated by dividing the number of mummies from which hyperparasitoids emerged by the number of mummies from which primary or hyperparasitoids emerged from each sentinel trap multiplied by 100.

2.4. Species identification

Mealybug specimens in 70% alcohol were sent to USDA ARS SEL, Beltsville, MD for species identification. Specimens in 95% alcohol were identified using molecular techniques as outlined in Rung et al. (2008). Voucher specimens were retained by SEL. Some mealybug specimens were also sent for identification to Florida Department of Agriculture and Consumer Services – Division of Plant Industry, Gainesville, FL, and likewise, voucher specimens were kept at FDACS-DPI. Specimens of natural enemies were also identified at USDA ARS SEL. Voucher specimens were retained by SEL.

2.5. Data analysis

A chi-square test of independence (PROC FREQ) was used to determine the effect of habitat type on infestation levels of *P. minor*. For the survey of natural enemies, the most abundant adult predators were grouped according to family and the numbers of adults collected per sentinel trap were square-root transformed to satisfy the assumptions of the analysis of variance. Parasitism data for recovered parasitoids were separately analyzed based on primary parasitoid species and hyperparasitoids. For this, percent data underwent an arcsine square-root transformation (Zar, 1984) prior to analysis. The sources of variation were habitat type and sampling date and a two-factor analysis of variance (PROC GLM) was applied to all transformed data. Means separation for percent parasitism at two habitat types was performed using a *t*-test (PROC TTEST) and Tukey's honestly significant difference (HSD) test at three habitat types. Means were back-transformed for reporting. The SAS Statistical Software Version 9.2 (SAS Institute, 2002) was used to perform the statistical analyses.

3. Results

3.1. Occurrence and pest status of P. minor

Besides cocoa, *P. minor* was not found on any of the other plants inspected (Table 1). Mealybug specimens collected from 20 of 33 field sites were confirmed as *P. minor*. These field sites were found in 7 of the 8 counties on the island (Fig. 2). The habitat type composition had a significant effect on infestation levels of *P. minor* ($\chi^2 = 27.61$; df = 6; $P < 0.05$). There were no mealybugs in >50% of

Table 1
List of plants inspected for *Planococcus minor* at field sites, June 30–July 27, 2006.

Family	Scientific name	Common name
Amaranthaceae	*Amaranthus dubius*[a,b]	Bhaji
Araceae	*Colocasia* sp.[a]	Dasheen
Caricaceae	*Carica papaya*	Papaya
Convolvulaceae	*Ipomoea batatas*[a]	Sweet potato
Convolvulaceae	*Ipomoea tiliacea*[b]	Morning glory
Dioscoreaceae	*Dioscorea* sp.[a]	Yam
Euphorbiaceae	*Manihot esculenta*[a]	Cassava
Fabaceae	*Cajanus cajan*[a]	Pigeon pea
Malvaceae	*Abelmoschus esculentus*[a]	Okra
Musaceae	*Musa* sp.[a]	Banana
Myrtaceae	*Syzygium malaccense*[a]	Pomerac
Poaceae	*Saccharum* sp.	Sugar cane
Poaceae	*Panicum* maximum[c]	Guinea grass
Poaceae	*Eleusine indica*[c]	Fowlfoot grass
Rubiaceae	*Coffea* sp.[a]	Coffee
Rutaceae	*Citrus* spp.[a]	Citrus
Solanaceae	*Solanum melongena*[a]	Eggplant
Sterculiaceae	*Theobroma cacao*[a]	Cacao

[a] Listed host plant (Venette and Davis, 2004).
[b] Herbaceous weed.
[c] Grass weed.

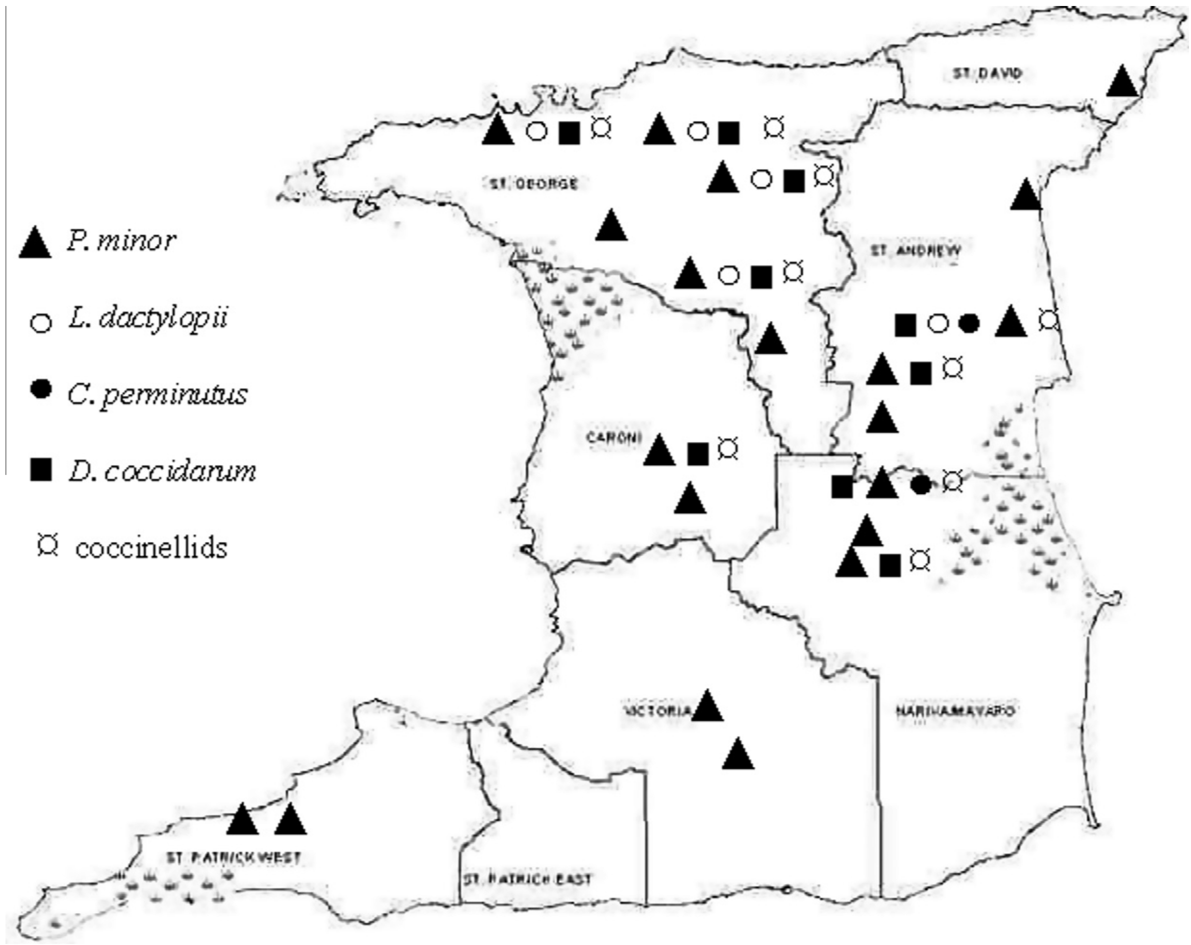

Fig. 2. Map of the island of Trinidad showing the distribution of cocoa field sites where *P. minor*, primary parasitoids, and key predator species were found.

the trees in all habitat types (Fig. 3). Conversely, infestation levels 1–3 were <15% on sampled trees in habitat types 1 and 2, but 45% of sampled trees in habitat type 3 field sites exhibited infestation level 1 (Fig. 3).

3.2. Natural enemies of P. minor

Twelve species comprising of predators, primary parasitoids, and hyperparasitoids from four insect orders and six families were

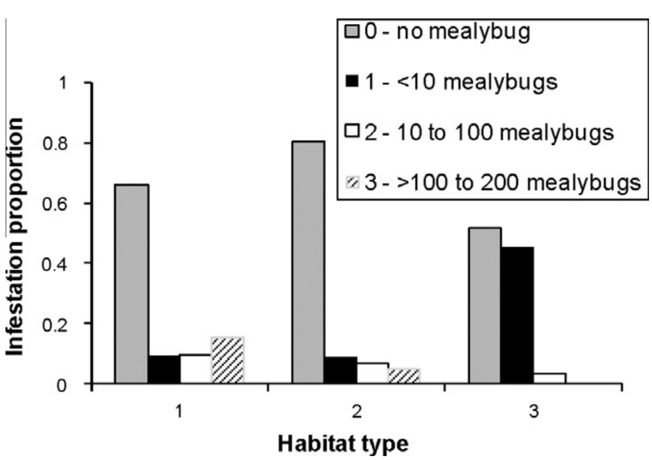

Fig. 3. Infestation proportion of *P. minor* scored qualitatively from 0 to 3 at cocoa field sites categorized into habitat types in Trinidad, June 30 to July 27, 2006. Habitat type 1 sites were commercial fields, type 2 sites were abandoned fields, and type 3 sites were cocoa with mixed crops.

collected and identified. Table 2 lists the species from a total of nine field sites.

3.2.1. Predators

Diadiplosis coccidarum Cockerell (Diptera: Cecidomyiidae) was collected from all field sites (Table 2). The interaction between habitat type and sampling date did not have a significant effect on the mean numbers of adults collected from sentinel traps. However, when analyzed separately, habitat type significantly affected adult collection ($F = 7.82$; df = 2, 65; $P < 0.05$). More adults (>2×) were collected from sentinel traps at habitat type 2 sites than from either habitat type 1 or habitat type 3 sites (Fig. 4). The different sampling dates did not affect the mean numbers of adults collected.

Three coccinellid species were recovered including: *Diomus robert* Gordon from two field sites, *Tenuisvalvae bisquinquepustulata* Fabricius from four field sites, and *Diomus* sp. from six field sites (Table 2). Collection data for the coccinellids were pooled for analysis. The interaction term (habitat type and sampling date) did not significantly affect the mean numbers of adults collected from sentinel traps. After separate analysis of these two factors of variation, the sampling dates did not affect the mean numbers of adults collected, but there was statistical difference among the mean numbers collected from the three habitat types ($F = 14.62$; df = 2, 65; $P < 0.05$). More adults (>2×) were collected at habitat type 2 sites than from either habitat type 1 or habitat type 3 sites (Fig. 5).

Three other predator species were recovered: *Calliodis* sp. (Hemiptera: Anthocoridae), *Cryptognatha nodiceps* Marshall (Coleoptera: Coccinellidae) and *Ocyptamus stenogaster* species group

Table 2
Natural enemies found at cacao field sites, June 28–Oct 19, 2006.

Species	Field site
Hymenoptera: Encyrtidae	
Leptomastix dactylopii Howard[a]	Fishing Pond, La Reunion, Lopinot, Maracas, Santa Cruz
Coccidoxenoides perminutus Girault[a]	Biche, Fishing Pond
Gahaniella tertia Kerrich[b]	Maracas
Coccidoctonus trinidadensis Crawford[b]	Lopinot
Hymenoptera: Signiphoridae	
Signiphora n. sp. #11 (Woolley)[b]	La Reunion
Diptera: Cecidomyiidae	
Diadiplosis coccidarum Cockerell[c]	Biche, Fishing Pond, Gran Couva, La Reunion, Lopinot, Maracas, Navet, Plum Mitan, S. Cruz
Diptera: Syrphidae	
Ocyptamus stenogaster	La Reunion
Coleoptera: Coccinellidae	
Tenuisvalvae bisquinquepustulata Fabricius	Biche, Lopinot, Navet, S. Cruz
Diomus sp.	Biche, Fishing Pond, La Reunion, Maracas, Navet, S. Cruz
Diomus robert Gordon	Gran Couva, Plum Mitan
Cryptognatha nodiceps Marshall	Gran Couva
Hemiptera: Anthocoridae	
Calliodis sp.[d]	Gran Couva, Maracas, S. Cruz

[a] Primary parasitoid.
[b] Hyperparasitoid.
[c] Predatory on many coccoids.
[d] Undescribed species.

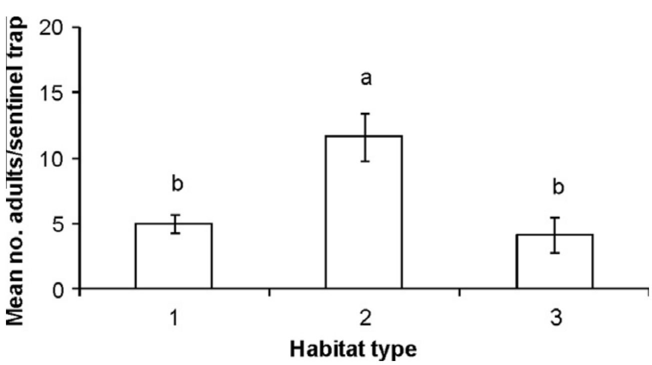

Fig. 4. Mean (±SEM) number of *D. coccidarum* at cocoa field sites categorized into habitat types in Trinidad, June 28 to August 8, 2007. Habitat type 1 sites were commercial fields, type 2 sites were abandoned fields, and type 3 sites were cocoa with mixed crops. Means with the same letters were not significantly different from each other (Tukey's HSD test, $P \leqslant 0.05$).

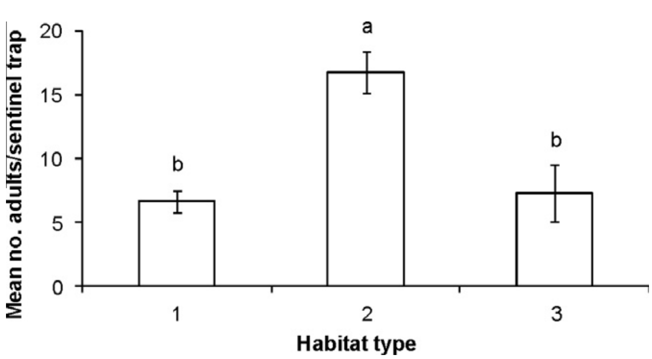

Fig. 5. Mean (±SEM) number of coccinellids at cocoa field sites categorized into habitat types in Trinidad, Jun 28 to Aug 8, 2007. Habitat type 1 sites were commercial fields, type 2 sites were abandoned fields, and type 3 sites were cocoa with mixed crops. Means with the same letters were not significantly different from each other (Tukey's HSD test, $P \leqslant 0.05$).

(Diptera: Syrphidae) (Table 2). *Calliodis* sp. is an undescribed species collected from Maracas (2 adults and 4 nymphs), Gran Couva ((1 adult and 4 nymphs), and Santa Cruz ((3 adults and 3 nymphs). *C. nodiceps* was collected from Gran Couva (8 adults), and *O. stenogaster* was collected from La Reunion (9 adults).

3.2.2. Primary parasitoids

Leptomastix dactylopii Howard (Hymenoptera: Encyrtidae) was reared from 3rd instar nymphs and adult females at 5 of 9 field sites (Table 2). Habitat type did not affect mean percent parasitism; however, the parasitoid was found at four field sites categorized as habitat type 1 and at one field site categorized as habitat type 3. Sampling date had a significant effect on this variable ($F = 2.81$; df = 7, 104; $P < 0.05$). Percent data recorded from 8 to 22 Aug (<11%) were higher than the other similar sampling dates (Fig. 6). Another primary parasitoid, *Coccidoxenoides perminutus* (Girault) (=*Pauridia peregrina* Timberlake, =*Coccidoxenoides peregrinus* (Timberlake)) (Hymenoptera: Encyrtidae), was reared from 2nd instar nymphs at two field sites (Table 2). Sampling date did not affect mean percent parasitism, but the percent data pooled across sample dates were significantly different between the habitat types 1 and 2 field sites, respectively, where *C. perminutus* was found ($t = 3.48$; df = 22; $P < 0.05$). At the habitat type 2 field site, a mean percent parasitism of 25.6 ± 8.5% was recorded, compared to 15.7 ± 9.4% from the habitat type 1 field site.

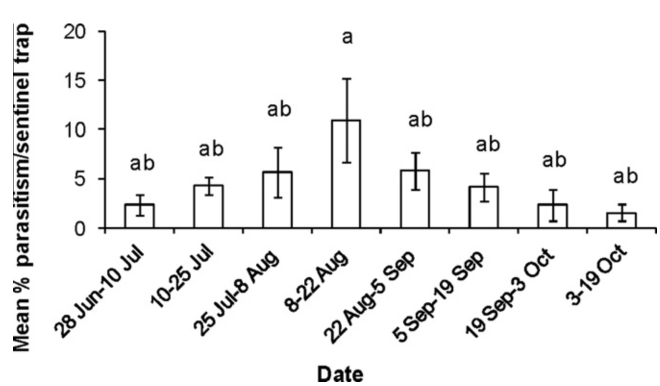

Fig. 6. Mean (±SEM) percent parasitism by *L. dactylopii* at cocoa field sites from different sampling dates in Trinidad, Jun 28 to Oct 19, 2007. Means with the same letters were not significantly different from each other (Tukey's HSD test, $P \leqslant 0.05$).

Three species of hyperparasitoids were reared from mummified 3rd instar nymphs and adult female *P. minor* and were associated with *L. dactylopii*. These were identified as *Gahaniella tertia* Kerrich and *Coccidoctonus trinidadensis* Crawford (Hymenoptera: Encyrtidae) and *Signiphora* n. sp. #11 (Woolley) mexicanus group (Hymenoptera: Signiphoridae). Each species was found at one different field site during the sampling period from June 26 to October 19, 2007 (Table 2). No analysis was undertaken on percent data due to the negligible numbers of hyperparasitoids found and their sporadic recovery at the field sites. No hyperparasitoids were found associated with *C. perminutus*.

4. Discussion

Planococcus minor was widely distributed in Trinidad as evidenced by its recovery from nearly all of the island's counties. The mealybug was reliably found on cocoa, an indicator host plant for *Planococcus* spp. in many areas (Cox and Freeston, 1985), and not on any of the other listed host plants inspected. It is therefore likely that the long list of host plants reported in the literature includes many secondary hosts that may not be preferred by *P. minor*. Similar patterns were observed when *M. hirsutus* invaded the Caribbean (Kairo et al., 2000). Additionally, Franco et al. (2009) noted that some mealybug populations are found on a high number of host plants when they spread into new areas and are under low natural enemy pressure, but the number of hosts decline over time once natural enemies become established. The narrow host plant range in Trinidad might also be indicative that the mealybug became established on the island many years previously.

Although Bigger (1973) and Campbell (1983) reported that some mealybugs in the genus *Planococcus* favored the bark of canopy branches or green shoots of cocoa trees, this study showed that pods were more likely to be infested than other plant parts. These findings were similar to Kirkpatrick (1953), who reported that mealybugs identified at the time as *Planococcus citri* (Risso) mainly attacked green pods, but also infested other plant parts to a lesser degree in Trinidad. With the aid of a morphological scoring matrix developed by Cox (1983) to address the taxonomic complexities of identifying the two species and molecular diagnostics by Rung et al. (2008), only *P. minor* was identified from submitted specimens.

Given that populations of *P. minor* were generally low, it was interesting that a diverse assemblage of predators and parasitoids were recovered, suggesting that these species may have a significant impact on field populations of the mealybug. Most of these natural enemies were observed feeding and/or parasitizing mealybugs in cocoa fields prior to their recovery on infested potatoes in the sentinel traps. Also, nearly all of the predators collected have been previously documented feeding on different mealybugs and other hosts in Trinidad (Bennett and Simmonds, 1964; Kirkpatrick, 1953). Of these, *D. coccidarum* and several coccinellids such as *T. bisquinquepustulata*, *Diomus* sp., and *D. robert* were the most widespread. Their recovery in greater numbers from habitat type 2 field sites compared to habitat types 1 and 3 field sites conformed somewhat with the findings of Altieri and Nicholls (2004), who noted that heterogeneous crop settings tended to encourage greater and more diverse numbers of natural enemies. Although their direct impact on infested potatoes was difficult to quantify, predator larvae were observed feeding voraciously on mealybug stages when the potatoes were retained in the laboratory.

Despite the relatively low parasitism rates recorded, *L. dactylopii* and *C. perminutus* were found for the entire duration of the field sampling. The parasitism rates were most likely a result of the experimental approach using sentinel traps, which limited the amount of time mealybug hosts were left exposed. Their persistence is important from a biological control standpoint because it suggests that they were intimately associated with, and perhaps providing sustainable control of *P. minor* populations. *L. dactylopii* was the predominant of the two primary parasitoids found at cocoa field sites. This parasitoid is thought to be of Afrotropical origin (Noyes and Hayat, 1994), while *C. perminutus* is of Australian origin (Girault, 1915), and both parasitoids have been reared from other mealybug hosts (Berlinger, 1977; Greathead, 1971; Le Pelley, 1943; Noyes and Hayat, 1994). There are no records of any intentional introduction of either parasitoid to Trinidad, but *L. dactylopii* was shipped from the island to other areas for biological control of *P. citri* (Cock, 1985). These two parasitoids were probably introduced fortuitously and have likewise been present on the island for quite some time. Fortuitous biological control is described as the unintentional reduction and maintenance of a pest population by a natural enemy wherein both the natural enemy and pest may be nonindigenous (Nechols, 2002). Examples include the control of *Nipaecoccus viridis* (Newstead) (Hemiptera: Pseudococcidae) in the Pacific islands principally by *Anagyrus indicus* Shafee, Alam, and Agarwal (Hymenoptera: Encyrtidae) (Nechols and Seibert, 1985) and the control of *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcidae) by another encyrtid wasp, *Aenasius bambawalei* Hayat in India (Gautam et al., 2009).

The low, sparse populations of *P. minor* on cocoa and its absence from other listed host plants suggests that the mealybug is not a pest of economic importance in Trinidad. The current pest status is probably attributed to the existing natural enemy complex that regulates its populations. The identified primary parasitoids have been used successfully elsewhere against *Planococcus* spp. (Mani, 1994; Meyerdirk et al., 1978; Smith, 1991), and they are also available from commercial insectaries at short notice for use in outbreak areas if the need were to arise. *P. minor* poses a serious threat to numerous crops grown in the U.S., especially in Florida where it was discovered on *Mussaenda* sp. in the county of Miami-Dade in December 2010 (Stocks and Roda, 2011) and California and Texas where similar crops are grown. Given the high likelihood that *P. minor* will pose a threat in these new and sensitive areas, knowledge and detailed evaluation of these primary parasitoids should be useful in the development of biological control approaches for the pest.

The study also vindicated the use of sentinel traps as an effective recovery/monitoring tool for natural enemies. Other investigators have used similar methods in diverse settings to collect and document natural enemies with varying degrees of success (Ceballo and Walter, 2005; Walton and Pringle, 2004). These sentinel traps can be deployed elsewhere where the natural enemy complex of *P. minor* is not known or not properly documented.

Acknowledgments

We gratefully acknowledge USDA APHIS and FAMU CESTA Center for Biological Control for providing financial support for this offshore work. We also acknowledge Lance Osborne, Raymond Hix, and Tim Momol for providing comments on earlier drafts. We thank Cynthra Persad, Petal Ram, Lilory McComie and staff at the Central Experiment Station, Ministry of Agriculture, Land and Marine Resources, Centeno, and Elizabeth Johnson and staff at CABI Caribbean and Latin America, Curepe, Trinidad for assistance in providing research facilities, personnel and space, and facilitating insectary setup and other essential services. We thank D. Miller and A. Rung (Pseudococcidae), N. Vandenberg (Coccinellidae), T. Henry (Anthocoridae), R. Gagne (Cecidomyiidae), C. Thompson (Syrphidae) and G. Evans (Encyrtidae and Signiphoridae) at the Systematic Entomology Laboratory, USDA-ARS, Beltsville, MD, and also G. Hodges (Pseudococcidae) at Florida Department of Agriculture and Consumer Services – Division of Plant Industry, Gainesville, FL for insect identifications. We also extend our gratitude to Gilbert Queeley, FAMU CESTA Cooperative Extension Program and Stuart Reitz, USDA-ARS-CMAVE, Tallahassee, FL for their help with the statistical analyses. Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

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