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Survey of Papaya Mealybug, *Paracoccus marginatus* and its Introduced Parasitoids on Papaya Plants in the Low Country Dry Zone of Sri Lanka

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Abstract

Papaya mealybug, *Paracoccus marginatus* Willams and Granara Willink, is an invasive hemipteran that attacks several genera of host plants, including economically important tropical fruits and ornamentals. It is an alien invasive species and was reported for the first time in Sri Lanka in 2008 and the biocontrol programme was implemented with the introduction of three natural enemies *Acerophagus papayae*, *Anagyrus loeki*, and *Pseudleptomastix mexicana* imported from Puerto Rico in some selected regions in 2008 and 2009. After a decade following the initial introduction it is essential to investigate the presence of the parasitoids for the management of papaya mealybug pests. Therefore a survey was conducted to study the pest status of papaya mealybugs and to check the availability and the abundance of their introduced parasitoids is some randomly selected locations of the low country dry zone of Sri Lanka during the period from January 2018 to December 2019. The survey revealed that *P. marginatus* is still spreading in Sri Lanka but is present at lower population levels than in previous years, probably due to the action of introduced hymenopteran parasitoids. Among the three parasitoids the *A. papayae* and *P. mexicana* were found to be established on the papaya plants infested with papaya mealybug. The parasitoid with the greatest impact on the mealybug is generally *Acerophagus papayae* , whereas *A. loeki* was failed to establish. The finding would be very essential to tackle if there are any future threats caused by *P.marginatus.*

Keywords: Papaya mealybug; parasitization; *Acerophagus papayae*; Sri Lanka.

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1. Introduction

The papaya mealybug, originated from Mexico[1] and spread to the Caribbean Islands in 1994, South America in 1999, the Pacific Islands in 2002, and Southeast Asia in 2009 [2,3]. This polyphagous mealybug is known to attack plants belonging to 20 families, including numerous crops. The papaya mealybug *Paracoccus marginatus* is likely to invade several countries in the World. Several methods like cultural, chemical, legal and biological have been adopted to tackle the mealybug problem. However only chemical and biological control methods have been widely practices for the management of mealybugs. Only the host specific parasitoids have given control of *P. marginatus*. More specifically the hymenopteran parasitoid *Acerophagus papayae* played a predominant role in suppressing the papaya mealybug in several countries [4]. Several countries in the Caribbean, South America, and the Pacific region have successfully implemented classical biological control to suppress populations of *P. marginatus* by introducing the endoparasitoids *Acerophagus papayae* Noyes & Schauff, *Anagyrus loeki* Noyes, and *Pseudleptomastix mexicana* Noyes & Schauff (Hymenoptera: Encyrtidae) from the USDA APHIS parasitoid-rearing laboratory in Puerto Rico [5,6]. In Asia, Sri Lanka was the first country to import these parasitoids and to release them in May 2009; this brought about complete control of papaya mealybug by August 2009 [7]. Following the introduction there was very limited information available regarding the establishment of the parasitoids. Therefore the present survey aims to investigate the efficiency of establishment of these introduced biocontrol agents in papaya growing areas of Sri Lanka.

2. Materials and methodology

As a part of the survey which was conducted in the Low country dry zone of Sri Lanka, samples of infested papaya fruits and leaves were collected to observe pest infestation on papaya other plants and natural enemies from January 2018 to December 2020. Also samples were collected from managed commercial orchards, home gardens and wild systems during the periods of 6 months from March 2019 to August 2019 (peak season of mealybugs in the dry zone). Sample collections were conducted at 6 districts of low country dry zone (Batticaloa, Trincomalee, Polonnaruwa, Vavuniya, Kilinocchi and Jaffna). At each district 25 randomly selected papaya trees from homegardens and selected orchards were selected for sampling. The following table 1 shows the details of sampling locations.

Table 1: Locations of the survey conducted in the low country dry zone to study on *P.marginatus* and the introduced parasitoids.

Location code	Sampling Location	Location code	Sampling Location
HGD1	Trincomalee	OD1	Muthur, Trincomalaee
HGD2	Batticaloa	OD2	Puthukudiyirup pu, Batticaloa
HGD3	Polonnaruwa	OD3	Aralaganvila, Polonnaruwa
HGD4	Vavuniya	OD4	Nellukulam, Vavuniya
HGD5	Jaffna	OD5	Kopay, Jaffna
HGD6	Kilinocchi	OD6	Vattakachi, Kilinocchi

2.1 Assessment of parasitism of the introduced parasitoids in the field

A total of 10 severely infested papaya leaves were collected from the locations where *P. marginatus* were surveyed and taken to laboratory to investigate natural enemies of the pest. Adult mealybugs and Mummies were counted in a 25 cm^2 leaf area and the collected mummies were separately placed in eppendorf tubes covered with muslin cloth until the emergence of all parasitoids and the emerged parasitoids were counted. *P. marginatus* mummies were collected and observed for diversity of parasitoids. The specimens of natural enemies (predators and parasitoids) collected were identified with the help of available literature [8, 9]

Infestation percentage of *P.marginatus* in the papaya plants was calculated using the equation below.

$$\text{Infestation \%} = \frac{\text{Number of plants with infestation}}{\text{Total number of plants observed}} * 100$$

Parasitization percentage of parasitoids was calculated using the equation below.

$$\text{Parasitization \%} = \frac{\text{Number of parasitized cocoon}}{\text{Total number of mealybugs}} * 100$$

Infestation by mealybugs was expressed as the total number of mealybugs of all developmental stages per number of plant part sampled for each locality. All data were expressed as mean ± SE of the number of experiments. All computations were performed using the statistical software Minitab17.0.

3. Results and discussion

Papaya mealybug is a highly invasive pest and is attaining the status of regular insect pest of papaya in South and South-East Asia. It attacks several genera of host plants, including economically important tropical fruits and ornamentals. Generally papaya yields throughout the year. However, month following warm temperature or moisture stress causes skip in production. Papaya is cultivated in Sri Lanka primarily as a home garden crop. However, there is limited extent under commercial scale and this extent is steadily increasing but there is no significant increase in production [10] Keeping in view on the importance of the papaya crops, the damage caused by mealybug and the establishment of these introduced parasitoids *Acerophagus papayae, Anagyrus loeki* and *Pseudleptomastix Mexicana*, the present survey was conducted in six districts of Sri Lanka to observe pest infestation on papaya and other host plants and the natural enemies from January 2018 to December 2019. The results revealed that establishment of parasitoids that are introduced against the mealybug *Paracoccus marginatus* were successful in the Dry zone of Sri Lanka. The parasitoids were released only in the Western and North Central parts of the country and not released at the North, East and South Eastern parts of Sri Lanka, but the parasitoids *A.papayae* and *P.mexicana* are now has established all over the country. The third parasitoid *A.loeki* was not successfully established as there were no *A.leoki* samples collected during the survey. Figure 1 shows the relative abundance of the three introduced parasitoids of papaya mealybug in sic districts of the low country dry zone of Sri Lanka.

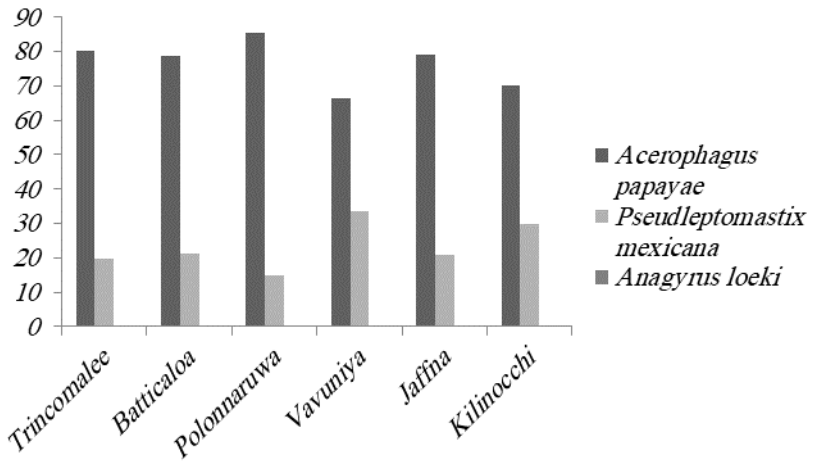

Figure 1: Relative abundance of the parasitoids in the sampling locations

In the papaya orchards where no pesticides applied were having significantly a low level of pest population due to the parasitization with the mean percentage of 20.2, whereas the parasitization percentage on papaya plants from home gardens was of 73.57. In the orchards plants are regularly maintained, therefore the plants receive necessary requirements for growth as well as free of pest attack by mechanical control methods. In the farm managed systems mealybug infestation were observed mostly on leaves rather than fruits, where the fruits are not allowed to get infect by applying forced shower of water. The trees were managed time to time by removing infected leaves and debris from the orchard. In the home gardens the higher infestation is due to the availability of wide range of alternative hosts.

Table 2: Percent infestation of *P.marginatus* and percent parasitization of *A.papaya*e on commercial orchards

Location code	Sampling Location	Infestation % of *P.marginatus*	Parasitization % of parasitoids	Relative % of Emerged *A.papayae*	Relative % of emerged *P.mexicana*
OD1	Trincomalee	12.54	52.75	75.78	24.22
OD2	Batticaloa	20.69	46.02	70.20	29.80
OD3	Polonnaruwa	19.67	35.41	85.50	14.50
OD4	Vavuniya	28.00	54.55	80.75	19.25
OD5	Jaffna	34.64	67.66	86.22	13.78
OD6	Kilinocchi	12.26	18.27	88.80	11.20

*mean percentage of 15 plants per location

Table 2: Percent infestation of *P.marginatus* and percent parasitization of *A.papaya*e in home gardens

Location code	Sampling location	*Infestation % of *P.marginatus*	*Parasitization % of parasitoids	*Relative % Emergence of *A.papayae*	*Relative % Emergence of *P.mexicana*
HGD1	Trincomalee	69.69	55.22	80.40	19.6
HGD2	Batticaloa	83.00	58.12	92.30	7.7
HGD3	Polonnaruwa	79.67	42.49	75.80	24.2
HGD4	Vavuniya	88.00	65.4	90.15	9.85
HGD5	Jaffna	62.26	21.92	78.10	21.9
HGD6	Kilinocchi	70.78	33.86	85.40	14.6

*mean percentage of 15 plants per location

The results show that there is no significant difference in percentage parasitism between the orchards and home gardens. Therefore it is evident that the activity of introduced parasitoids on the papaya mealybugs on both orchards and homegardens is not affected by the farm management measures. Among the parasitoids relative percentage of emergence of the parasitoid *A.papayae* was higher than that of *P.mexicana* in both. Among the parasitoids released, the highest emergence and field activity was observed *for A. papayae* in both orchards and home gardens of the six districts surveyed (Table 2 and 3) accounting for an average of 75.80– 92.30% of the parasitization followed by *P. mexicana* (7.7-24.2%), whereas *A. loeki* registered comparatively very poor performance and it was not recovered from the field 4 years after release in the dry zone areas of Sri Lanka. The observation on *A. papayae* was similar to the findings of [11] and [12], who reported highest acclimatization and predominant activity of this parasitoid in Republic of Palau and Florida, whereas they recorded low recovery of *A. loeki* and non-establishment of *P. mexicana* under field condition. Sympatric parasitoid species that share the single host species may become the competitors to each other and their competitive abilities, among other factors, may determine their relative abundance [13]. When two species compete intensely enough over limited resources, then with time, one or the other can become extinct. The interspecific competition of these three parasitoids showed that *A. papayae* and *P. mexicana* prefer second instar papaya mealybug while *A. loecki* prefers third instars. *P. mexicana* exhibited a longer life cycle than the other two species (Amarasekare, 2010). However, superior competitive ability of *A. papayae* was recorded over *P. mexicana* and *A. loeki* in early instar, especially second instar mealybugs [14]. This might have limited the availability of un-parasitized later instar mealybugs which are preferred by *A. loecki*, to develop its progeny under field condition and which could lead to its extinction. At the same time, the longer development time of *P. mexicana* ultimately reduces its competitiveness to share second instar nymphs and it could be an important reason for its reduced effectiveness in the field compared to *A. papayae*. Therefore, when there is a dominant parasitoid species which can displace other species, the releasing of several species might not provide the expected efficiency of a biological control program. However, field diversity of *A. papayae* need to be conserved by avoiding application of insecticides with high toxicity and prolonged persistency to control other major pests of papaya.

4. Conclusion

According to the results of the survey conducted in six districts of Sri Lanka to observe pest infestation on papaya and other host plants and the establishment of introduced natural enemies revealed that establishment of *Acerophagus papayae* and *Pseudleptomastix mexicana* against the mealybug *Paracoccus marginatus* was successful in the Dry zone of Sri Lanka. However, field diversity of these parasitoids need to be conserved by avoiding application of insecticides with high toxicity and prolonged persistency to control other major pests of papaya.

5. Recommendations

The present survey explored the existence of the parasitoids that are introduced before a decade and found two species out of three are successfully established. Further researches are required for the conservation and management of those parasitoids in the agro ecosystems. Improper pesticide use and poor management practices may harm the natural enemies and also may reduce their field efficiency. Molecular studies are essential to investigate the genetic changes with time and for the conservation of the species. Farmers should be given with proper awareness to preserve the biocontrol agents *Acerophagus papayae* and *Pseudleptomastix mexicana.* Mass production technologies must be developed locally by adopting the local environmental conditions.

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