

Occurrence, distribution and control of papaya mealybug, *Paracoccus marginatus* (Hemiptera: Pseudococcidae), an invasive alien pest in Sri Lanka

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ABSTRACT

A hitherto unrecorded species of mealybug was discovered in early 2008 in the western provincial districts Colombo and Gampaha in Sri Lanka, infesting a large number of plant species. Investigations were done to identify the pest and to study its host range, nature of damage and distribution, and to design and implement control measures. The pest was identified as papaya mealybug, *Paracoccus marginatus* Williams & Granara de Willink (Hemiptera: Pseudococcidae), an invasive alien species originating from Mexico and/or Central America. The mealybug found to heavily infest more than 40 plant species including papaw, the major host, and several horticultural and floricultural crops like *Plumeria*, manioc, bread fruit, *Alstonia macrophylla* and *Jatropha* spp. By 2009 the pest had spread to other parts of the country including the North Western, Sabaragamuwa, Southern, North Central, Central and Eastern provinces. As an immediate control measure, imidacloprid 200SL, thiamethoxam 25%WG and Mineral oil were recommended for the control of this pest until biological control agents could be introduced.

Keywords: Papaya Mealybug, *Paracoccus marginatus*, Distribution, Host Range, Control

INTRODUCTION

A mealybug species was reported infesting a large number of plant species in Colombo and Gampaha districts in Sri Lanka for the first time in July 2008 by Extension Officers of the Department of Agriculture. The pest was observed to spread rapidly and occurred in large colonies on all aerial plant parts, including leaves and fruits, destroying many plants including papaw and *Plumeria* (temple trees). This mealybug species, which had not been recorded from Sri Lanka before, posed a great threat to commercial papaw plantations in Sri Lanka spanning approximately 6,200ha. The plantations produce 25,000t of fruit per annum (Anon 2009). The area affected by this invasive pest includes several of the districts where the greatest quantities of papaw are grown.

The Horticultural Crops Research and Development Institute and the Plant Protection Service of the Department of Agriculture, in collaboration with the Provincial Departments of Agriculture, initiated a comprehensive program to control the pest and prevent it from spreading to other areas. For present study, the study area was confined to Colombo, Gampaha, Matale, Kandy, Kurunegala and Kegalle districts. This paper summarizes the information collected on the identity, host plants, distribution and damage caused by the mealybug,

and the control measures adopted against it in Sri Lanka.

MATERIALS AND METHODS

Sampling

The infested area was visited in August 2008, immediately after the problem was reported. Mealybugs were collected from 12 locations in four districts for identification. The insects, collected on infested plant material, were brought to the laboratory, and were transferred on infested plant fragments to glass vials. Three quarters of the vial was then filled with 95% ethanol, labeled, sealed and immersed in a water bath 100°C for 20minutes.

Identification

Preserved and live mealybugs were studied under a binocular microscope to observe morphological and taxonomic characters for identification. The pest species was initially determined by comparison with the descriptions given by Miller and Miller (2002).

Preserved samples (each containing approximately 100 specimens including all developmental stages) were collected from three different host plant species (papaw -*Carica papaya* L, manioc -*Manihot esculenta* Crantz and plumeria -*Plumeria acuminata* WT Aiton) and from three different locations in

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Gampaha and Colombo districts (Kosgoda, Pugoda and Warakapola). The samples were sent to the Plant Pest Diagnostic Centre, California Department of Food and Agriculture, Sacramento, California, USA (CDFA-PPDC) for authoritative confirmation of the pest's identity. Adult female specimens from these samples were prepared in archival microscope slide mounts (stained with Acid Fuchsin and mounted in Canada balsam) using the method given by Watson and Chandler (2000). Authoritative identification was made using the keys and description in Williams and Granara de Willink (1992).

Host range and distribution

The host range and distribution of papaya mealybug were determined through field observations and systematic sampling of infested plants in five districts.

Damage assessment

Damage caused to papaw by the pest was assessed in 12 farmer fields in Gampaha district. The number of infested and healthy plants was recorded over a period of two months at bi-weekly intervals, beginning in September, 2008. The level of damage was rated using the scale given below (Table 1).

Control measures

A number of insecticides were available to control mealybugs, although none were registered specifically for control of papaya mealybug. Since the mealybug-infested area was highly urbanized, insecticides belonging to WHO toxicity Class III and IV were selected for testing in commercially cultivated crops. Five insecticides: namely, imidacloprid 200 g/l SL, thiamethoxam 25%WG, acetamiprid 20%SP and Sparrow oil in comparison with carbosulphan 200 g/l SC as the treated control, were tested on commercial plantings of manioc and papaw in farmer fields at three different locations (Balummahara, Dompe and Lenadora). The sampling method and insecticide application technique were determined depending on the crop, infested plant part and the level of infestation (Galanihe 2010). In addition, Integrated Management techniques were recommended to the general public.

Table 1: Damage scoring system used to measure the level of papaya mealybug damage to papaw

Damage score	Severity of damage
0	Undamaged
1	1- 25% of leaves/fruits damaged
3	25-50% of leaves/fruits damaged
5	50-75% of leaves/fruits damaged
7	75-100% of leaves/fruits damaged
9	100% of leaves/fruits damaged, plant dead

RESULTS AND DISCUSSION

The damage symptoms, rapid post-mortem colour change and diagnostic morphological characteristics described below initially determined the invasive pest as the papaya mealybug, *P. marginatus*.

Authoritative identification

The specimens sent to CDFA-PPDC were identified and confirmed as *Paracoccus marginatus* Williams and Granara de Willink, the papaya mealybug.

Morphological and taxonomic characteristics of papaya mealybug

Adult female

In life, the body was soft, oval, about 2.2mm long and 1.4mm wide, and was covered with mealy white wax; the body contents were yellow in life. The surface wax on the dorsum showed transverse creases between the body segments and the margin had a series of 16 or 17 very short, waxy filaments spaced evenly along each side. The mature female secreted an ovisac of white wax filaments from the ventral margins of the abdomen (Plate 1) which eventually extended three to four times the body length and entirely covered the female. These features matched the morphological characteristics described for papaya mealybug by Walker, Hoy and Meyerdirk 2003 and Heu *et al.* 2007.

When specimens of papaya mealybug were killed in 100% ethanol and not heated subsequently, the specimens turned bluish black within 24 hours as described by Heu *et al.* 2007. Members of the mealybug genus *Paracoccus* (and several other genera) are known to do this, although most of



Plate 1. Adult females of Papaya mealybug with the ovisac (Photograph: L.D.Galanihe)

them take several days to weeks to turn black at room temperature. The blackening process happened unusually quickly in *P. marginatus*. Black body contents were extremely difficult to remove for slide-making and identification purposes, so samples for authoritative identification were heated to denature the enzymes that cause body blackening after death.

Diagnostic characteristics of the slide-mounted adult female: members of the genus *Paracoccus* possess up to 18 pairs of cerarii on body margins, eight-segmented antennae, ventral anal lobe bars, translucent pores on the hind coxa and usually on the tibia; auxiliary setae are present in the anal lobe cerarii only, and oral rim ducts are present somewhere on the body. *P. marginatus* differs from other members of the genus as follows: dorsal surface with short, slender setae; cerarii numbering 16 or 17 pairs only; oral rim tubular ducts restricted to marginal areas of dorsum and venter; hind leg with translucent pores present on coxa only (Williams and Granara de Willink 1992; Miller and Miller 2002). The eight-segmented antenna distinguishes this species from the pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green), which has a nine-segmented antenna (Miller and Miller 2002).

Adult male

P. marginatus is a sexual species. The adult male appeared yellow and was approximately 1.0mm long, with an elongate oval body widest at the thorax (about 0.3mm). The antennae were 10-segmented; the thorax and head were heavily sclerotized, and the wings were well developed; the genital capsule was distinctly sclerotized, and a pair of lateral pore clusters occurred near the apex of the abdomen. The lateral pore clusters secreted a pair of white wax caudal filaments in life.

Host range

Papaya mealybug infested more than 40 host-plant species in Sri Lanka, compared to over 55 plant species recorded elsewhere (Walker *et al.* 2003). The main host is papaw (Williams and Granara de Willink 1992). In Sri Lanka, it damaged mainly papaw and *Plumeria*, but jackfruit, breadfruit, *Jatropha* spp and *Alstonia* trees were heavily infested also. The host-plants recorded so far in Sri Lanka are listed in Table 2.

Distribution

Papaya mealybug was first reported in Sri Lanka in early 2008. The first specimens were obtained from Colombo in July, 2008. By the end of August, the mealybug had spread to parts of Colombo and

Table 2: List of host plants of papaya mealybug in Sri Lanka

No.	Common name	Botanical name	Host status
1	Papaw	<i>Carica papaya</i> L.	Favoured
2	Manioc	<i>Manihot esculenta</i> Crantz	Favoured
3	Plumeria (Araliya)	<i>Plumeria acuminata</i> W.T. Aiton	Favoured
4	Weta endaru	<i>Jatropha curcas</i> L.	Favoured
5	Hibiscus	<i>Hibiscus rosa-sinensis</i> L.	Secondary
6	Jack	<i>Artocarpus integrifolia</i> L. f.	Secondary
7	Breadfruit	<i>Artocarpus altilis</i> (Parkinson) Fosberg	Secondary
8	Hawari nuga	<i>Alstonia macrophylla</i> Wall. ex G. Don	Secondary
9	Guava	<i>Psidium guajava</i> L.	Secondary
10	Citrus	<i>Citrus</i> spp.	Secondary
11	Tomato	<i>Lycopersicon esculentum</i> Mill.	Secondary
12	Brijnjal	<i>Solanum melongena</i> L.	Secondary
13	Chili	<i>Capsicum annuum</i> L.	Secondary
14	Beans	<i>Phaseolus vulgaris</i> L.	Secondary
15	Okra	<i>Hibiscus esculentus</i> L.	Secondary
16	Curry leaves	<i>Murraya koenigii</i> L.	Secondary
17	Marigold	<i>Tagetes erecta</i> L.	Secondary
18	Jasmine	<i>Jasminum</i> spp.	Secondary
19	Euphobia	<i>Euphobia</i> spp.	Secondary
20	katuru murunga	<i>Sesbania grandiflora</i> (L.) Pers.	Secondary
21	Rambutan	<i>Nephelium lappaceum</i> L.	Secondary
22	Mango	<i>Mangifera indica</i> L.	Secondary
23	Ambarella	<i>Spondias pinnata</i> (L. f.) Kurz	Secondary
24	Banana	<i>Musa sapientum</i> L.	Secondary
25	Pomegranate	<i>Punica granatum</i> L.	Secondary
26	Wild jatrophia	<i>Jatropha</i> spp.	Secondary
27	Gliricidia	<i>Gliricidia sepium</i> (Jacq.) Kunth ex Walp.	Secondary
28	Boo Daeliya	<i>Ficus</i> sp.	Secondary
29	Thembu	<i>Costus speciosus</i> (J. König) Sm.	Secondary
30	Rubber	<i>Hevea brasiliensis</i> (Willd. ex A. Juss.) Müll. Arg.	Secondary
31	Coconut	<i>Cocos nucifera</i> L.	Secondary
32	Kan kun	<i>Ipomoea aquatica</i> Forssk.	Secondary
33	Rathmal	<i>Ixora</i> spp.	Secondary
34	Mussenda	<i>Musseanda frondosa</i> L.	Secondary
35	Mugunuwenna	<i>Alternanthera sessilis</i> (L.) R. Br. ex DC.	Secondary
36	Gotukola	<i>Centella asiatica</i> (L.) Urb.	Secondary
37	Me	<i>Vigna sesquipedalis</i> (L.) Fruwirth	Secondary
38	Anona	<i>Annona squamosa</i> L.	Secondary
39	Sooriya kaantha / Sunflower	<i>Helianthus annuus</i> L.	Secondary
40	Ornamental plants	Many species	Secondary

Gampaha districts in the Western Province. It was reported from Sabaragamuwa and Southern provinces towards the end of 2008 and from Polonnaruwa district (North Central Province) in February 2009. In April 2009, the pest was observed in Matale, Dambulla and Kandy districts (Central Province) and in the Eastern province, indicating its ability to spread very rapidly.

The papaya mealybug is believed to be native to Mexico and/or Central America. It has never been a



Plate2. Cotton-like masses on leaf stalk
(Photograph: MUP Jayasundera)



Plate3. Damage symptoms on Papaw tree
(Photograph: MUP Jayasundera)

serious pest there, probably due to the presence of an endemic natural enemy complex (Walker *et al.* 2003). After invading the Caribbean Islands in 1995, it spread to 24 countries including Sri Lanka within a period of 14 years (Walker *et al.* 2003; Meyerdirk *et al.* 2004; Hue *et al.* 2007; Rich 2008).

Damage symptoms

On lightly infested plants, papaya mealybugs looked like small pieces of cotton attached to the plant. On papaw trees this symptom was more prominent, as the insects were attached to the fruits and looked like the oozing of milky sap. On heavily infested plants, the mealybug colonies formed cotton-like masses on the aerial parts (Plate 2). These plants showed symptoms of chlorosis, leaf defor-



Plate4. Heavily damaged papaw trees
(Photograph: LD Galanihe)

mation, and early drop of leaves and fruits; the growth of young plants was stunted. Honeydew excreted by the mealybugs resulted in heavy sooty mould growth, especially on papaw (Plate 3) and *Plumeria*. The sooty mould turned the leaves completely black, blocking out light and air, so interfering with photosynthesis. Heavily attacked plants, mainly papaw, were killed (Plate 4). New flushes of growth on damaged plants were deformed, especially in *Plumeria*, probably due to toxicity of the saliva injected into the plant by the mealybugs while feeding. These damage symptoms resembled those caused by papaya mealybug described by Walker *et al.* (2003) and Hue *et al.* (2007).

Damage assessment

The damage assessment conducted in 12 farmer fields in Gampaha district revealed that by mid-September 2008, an average of 85.9% (range 60-100%) of the papaw plants in the area were infested with papaya mealybug. Of the infested plants that were left untreated with the recommended insecticides, 94.8% were died, Of the infested plants that were treated, 27.0% died while the survivors

Table 3: The effect of pesticide treatments to control papaya mealybug on papaw plants.

Damage Severity of damage score		% of insecticide-treated plants
0	Undamaged	61.0
1	1- 25% of leaves/fruits damaged	8.0
3	25-50% of leaves/fruits damaged	4.0
5	50-75% of leaves/fruits damaged	0
7	75-100% of the leaves/fruits damaged	0
9	100% of leaves/fruits damaged, plant dead	27.0

showed varying degrees of control (Table 3). According to the Extension Division of the Department of Agriculture, by March 2009, 90% of the papaw plants in Gampaha district were damaged.

Chemical control

The three most effective insecticides identified in the experiments were recommended for use as foliar sprays against the papaya mealybugs on cultivated crops: thiamethoxam 25%WG at the rate of 1g per liter; imidacloprid 200g/l SL at the rate of 1ml per liter; and Mineral oil (Sparrow oil) at the rate of 5ml per liter (Galanihe 2010). For larger trees, soil application of thiamethoxam 25%WG at the rate of 1g/l was recommended.

Physical control

During the rainy season (October to January 2008), papaya mealybug populations decreased drastically because heavy rain washed the insects off the plants. However, mealybugs sheltered within unopened leaves and other hiding places survived and built up their numbers again during the warm, dry weather (January to March 2009). This observation suggested that, by directing a powerful jet of water at infested plant parts, the pest could be controlled to some extent. The mealybugs spread by being carried by the wind, on birds and animals, and by infested plant parts/ planting material being transported by man. Therefore, good crop sanitation could stop the insects spreading. Mealybug colonies were attended by many ant species, which visited infested plants to feed on the honeydew excreted by the mealybugs. Ants were seen carrying mealybugs also, thus helping the mealybugs to disperse. Burning heavily infested plant parts helped to reduce the mealybug population. These observations led to formulate the following Integrated Pest Management practices, which were recommended to the general public for control of papaya mealybug:

1. Destruction of all heavily infested plant parts on the spot
2. Avoiding transportation of infested plant material
3. Avoiding pruned, infested plant parts being left unattended or being placed in garbage bins or vehicles
4. Washing the insects off the plants with a powerful water jet
5. Spraying plants near houses and in home gardens with a soap + kerosene oil + water mixture
6. Use of recommended insecticides to treat commercially important crops
7. Use of botanical pesticides to treat agricultural crops in home gardens
8. Wrapping polythene/spongy tapes impregnated with insecticides around tree trunks to exclude ants from the canopy

Biological control

Generalist predators such as larvae of ladybird beetles (Coleoptera: Coccinellidae) and green lacewings (Neuroptera: Chloropidae) were found to have a low impact on papaya mealybug populations. The same predator groups including the commercially available mealybug destroyer, *Cryptolaemus montrouzieri* Mulsant (Coleoptera: Coccinellidae) have been reported from USA (Walker *et al.* 2003). In addition to predators, five efficient parasitoids (Hymenoptera: Encyrtidae) specific to papaya mealybug were identified by the United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) and USDA Agricultural Research Service (ARS) in 1999: *Acerophagus papayae* Noyes and Schauff, *Anagyrus loecki* Noyes, *Anagyrus californicus* (Compere), *Pseudaphycus* sp. And *Pseudleptomastix mexicana* Noyes & Schauff (Walker *et al.* 2003; Meyerdirk *et al.* 2004).

The five parasitoid species have been efficient at controlling papaya mealybug in all the countries where they have been released. USDA-APHIS found that the five parasitoid species brought about a 99.7% reduction in papaya mealybug populations in the Dominican Republic, and a 97% reduction in Puerto Rico, with parasitism levels of 35.5-58.3% (Kauffman *et al.* 2001; Meyerdirk and Kauffman 2001). All five parasitoids have been observed attacking second- and third-instar *P. marginatus*. However, *Acerophagus* sp. emerged as the dominant parasitoid species in both Puerto Rico and the Dominican Republic (Meyerdirk and Kauffman 2001). Biological control was therefore identified as the key component in a management strategy for the papaya mealybug in Sri Lanka. A classical biological control program has been initiated by the Sri Lankan Department of Agriculture, using parasitoids received from the USDA-APHIS parasitoid-rearing facility at the Puerto Rico Department of Agriculture.

CONCLUSIONS

The invasive mealybug found infesting a large number of crops in Colombo and Gampaha districts in 2008 was identified as the papaya mealybug, *P. marginatus*. The mealybug attacked more than 40 host plants in Sri Lanka, but papaw and *Plumeria* were its most favoured hosts. By 2009, the pest had spread from the Western province to North Western, Sabaragamuwa, Southern, North Central, Central and Eastern provinces. Three insecticides, imidocloprid 200SL, thiamethoxam 25%WG and Sparrow oil were found to provide effective chemical control, and were recommended along with an IPM practices for the control of this pest until biological control agents were introduced.

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