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Havoc of Papaya Mealybug (*Paracoccus marginatus*) and Its Management Strategies

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Abstract

The papaya mealybug (Paracoccus marginatus) is a serious problem that affects mulberries, citrus, and papaya among other agricultural and horticultural crops. Originating in Central America, it has spread around the world and caused extensive harm because of its capacity to consume plant sap, which results in reduced crop yields, fruit drop, and chlorosis. In addition, the insect releases honeydew, which encourages the development of sooty mold, further impeding photosynthesis and lowering the quality of fruit. Reducing its economic impact requires the use of effective management measures. The successful application of Integrated Pest Management (IPM) techniques combines cultural customs, the prudent use of chemical pesticides, and biological control agents like parasitoids (like Acerophagus papayae). Biological management has shown a lot of promise for long-term pest population suppression, reducing crop residue from chemicals, and fostering environmental sustainability. Creating control plans tailored to a given location requires a thorough understanding of the biology, ecology, and spread of the pest. Environmentally friendly techniques and biological agents are the focus of natural control strategies. Because parasitoid wasps lay their eggs within mealybugs and subsequently kill them, using wasps like Acerophagus papayae, Anagyrus loecki, and Pseudleptomastix mexicana is a highly successful method. Mealybug populations are also decreased by entomopathogenic fungi like Beauveria bassiana and Lecanicillium lecanii, as well as predatory beetles like Cryptolaemus montrouzieri, also known as the "mealybug destroyer". Insecticides that are botanical, like pyrethrum and neem oil, provide a natural substitute by stopping insects from feeding and reproducing, and cultural methods like keeping fields clean, managing ants, and examining plants can stop pests from spreading. To help with pest control, physical techniques like high-pressure water sprays can be used to remove mealybugs from plants. These strategies have proved to be beneficial in terms of management for papaya mealybug and has better opportunities in the coming future.

Keywords: Agriculture, integrated pest management, horticulture, mealybug, *Paracoccus marginatus*

INTRODUCTION

Because of their small size, high rate of reproduction, and remarkable adaptability, insects make up most invasive organisms. According to some estimates, insects made up over 70% of the invasive species that were brought to China over the previous 20 years, resulting in yearly losses of more than 50 billion Yuan. A little, oval-shaped, sap-sucking papaya mealybug (*Paracoccus marginatus*) is distinguished by its soft body and waxy, white powder covering, which shields it from predators and desiccation. These insects, which typically have a length of less than 3 mm, are frequently found in dense colonies on a variety of plant parts, such as stems, leaves, flowers, and fruits. Due to international trade and the migration of infected plants, the papaya mealybug, which is native to Central America, has shown incredible adaptability by spreading to tropical and subtropical regions throughout Asia, Africa, the Caribbean, and the Pacific.

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This pest is known for its prolific reproduction. Females can lay hundreds of eggs in a waxy, protective sac. The eggs hatch into nymphs, which are highly mobile and actively disperse to colonize new areas. This high reproductive potential combined with their ability to infest over 60 host plant species – including papaya, citrus, cotton, hibiscus, and ornamental plants – makes them a significant agricultural and ecological problem.

Papaya mealybugs cause direct damage by piercing plant tissues to feed on sap, leading to symptoms, such as yellowing, curling, wilting, reduced fruit quality, stunted growth, and, in severe infestations, plant death. Indirectly, their excretion of sugary honeydew promotes the growth of sooty mold, further hampers photosynthesis, and reduces plant vigor. Their rapid population growth and ability to thrive in diverse environments make them one of the most abundant and challenging pests in regions where they are established. The infestation of Papaya mealybug can also cause long-term secondary impacts as they transmit viral diseases between host plants [1].

This pest's rapid growth and capacity for prolific reproduction have contributed to its success. Thankfully, the introduction of biocontrol, such as *Acerophagus papayae* and *Anagyrus loecki*, has prevented the spread in many locations. However, if appropriate phytosanitary or control measures are not taken, *Paracoccus marginatus* may quickly spread to new locations and achieve large populations. Therefore, knowledge of this pest's possible range is crucial because it can identify critical locations vulnerable to invasion, providing decision-makers with an early warning to implement phytosanitary measures to stop or slow the pest's entry into their territory.

The pest's abundance is compounded by its resistance to natural predators in newly invaded areas, allowing populations to grow unchecked without intervention. This necessitates the implementation of integrated pest management strategies, including biological control agents like parasitic wasps (*Acerophagus papayae*), chemical treatments, and cultural practices, like removing infested plant material. The papaya mealybug's characteristics, adaptability, and ability to spread rapidly underscore its potential to cause significant agricultural losses and the need for vigilant monitoring and control measures.

Historical Significance

Originating in South and Central America, *Paracoccus marginatus* was initially identified there in 1992. It expanded to the Caribbean and neotropical areas of Belize, Costa Rica, and Guatemala in the 1990s. In 1998, the pest was also discovered on hibiscus in Bradenton, Florida, and it was found on over 25 different plant genera. More specific morphological traits were presented by Finch et al. (2021) [2] to differentiate Papaya Mealy Bugs from other significant mealybugs and closely related *Paracoccus* species. It was first documented in the Republic of Kenya [3] followed by Indonesia (Java) and India (Tamil Nadu) in 2008 [4]. Other Indian states (Kerala and Rajasthan) also experienced infestations.

Beginning in 2008, reports of PMB came from Asia, particularly Sri Lanka. Bangladesh and the Republic of the Maldives reported on it in 2009 and 2010, respectively. Additionally, it has been found in Thailand, the Philippines, and Cambodia. In 2009, the first reports of PMB on papaya, cassava, eggplant, jatropha, and hibiscus plants were made in Malaysia. Guangdong Province in southern China and Yunnan Province in southwestern China made the first observation in China in 2013. Israel's species on papaya, mulberry, hibiscus, Annona, and the invasive weed *Parthenium hysterophorus* L. were reported by Kumar et al. (2011) [4].

The species initially appeared in Africa in Ghana in 2010, and it later migrated to Gabon, Nigeria, Togo, and Benin. This damaging pest was recently reported from South Sudan's Jubek State. Uganda is the source of the most recent report on this pest in Africa. PMB was originally discovered on papaya and frangipani trees (*Plumeria spp*.) in Tahiti, French Polynesia, in 2017 [4].

Morphological Characters

The hemipteran insect *Paracoccus marginatus* is a member of the *Pseudococcidae* family as Mandal et al. (2014) [5] have described and illustrated the morphological characteristics of all stages of this pest. The adult females are oval, about 1.5 to 2.7 mm long, and have 17 pairs of cerarii, or oral-rim tubular ducts that are restricted to the dorsum's margin and sub-margin, with translucent pores only on the hind coxa. These unusually large and abundant ventral oral-rim tubular ducts are present on lateral areas of the thorax, while ventral multilocular pores are absent from lateral areas of the abdomen. Additionally, each anal lobe has a ventrally located anal bar, and the dorsal setae are typically as long as or shorter than the conical cerarian setae [6, 7]. Females are covered with a white waxy covering and have a yellow body. Females lack dorsal stripes, and the mealy waxes that are applied to their backs are insufficiently thick to cover up their body color. Around the margin are several short, waxy caudal filaments that are less than 25% of the body's length. The antennae of adult females have eight segments, whereas those of *Maconellicoccus hirsutus* (green), which is comparable to PMB [8], have nine segments.

Molecular Identification

The drawbacks of morphological identification are outweighed by molecular identification, which uses a genetic identifier in an organism's DNA to identify the person. Exposing evolutionary trends among many species also advances our understanding of the diversity and similarities of mealybugs [9]. A crucial tool for documenting mealybugs is DNA analysis. Several studies have used DNA markers to distinguish between closely related mealybug species for control purposes. To support species-specific management initiatives including biological control and the use of entomopathogenic agents, *Pseudococcidae* phylogenies have demonstrated the species' relatedness

Mealybug molecular identification can be accomplished with the COI and 28SD2 sections because they avoid the need for gene cloning and are quick, inexpensive, and compatible with inexpensive PCR enzymes. These two genomic regions using universal primers have been used in other *Pseudococcidae* species identification and genetic diversity studies. Identifying papaya mealybug can also be made easier with the use of these universal primers. Numerous investigations have effectively characterized many mealybug species using the COI gene. Compared to other genes, including the 28S gene sequence, the mt DNA COI sequences of *Planococcus ficus*, *P. minor*, and *P. citria* showed greater diversity. The sequenced DNA can also produce species-specific PCR, which allows for species identification using amplified sequences.

Damage

Paracoccus marginatus is a global, polyphagous pest. On the aerial sections of plants, infestations are usually seen as a collection of cotton-like masses, with all life stages (egg, various nymphs, and adults) present. Adult females tend to the ovisacs in which the eggs are placed on the shoots, midribs of young leaves, and fruits. Furthermore, extensive PMB infestations on plants have been observed in all regions of the tender leaves and fruits, as well as in the veins and midribs of older leaves. Mealybugs feed by sucking sap from plant tissue, such as the stem, fruit, and leaf epidermal, using their piercing-sucking mouthparts.

Severe infestations of this insect cause the entire plant to be destroyed in addition to reducing output. It was projected that 57% of Kenyan papaya trees suffered crop losses due to PMB infestation. Furthermore, if PMB populations are not controlled, they may proliferate and eventually kill the host plant by destroying its sap and, on occasion, by injecting poisons, spreading viruses, or releasing honeydew, which serves as an ideal environment for the development of sooty Molds. The plant is frequently so completely covered in mold that normal photosynthesis is significantly diminished [10].

Effective Management Technology

Biological Control

Utilizing natural organisms to manage pest species is known as biological control. Potential pest populations can be reduced in large part by natural enemies, such as parasites, parasitoids, predators, or

disease-causing organisms. Parasitoids are frequently quite effective and host-specific among the wide variety of natural enemies. Free-living parasitoids mostly consume nectar or pollen, while some are also capable of host-feeding.

The USDA Agricultural Research Service (ARS) and USDA Animal and Plant Health Inspection Service (APHIS) launched the traditional biological control program for the papaya mealybug within the United States of America. Five genera of encyrtid endoparasitoid wasps specific to papaya mealybugs were collected in Mexico to act as potential biological control agents. These included *Acerophagus papayae*, *Anagyrus loecki*, *Anagyrus californicus*, *Pseudaphycus sp.,* and *Pseudleptomastix mexicana* [11]. Another study showed that introducing *A. papayae, A. loecki, A. californicus, Pseudaphycus sp.*, and *Acerophagus sp*. led to parasitism rates of 35.5% to 58.3%. As a result, the mealybug population in the Dominican Republic and Puerto Rico nearly went extinct. Papaya mealybug biological management program in the United States of America. To serve as possible biological control agents, five genera of encyrtid endoparasitoid wasps that are unique to papaya mealybugs were gathered in Mexico. *Pseudaphycus sp*., *Anagyrus loecki*, *Anagyrus californicus*, *Acerophagus papayae*, and *Pseudleptomastix mexicana* were among them (Noyes and Schauff 2003). According to a different study, parasitism rates ranged from 35.5% to 58.3% when *A. papayae, A. loecki, A. californicus, Pseudaphycus sp.*, and *Acerophagus sp*. were introduced. The Dominican Republic and Puerto Rico's mealybug populations thus came dangerously close to extinction. Rostami et al. (2024) [12] found that the papaya mealybug in Malaysia had one main parasitoid (*A. papayae*) and two predators *(C. montrouzieri and Apertochrysa sp.).* According to their findings, *A. papayae* exhibits greater parasitism efficiency against adults and nymphs in their third instar. According to a study, the parasitoid *Acerophagus papaya* has great potential for use in integrated control programs against *P. marginatus*. It was found to be effective against adult females and PMB nymphs in their second instar. Bacillus subtilis, *Serratia marcescens*, and *Pseudomonas aeruginosa's* capacity to break down wax was found to have an impact on the longevity, fecundity, and offspring weight of the pink Hibiscus female mealybug (*Maconellicoccus hirsutus*) (as green) (*Pseudococcidae*: Hemiptera).

CONCLUSIONS

Papaya mealybugs are notorious polyphagus pests that have a huge range of host suitability. Various studies have been all over the world to study its biological parameters so that the management strategies can be implemented. Earlier the pest was considered to be of minor status but with the time, the pest has evolved with higher damage intensity and more host range. There are a number of management strategies for several insect pests but mealybugs are a bit tougher to control. Hence, more advanced research and technology is required to implement new methods of management. There is scope in future for developing new management practices for this pest. Molecular identification of the pest is a key role to produce better techniques as the pest is more host specific. Host plant resistance methods can also be a strategy in future. Biological control methods are already giving better results in many countries and can be a replacement for chemicals as it will always prove to be more environmental friendly.

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