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Invasive Pests of Mulberry in India: A Review

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ABSTRACT

Mulberry (*Morus alba* L.) is the primary food plant of the silkworm (*Bombyx mori* L.) and plays a crucial role in sericulture. India, being the second-largest silk producer, depends heavily on the quality and quantity of mulberry leaves for cocoon production. However, invasive pests such as spiralling whitefly (*Aleurodicus dispersus* Russell) and papaya mealybug (*Paracoccus marginatus* Williams and Granara de Willink) have emerged as serious threats to mulberry cultivation. These pests significantly reduce leaf yield and quality, thereby affecting silkworm growth and silk productivity. This paper reviews the biology, ecology, damage symptoms, and management strategies of these invasive pests in the mulberry ecosystem.

Keywords Mulberry, Pests, Mealy bug, Whitefly, Symptoms.

INTRODUCTION

India ranks as the second-largest producer of silk globally, contributing approximately 41,121 metric tonnes (MT) to the total world raw silk production during 2024–2025. The success of cocoon crop production is governed by multiple interrelated factors, including mulberry leaf quality (38.2%), climatic conditions (37.0%), rearing technology (9.3%), silkworm race (4.2%), silkworm egg quality (3.1%), and other factors (8.2%) (Miyashita 1986). Mulberry (Morus spp.) leaves serve as the exclusive feed for silkworms and are therefore fundamental to cocoon production. The nutritive composition of mulberry leaves is a critical determinant of silkworm growth and development, in addition to environmental conditions and technological interventions. The production of high-quality mulberry foliage is influenced by several factors, including varietal selection, agronomic practices, and biotic as well as abiotic components (Krishnaswami *et al.* 1970). However, despite the adoption of improved agronomic practices and rearing technologies, the quality of mulberry leaves is often compromised due to the incidence of diseases and pest infestations, which adversely affect both leaf

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Plate 1. Papaya mealybug.



Plate 2. Spiralling Whitefly.

yield and nutritional value.

Mulberry cultivation is highly susceptible to infestation by a wide range of pests, primarily due to factors such as intensive cultivation practices, monocropping, excessive application of chemical fertilizers, and the resultant luxuriant growth and succulence of leaves. Furthermore, the indiscriminate use of toxic chemicals often disrupts the natural enemy complex within the mulberry ecosystem, thereby aggravating pest incidence. Climatic variations, particularly erratic rainfall followed by prolonged dry and hot conditions, further stimulate pest resurgence, facilitate population buildup of minor pests, and may even lead to the emergence of new pest species from adjacent crops (Sakthivel *et al.* 2019).

Santhi and Kumar (2010) documented the taxonomic diversity of insect communities in the mulberry ecosystem, reporting that the majority belong to the order Hemiptera (60.86 %), followed by Hymenoptera (22.05 %) and Coleoptera (8.65 %), while the remaining species are distributed among Isoptera, Lepidoptera, Thysanoptera, Orthoptera, and Dictyoptera. Furthermore, Govindaiah *et al.* (2005) reported the relative incidence of major sucking pests on mulberry, with mealybugs accounting for 19.21 percent, followed by thrips (17.18%), whiteflies (12.62%), jassids (9.08%), and scale insects (8.24%).

Among the various pests infesting mulberry, the leaf webber (*Diaphania pulverulentalis*), mulberry thrips (*Pseudodendrothrips mori*), pink mealybug (*Maconellicoccus hirsutus*), papaya mealybug (*Paracoccus marginatus*), and spiralling whitefly (*Aleurodicus dispersus*) are considered major pests, causing severe damage and significant crop losses. Among these, the papaya mealybug (Plate 1) and spiralling whitefly (Plate 2) are recognized as invasive pests in the mulberry ecosystem. The successful establishment and rapid spread of these invasive pests can be attributed to their biological and ecological advantages, including high resilience, short life cycles, broad host range, strong dispersal ability, adaptability to diverse environmental conditions, high fecundity, and voracious feeding behavior. In addition, their association with mutualistic organisms further enhances their survival and population buildup, often leading to pest outbreaks in newly introduced regions.

Spiralling Whitefly (*Aleurodicus dispersus* Russell)

A. dispersus is native to the Caribbean Islands and

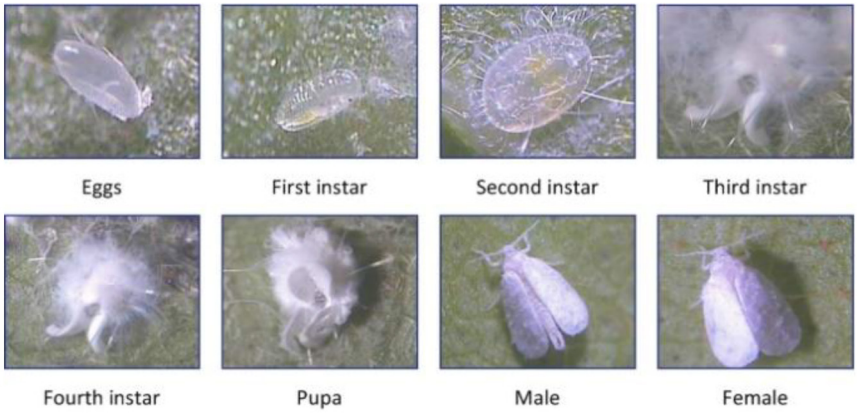


Plate 3. Life cycle of Whitefly.

Source: (https://link.springer.com)

Central America and has since spread to several parts of the world, including Guam, Brazil, Haiti, Papua New Guinea, Hawaii, Indonesia, Peru, the Philippines, Puerto Rico, Sri Lanka, Taiwan, and the United States. The pest was first recorded in Hawaii in 1987 on *Terminalia catappa,* a non-mulberry host plant (Martin 1987). In India, it was first reported during 1994 on wild tapioca and rubber plantations in Kerala and Tamil Nadu (Vasantharaj David and Regu 1995). Subsequently, Palaniswami *et al.* (1995) documented an outbreak on cassava in Kerala during the dry season of 1993–1994. The first incidence of *A. dispersus* on mulberry (*Morus alba* L.) was reported in May 1998 at the Karnataka State Sericulture Research and Development Institute (KSSRDI), Thalaghattapura campus (Bai *et al.* 2001).

A. dispersus is a highly polyphagous pest, known to infest approximately 500 plant species globally and about 280 species in India (Mani 2010). Rajadurai and Thiagarajan (2003) reported its occurrence on 38 genera belonging to 27 families, encompassing more than 100 plant species. In India, its preferred host plants include tuber crops such as *Manihot esculenta;* vegetables like *Capsicum annuum, Solanum melongena, Lycopersicon esculentum, Abelmoschus esculentus,* and *Cucurbita maxima;* oilseed crops such as *Arachis hypogaea* and *Ricinus communis;* fibre crops like *Gossypium* spp.; fruit crops including *Psidium guajava, Carica papaya, Musa* spp., and *Punica granatum;* ornamental plants such as *Rosa indica, Hibiscus* spp., *Acalypha indica, Poinsettia pulcherrima,* and *Michelia champaca;* and shade trees including *Ficus religiosa, Bauhinia purpurea, Cassia fistula, Thespesia populnea,* and *Manihot glaziovii* (Geetha 2000). The spiralling whitefly, *Aleurodicus dispersus* Russell, was earlier considered a minor pest of mulberry due to its sporadic occurrence and relatively low level of damage. However, in recent years, it has emerged as a major pest, causing extensive damage to mulberry plantations, particularly in South India.

Taxonomic Classification

Kingdom : Animalia
Phylum : Arthropoda
Class : Insecta
Order : Hemiptera
Suborder : Sternorrhyncha
Superfamily : Aleyrodoidea
Family : Aleyrodidae
Genus : *Aleurodicus*
Species : *dispersus*

Biology and Morphology of Spiralling Whitefly (*Aleurodicus dispersus* Russell)

Egg Stage

The female lays approximately 50–64 eggs (Plate 3), which are yellowish-white, smooth, and elliptical in

shape, measuring about 0.3 mm in length. The eggs are laid singly on the lower surface of leaves, typically at right angles to the leaf veins, and are associated with characteristic irregular spiralling deposits of white flocculent wax. Each egg possesses a short subterminal stalk (pedicel), which is inserted into the host plant tissue, often through the stomata, facilitating moisture absorption. The incubation period ranges from 4 to 7 days (Geetha 2000).

Nymphal Stages

The life cycle includes four distinct nymphal instars. The first instar nymph (crawler stage) is mobile, possessing functional legs and antennae, while subsequent instars are sessile.

First instar: The nymphs are translucent, yellowish-green, elliptical in shape with a convex dorsum, measuring approximately 0.35 ± 0.04 mm in length and 0.16 ± 0.02 mm in width. They are usually found aligned parallel to the leaf veins and possess sparse deposits of white powdery wax (Plate 3).

Second instar: These nymphs are oval and translucent, measuring about 0.51 ± 0.03 mm in length and 0.29 ± 0.01 mm in width. The body is covered with marginal waxy fringes, and a pair of mycetomes becomes distinctly visible at the center of the body (Plate 3).

Third instar: The nymphs are oval, measuring 0.64 ± 0.02 mm in length and 0.43 ± 0.02 mm in width. They are characterized by numerous evenly spaced, glassy wax rods along the body margin, produced from abdominal pores, along with increased wax secretion covering the body (Plate 3).

Fourth instar: The nymphs measure about 1.23 ± 0.04 mm in length and 0.79 ± 0.03 mm in width. The body is completely covered with dense white waxy material. The final larval stage (often referred to as the pupal stage) exhibits prominent glass-like wax rods along the lateral margins (Plate 3).

The duration of the four nymphal instars ranges from 2.15–6.50, 2.70–5.00, 2.90–5.96, and 6.50–8.10 days, respectively. The pupal stage lasts for about 2–3 days, with a pupal length of approximately 1 mm (Geetha 2000).

Adult Stage

The adults resemble tiny moths, with a body length of approximately 2 mm and a wingspan ranging from 3.5 to 4.0 mm. The wings are typically plain white, occasionally bearing pale or dark spots on the forewings, and are coated with a fine white powdery wax shortly after emergence. The eyes are dark reddish-brown (Plate 3).

Sexual dimorphism is evident, with males possessing a short, simple aedeagus and often elongated claspers. The average body length of males and females is 2.41 ± 0.08 mm and 1.89 ± 0.06 mm, respectively, while the corresponding body breadth



Plate 4. Spiralling whitefly affected mulberry plant.



Plate 5. Sooty mould development.

is 1.06 ± 0.03 mm in males and 1.20 ± 0.03 mm in females (Geetha 2000).

Wax Secretion and Protective Mechanism

Adult females secrete a characteristic silken wax composed predominantly of long-chain saturated hydrocarbons (66.21%) and aromatic esters (26%), along with small quantities of acids and phenols. This wax plays a crucial role in protecting the developing stages, particularly the crawler (first instar nymph), by providing a physical barrier against natural enemies and environmental stress. Additionally, the wax may aid in aggregation and settlement of crawlers on host plants (Ling 2010).

Ecology of *Aleurodicus disperses*

The population dynamics of *Aleurodicus dispersus* are largely influenced by climatic factors such as temperature, rainfall, and relative humidity. Heavy and intermittent rainfall along with low temperatures temporarily suppresses its population. The pest is present throughout the year in South India, with peak incidence during summer (March–June) and minimum during winter (October–January).

Population levels show a positive correlation with temperature and a negative correlation with relative humidity (Vijaya Kumari 2011). Infestation generally occurs from February to August, reaching a peak during prolonged dry spells followed by hot and humid conditions (Bandyopadhyay and Santhakumar 2001). Maximum incidence has been reported during April–June, while minimal infestation is observed during the rainy season (August–October), coinciding with *kharif* rains (Hemalatha and Shree 2008).

Damage, Symptoms and Economic Loss

Both nymphs and adults of *Aleurodicus dispersus* colonize the lower surface of mulberry leaves and feed by sucking sap from the phloem using their piercing-sucking mouthparts. Infestation results in leaf curling, chlorosis, drying, defoliation, and premature leaf fall (Plate 4). Severe infestations also promote the development of sooty mould (Plate 5) due to the accumulation of honeydew, ultimately reducing plant vigor (Bandyopadhyay and Santhakumar 2001).

The honeydew excreted by the insects facilitates the growth of sooty mould fungi such as *Capnodium* sp. and *Curvularia affinis,* forming a black velvety coating on the leaf surface. This coating reduces chlorophyll content and photosynthetic efficiency, leading to yellowing and premature leaf senescence (Rao *et al.* 1992). Additionally, honeydew attracts ants and other insects, which protect the whiteflies from natural enemies, thereby enhancing pest survival. The presence of sooty mould also increases leaf temperature and further deteriorates leaf quality (Byrne *et al.* 1990).

The economic threshold level for A. *dispersus* in mulberry is approximately 20 individuals per plant, beyond which control measures are recommended (Bandyopadhyay *et al.* 2002). Severe infestations (greater than 50% leaf area damage) can reduce mulberry leaf yield by up to 28.09%. Feeding such infested leaves to silkworms significantly affects cocoon production, resulting in up to 48.09% reduction in cocoon yield and 71.31% monetary loss (Quadri *et al.* 2010). Furthermore, key economic traits such as cocoon quality and effective rate of rearing (ERR) are adversely affected when silkworms are fed with infested leaves (Narayanaswamy and Ramegowda 1999).

Population Dynamics in Different Mulberry Genotypes

The population level of spiralling whitefly (*Aleurodicus dispersus*) recorded over a 12-week period showed significant variation among mulberry genotypes. The adult population per leaf remained low (<1.0) in genotypes S708, Berhampur, BC 259, S46, China White, DD, S39, S1635, and C776. Moderate populations (1.0–1.50 adults/leaf) were observed in S30, S40, S54, V1, and C763, whereas higher populations (>2.0 adults/leaf) were recorded in M5, Erode Triploid, Palladam Local, Kosen, and S13. Similarly, the number of spirals per leaf was lowest (0.1–0.9) in genotypes S36, C763, China White, Palladam Local, S39, S1, and C776, while moderate levels (1.0–1.50) were observed in S30, C20, Berhampur, BC259, DD, and S1635. Higher spiral densities (>2.0 per leaf) were recorded in M5, Erode Triploid, and S13, indicating greater susceptibility of these genotypes to whitefly infestation (Asia Mariam 1999).

Influence of spiraling whitefly infestation on nutritional quality of mulberry leaves

Narayanaswamy and Ramegowda 1999, opined that, the moisture content in the spiraling whitefly affected M-5 mulberry leaves were less (62.25 %) compared to healthy leaves (70.21 %), exhibiting 11.34 per cent lower values over healthy leaves. The levels of chlorophyll a (1.98 mg/g) and b (1.66 mg/g) and the total chlorophyll (3.64 mg/g) were strikingly reduced in the affected leaves compared to healthy leaves (2.38, 2.14 and 4.52 mg/g). The levels of crude protein and sugars were reduced to the extent of 21.11 and 16.01 per cent respectively in spiraling whitefly infested M-5 mulberry leaves compared to healthy leaves. Further, the levels of mineral constituents like nitrogen, phosphorus, calcium and magnesium were reduced to the extent of 35.22, 26.53, 35.31 and 23. 59 per cent respectively in spiraling whitefly affected leaves compared to control. However, the levels of potassium (1.23 %) and sulfur (0.10 %) were comparatively higher in affected leaves compared healthy leaves (N-1.03 % & S-0.09 %).

The nutrient content in the mulberry leaf is altered in six popular indigenous mulberry varieties viz., M 5, MR 2, Mysore Local, S 36, S 54 and V 1 compared to healthy ones due to the infestation of Spiralling Whitefly. The nitrogen content was reduced in S-36 (0.23 %) and S-54 (0.95 %) mulberry varieties whereas there was no changes in the M 5, MR 2, Mysore local and V1 varieties respectively. Phosphorus content was decreased significantly in the mulberry whitefly infested leaves of M-5 (0.24 %), MR-2(0.26 %), S-36 (0.23 %), S-54 (0.16%) and V-1 (0.15 %) compared to healthy plants (0.27, 0.28, 0.27,0.19 and 0.17 %). The phosphorus content was reduced in the range of 7.14 to 15.79 per cent in the leaves of MR-2 and S-54 varieties respectively. However, the phosphorus content in Mysore local variety remained unaltered. The potassium (K) content was decreased in the leaves of MR-2 (0.24 %), Mysore Local (0.73 %), S-36 (2.08 %) and S-54 (0.51 %) varieties. The potassium content remained unchanged in the leaves of M 5 and V 1 varieties (Mahadeva and Nagaveni 2012).

Calcium (Ca) content was reduced significantly in the spiraling whitefly infested leaves of M-5 (1.02 %) and S-54 (1.12 %) varieties and non-significantly in Mysore Local (0.88 %) and S-36 (0.36 %) varieties. Calcium content in MR-2 and V-1 infested leaves remained same as healthy leaves. Magnesium (Mg) level was reduced significantly in MR-2, Mysore Local, S-54 and V-1. The minimum and maximum per cent reduction of magnesium content was recorded in MR-2 (1.43 %) and V-1 (6.82 %) varieties. However, the Mg content was increased significantly in the leaves of S-36 (0.73 %) and M-5 (0.34 %) compared healthy leaves (0.72 and 0.30 %) varieties respectively.

Sulfur (S) content was also reduced significantly in the spiralling whitefly infested leaves of M-5, MR-2, S-36 and V-1 varieties. The per cent decrease in sulfur content was ranged from 2.17% (MR2) to 8.33% (M5) in infested leaves. In addition, the per cent Sulfur content was increased in the infested leaves of Mysore local (3.23%) whereas remains unchanged in the leaves of S-54 inspite of spiraling whitefly infestation (Mahadeva and Nagaveni 2012).

Mahadeva and Nagaveni (2012) reported that, the zinc (Zn) content was reduced in the leaves of MR-2,

Mysore Local and S36, but it was significant only in MR2 variety. The reduction was negligible (0.51 %) in leaves of S36 and maximum (1.89 %) in leaves of MR2 var. It was increased in the leaves of S54 (0.46 %) var. The zinc content was not altered in the leaves of M5 and V1 varieties due to pest - attack. The iron (Fe) content was decreased significantly in the leaves of Mysore local and MR2 and non-significantly in S36, S54 and V1 varieties due to pest infestation. It was low (0.34 %) in the leaves of S54 and maximum (1.84 %) in the leaves of MR2. Manganese (Mn) was reduced in the spiralling whitefly infested leaves of M5, Mysore local, S36, S54 and V1 varieties. The leaves of Mysore local and S36 varieties recorded a negligible (0.55 %) and maximum (1.32 %) reduction in their manganese content respectively. In the leaves of MR2, the Mn level was not altered inspite of spiralling whitefly attack. Copper (Cu) was decreased significantly in V1 and non-significantly in MR2, Mysore local, S36 and S54 varieties. The decrease was negligible (0.10 %) in the leaves of Mysore Local and maximum (3.37 %) in the leaves of V1. It was not altered in the leaves of leaves of M5 although infested by the pest.

Mahadeva and Nagaveni (2012) reported that, the boron content was reduced significantly in the spiralling whitefly infested leaves of M5, MR2, Mysore local, S54 and V1 varieties. The reduction was minimum (2.13 %) in the leaves of V1 but maximum (3.33 %) in the leaves of S54. The was no change in leaves of S36 due to spiralling whitefly infestation. Molybdenum (Mo) was reduced significantly in the leaves of V1 and non-significantly in S36 varieties. The leaves of S36 and V1 varieties recorded a low (1.64 %) and maximum (3.57 %) reduction in their molybdenum content respectively. The Mo content was not altered in the spiralling whitefly infested leaves of M5, MR2, Mysore local and S54 varieties. The chloride (Cl) level was dropped significantly in the spiralling whitefly attacked leaves of V1 and non-significantly in Mysore local and S54 varieties. It was negligible (0.58 %) in the leaves of Mysore local and maximum (1.91 %) in the leaves of V1. It was not altered in the leaves of M5, MR2 and S36 varieties.

The free amino acid content was reduced in spiraling whitefly infested leaves of MR 2 (9.96 mg/g) and S 36 (9.48 mg/g) where it was increased in M 5 (11.88 mg/g), Mysore Local (9.48 mg/g), S 54 (14.92 mg/g) and V1 (3.48 mg/g) compared to healthy leaves (11.04, 11.64, 9.94, 8.2, 13.88 and 2.16 mg/g). The total soluble protein content was reduced in all the six varieties in the range of 3.23- 8.57 per cent in Mysore Local and S 36 varieties. The total reducing sugars was increased in M5 (5.71 %), MR 2 (4.08 %) Mysore Local (4.33 %) S36(8.16%) and S 54(7.10 %) except in V1(9.62 %) respectively. The total soluble sugar content reduction was minimum (3.70 %) and maximum (32.20 %) in the leaves of MR 2 and M 5 varieties. The starch content was increased maximum (28.57 %) and minimum (8.16 %) in the leaves of S 36 and S 54 varieties. The phenol content reduction was maximum (61.21 %) and minimum (11.81 %) in the leaves of Mysore local and MR 2 varieties respectively. In addition, the maximum reduction in the total chlorophyll content was noticed in MR 2 (31.35 %) and minimum in M 5(1.95%) varieties whereas increased S36 (4.54 %) and Mysore local (23.38 %) varieties respectively. The chlorophyll-a content was decreased in spiraling whitefly infested leaves of M 5 and V1 varieties respectively by 2.76 and 32.88 per cent compared to healthy and it was increased by 2.32% in S36 and 25.89% in Mysore local varieties. The chlorophyll – b content was increased in the range of 1.12 (M5) to 36.32 per cent (V1) whereas decreased in MR2 (28.57%) and no changes in Mysore local variety. The carotenoid content (%) was decreased in the range of 2.20 in M5 and 35.89 in V1 on contrary it was increased in S36 (2.57 %) and Mysore local (11.43 %) respectively (Mahadeva 2016).

Influence of spiraling whitefly infestation on silkworm cocoon production

Qadri *et al.* (2010) reported that, the varied degrees of spiralling whitefly infested leaves (D1:1-15 %, D2:16-50 %, D3:>51 %) fed to PM×CSR2 silkworms adversely affected the economic parameters as compared to healthy mulberry leaf. The larval period significantly extended up to 27:00, 25.10 and 23:12 (D:H) in the treatments D3, D2 and D1 compared to healthy leaf (23:03). The larval weight (21.95, 25.59 and 29.95 g /10), ERR by number (6240, 7880 and 9100), single cocoon weight (1.19, 1.31 And 1.40 g), single shell weight (0.17, 0.21 and 0.23



Scymnus *coccivora* *Chrysoperla*

Plate 6. Predators of Spiralling Whitefly.

g), cocoon yield(357.12, 497.76 and 621.12 kg/ha)) defective cocoon (24.40, 15.54 and 9.04 %) cocoon crop loss(48.09, 27.68 and 9.71 %), Number of eggs per layings (316.80, 367.00 and 435.20) and hatchability (71.84, 82.42 and 92.70 %) were significantly decreased when the increased degrees of spiralling whitefly infested (D3, D2 and D1) fed to silkworm compared to control (31.80/10 g, 9656, 1.49 g, 0.27 g, 688.32 kg/ha, 6.10 %, 454.20 and 97.48 %).

Management

Remove and destroy the infested leaves and install yellow sticky traps @ 75 per acre.

Spray of a strong jet of water in the affected mulberry garden will help to reduce the pest population below economic injury level without applying any chemical insecticides.

Spray 0.05% Dimethoate 30% EC (1.5 ml/litre) about 15 days after pruning (safe period 20-25 days).

Light trap coated with Vaseline, fluorescent light source smeared with castor oil and yellow sticky traps were effective in attracting and trapping a large number of adult white.

Release Scymnus coccivora @ 500 adults or Chrysoperla @ 1000 eggs / acre (Plate 6), a week after the insecticides spray.

Two parasitoids namely Encarsia quadeloupae and Encarsia haitiensis are known to parasitise A. dispersus in India.

An egg predator Axinoscymnus puttarudriahi was identified and it could also be used to destroy the pest in egg stage itself. (Sakthivel *et al*. 2019).

Papaya mealy bug

Paracoccus marginatus was first reported from the Neotropical region, including Belize, Costa Rica, Guatemala, and Mexico (Williams and Granara de Willink 1992), and is believed to be native to Mexico and Central America. Its occurrence was reported several times in Mexico as early as 1967 on cassava, although it was not identified at that time. During 1993–1994, it was introduced into the Caribbean islands, where it spread rapidly and became a pest of papaya in certain areas (Miller *et al*. 1999). In 1998, it was detected in the United States (Hollywood). More recently, its presence has been reported from Java in Indonesia and Coimbatore in Tamil Nadu, South India (Muniappan *et al*. 2008), as well as from Sri Lanka, Malaysia, Thailand, Bangladesh, and the Maldives..

In India, *P. marginatus* was first reported from Coimbatore (Tamil Nadu) during July, 2008, infesting

papaya in Tamil Nadu Agricultural University campus (Muniappan *et al.* 2008). Subsequently, the pest spread to neighboring districts of Thiruppur, Erode, Salem, Namakkal and Karur. As per a survey report during 2009, an area of about 1,500 acres of mulberry plantation in Tamil Nadu had been infested with this noxious pest. Many mulberry gardens had dried up due to severe infestation and a few farmers even went to the extent of uprooting mulberry (Mahalingam *et al*. 2010). Later, during July 2009, the pest appeared in the districts of Palakkad, Malappuram and Thrissur in Kerala, infesting mulberry, Jatropha, Lantana, Eupetorium and Parthenium (Krishnakumar and Rajan 2009).

During July 2010, *P. marginatus* made its entry into Karnataka state from Talawadi in Tamil Nadu, which is bordering with Chamarajanagar, through infested mulberry seed cuttings as well as transportation of infested papaya fruits. Further, extensive survey in mulberry gardens of adjoining districts revealed that the pest made its appearance in Mysore and Mandya districts during July and August 2010, respectively, the pest spread to other districts such as Ramanagaram, Bangalore Urban and Rural (Sreenivas *et al.* 2011).

Host range

Papaya mealybug incidence was observed on 84 plant species belonging to 35 families of which heavy population build-up and severe damage was recorded on 21 host plants including 10 economically important species viz. *Carica papaya* L.(Papaya), *Hibiscus cannabinus* L. (Sorrel leaves), *Jatropha curcas* L. (Physic nut), *Manihot esculenta* Crantz (Cassava), *Morus alba* L.(Mulberry), *Psidium guajava* L.(Guava), *Punica granatum* L. (Pomegranate), *Solanum melongena* L. (Brinjal), *Solanum tuberosum* L. (Potato) and *Tectona grandis* L. (Teak), six ornamental plants and five weeds species. High host preference was noticed on the plants belonging to the family Euphorbiaceae and Fabaceae followed by Malvaceae, Solanaceae, Apocynaceae and Amaranthaceae (Selvaraju and Sakthivel 2011).

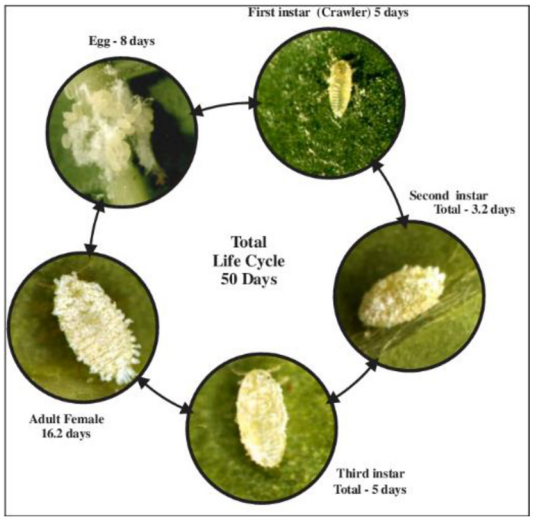


Plate 7. Life cycle of Papaya Mealybug.
Source: https://www.semanticscholar.org/paper

P. marginatus infestation was recorded in different levels on mulberry (3.50), followed by hibiscus (2.75), parthenium (2.50) and papaya (2.50) at Chinnaballi village, Mysore district during 20-7-2012 to 19-5-2013. In Ramanagara district surveys were conducted at two locations viz., Magadi and Channammahalli on 10-7-2013 for the pest incidence. In Magadi there was no infestation but in Channammahalli, the infestation was found on mulberry (3.25) followed by parthenium (2.11) and guava, (2.00) and curry leaves (1.33). In addition, the level of infestation was more on papaya (4.30) followed by mulberry (2.13) and parthenium (2.11) (Pradeep 2013).

The incidence of *P. marginatus* on mulberry was observed during 2nd week of November 2012, the incidence gradually increased to 20.25 mealy bug/10 cm shoot length in March, 2013 and then on wards its population declined further, pest population was significantly positively corelated with maximum temperature and sunshine hours and negatively correlated with rainfall, morning and afternoon relative humidity (Pradeep 2013). Mohan *et al.* (2017) recorded the higher incidence (22.78, 30.60 and 33.10) of Papaya Mealybug at Reddipudur village compared to Vaikkalpattarai village (3.47, 4.59 and 6.80) from December 2012 to February 2013.

Taxonomic position

Kingdom : Animalia
Phylum : Arthropoda

Class : Hexapoda (Insecta)
Order : Hemiptera
Super family : Coccoidea
Family : Pseudococcidae
Genus : Paracoccus
Species : Marginatus

Biology

Eggs

Eggs are greenish yellow and are laid in an egg sac that is three to four times the body length and entirely covered with white wax. The ovisac is developed ventrally on the adult females and contains around 600-900 eggs (Plate 7). The eggs hatch in 4 to 7 days.

Nymphs

Females have three nymphal instars occupying 24-26 days as against four in males extending upto 27-30 days at 25 ˚C temperature and 65per cent relative humidity. First instar nymphs called crawlers are quite active and moves freely to settle on the soft portion of the stems and leaves and starts feeding by sucking the sap with its piercing and sucking mouth parts. Normally, once settled, they do not move except when disturbed. The nymphs secrete and embed themselves in white waxy coating. The females are slow movers and live upto 30 to 60 days whereas the males survive for only 3 to 4 days, depending upon the environmental conditions. The females attract males with sex pheromones (Plate 7).

Adult females

The females are yellowish green in color and measuring approximately 2.2 mm length and 1.4 mm width. The body is covered with a white mealy wax coating. A series of short waxy caudal filaments less than ¼ the lengths of the body exist around the margin. They have no wings and move by crawling short distances.

Two characteristics that are important in distinguishing *P. marginatus* adult females from all other species of *Paracoccus* are the presence of oral-rim tubular ducts dorsally restricted to marginal areas of the body and the absence of pores on the hind tibiae further eight antennal segments are present (Plate 7).

Adult males

The males tend to be colored pink, especially during the pre-pupal and pupal stages, but appear yellow in the first and second instar. males are approximately 1.0 mm length with an elongate oval body that is widest at the thorax (0.3 mm) males have ten segmented antennae, a distinct aedeagus, lateral pore clusters, a heavily sclerotized thorax and head, and well-developed wings. *P. marginatus* males may be distinguished from other related species by the presence of stout fleshy setae on the antennae and the absence of fleshy setae on the legs.

Mode of dispersal

The papaya mealy bugs easily spread from infested plants to healthy plants. The nymph of mealy bug get readily dispersed by wind, rain, irrigation water, birds, ants, clothing, and vehicle.

The wax, which sticks to each ovisac and nymphs, also facilitates passive dispersal by equipment, animals or human beings.

In fact, human beings greatly facilitate in the transport of these mealy bugs.

Long-distance movement of papaya mealy bug is aided through transport of planting material and infested mulberry saplings.

Ants, attracted by the honeydew, have been seen carrying mealybugs from plant to plant (Tanwar 2010).

Factors responsible for high population buildup in mulberry plantation

The rapid development, high survival rate, and enormous reproductive capacity of *P. marginatus* population could potentially reach a high level.

Wax layer and waxy fibers over the ovisac and body of mealybug nymphs and adult females protect them from adverse environmental conditions and spraying of chemical pesticides. Availability of alternate hosts



Plate 8. Cluster of cotton-like masses on papaya mealybug infested plant.



Plate 9. Stunted growth, deformed leaves, chlorosis and black sooty mould development on papaya mealybug infested plant.

/ weeds around the mulberry garden favors the multiplication of the pest.

Intensive cropping system and wider acceptability of hosts by papaya mealybug.

Ants association provides a protection from parasitoids and predators and aiding in dispersal of the pest. (Tanwar 2010).

Damage and Symptoms

Papaya mealybug infestation appears on above ground parts on leaves, stem and fruits as clusters of cotton-like masses (Plate 8). The insect sucks the sap by inserting its stylets into the epidermis of the leaf, fruit and stem. While feeding, it injects a toxic substance into the leaves, resulting in chlorosis, plant stunting (Plate 9), leaf deformation or crinkling, early leaf and fruit drop, and death of plants. The honeydew excreted by the papaya mealy bug results in the formation of black sooty mould which interferes in the photosynthesis process and causes further damage to



Plate 10. Water Jetting in papaya mealybug infested mulberry garden.



Acerophagus papayae, *Pseudleptomastix Mexicana*

Plate 11. Parasitoids of papaya mealybug.

the crops. Heavy infestations are capable of rendering fruit inedible due to the buildup of thick white waxy coating (Sakthivel *et al.* 2019).

Influence of Papaya mealy bug on mulberry leaf

In mulberry, the adaxial epidermis was given rise to large sized vacuoles in between cells extended upto the palisade parenchyma. Palisade and spongy mesophyll seemed to be compact with poor differentiation. There was a reduction in size of palisade parenchyma cells due to the mealybug feeding in leaf was observed. Distortion of both adaxial and abaxial epidermal cells resulted in thick walled and irregular shaped cells in papaya melaybug infested leaf lamina of mulberry. There was not much change was observed in palisade cells of midrib of mulberry leaf (Nisha and Kennedy 2017).

The biochemical constituent's viz., carbohydrates, reducing sugars, protein, total free amino acid, secondary metabolites like phenol and tannin were altered in the papaya melay bug infested mulberry leaf. The total soluble protein content was reduced in infested mulberry (6.21 mg/g) leaf compared to healthy (9.99 mg/g) and of 37.84 per cent was reduced. Further, the lower content of carbohydrate content (38.41 mg/g) and reducing sugars (4.39 mg/g) were recorded in infested leaf compared to healthy leaf (55.16 and 5.2 mg/g). Further, total free amino acid (6.91 mg/g), phenol (8.25 mg/g) and tannin (3.55 mg/g) content was increased in papaya melaybug infested mulberry leaf compared to healthy (5.89, 6.01 and 2.72 mg/g) respectively (Nisha and Kennedy 2017).

Management

Monitoring and scouting to detect early presence of the mealybug.

Pruning of infested branches and burning them.

Removal and burning of crop residues.

Removal of weeds/alternate host plants like Hibiscus, Parthenium in and nearby crop.

Avoiding the movement of planting material from infested areas to other areas.

Prevention of the movement of ants and destruction of already existing ant colonies.

Sanitization of farm equipment before moving it to the uninfested crop.

Water jetting involves physical force which hits on the infested plant parts to dislodge and washout the insects so that the mulberry garden is kept free from the population of papaya mealybug (Plate 10).

As soon as the pest is noticed, release exotic parasitoid, Acerophagus papaya or Pseudleptomastix mexicana @ 250 parasitoids / acre of mulberry garden (Plate 11). These parasitoids are most effective in controlling papaya mealybug successfully rather than

spray of chemical insecticides. (Sakthivel *et al,* 2019).

CONCLUSION

Mulberry cultivation is highly affected by invasive pests like the spiralling whitefly (Aleurodicus dispersus) and papaya mealybug (Paracoccus marginatus), which reduce leaf quality and yield, thereby impacting silkworm growth and cocoon production. Their rapid spread is favored by intensive farming practices and climatic variations. Hence, adopting integrated pest management practices, including monitoring, cultural methods, biological control, and limited chemical use, is essential for sustaining mulberry productivity and sericulture success.

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