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Rugose Spiraling Whitefly, *Aleurodicus rugioperculatus* Martin: An Overview

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ABSTRACT: Rugose Spiralling Whitefly (RSW), *Aleurodicus rugioperculatus* Martin initially described from Belize. It is a tiny, sap-sucking, phloem feeder that is polyphagous. A review was conducted on sustainable and effective alternative techniques to pest management. Under biological management, coconut orchards sprayed twice with an introduction release of the parasitoid *Encarsia guadeloupae*, and twice with *Isaria fumosorosea* fungus (NBAIR-Pfu-5) @ 5 g/lt with sticker @ 10 g/lit, saw a substantial reduction in rugose spiralling whiteflies. In Karnataka, natural parasitism ranged from 7 to 80%, and the parasitoid *Encarsia guadeloupae* was identified as the main parasitoid linked to the pest. It was discovered that extensive infestations were more common in dwarf coconut types and hybrids than in tall kinds. The application of eco-friendly integrated pest management practices, such as light traps, yellow sticky traps, jet water spray, 0.5% neem oil, and the parasitization of *Encarsia guadeloupae* puparia on palm leaflets, significantly decreased both the incidence and intensity of the disease. The most successful method for lowering the RSW population on coconut was to spray *Isaria fumosorosea* (5 ml/l) and profenophos 50 EC (2 ml/l) twice at intervals of 15 days.

Keywords: *Aleurodicus rugioperculatus* Martin, Management, coconut.

INTRODUCTION

The coconut is commonly known as the "tree of heaven" or "kalpavriksha" due to its ability to yield a wide range of beneficial products for human use. Over 93 countries across the globe cultivate coconut on an area of 12 million hectares, producing 59.98 million tonnes of nuts annually. The Food and Agricultural Organization states that Indonesia is one of the top producers of coconuts, with an annual production of 18 million tonnes, followed by the Philippines with 15.86 million tonnes. India produces 10.56 million tonnes of coconuts a year, which puts it in third place in the world. More minerals, including sugars, ascorbic acids, vitamins B, phosphorus, magnesium, and sodium, potassium, and phosphorus, are present in this nourishing drink. Amino acids like cystine, arginine, and alanine are also abundant in it. Lauric acid, which has 12 carbons, makes up almost half of the fatty acids in coconut oil. According to Nadanasabapathy and Kumar (2013), coconut water is also used as an oral rehydration fluid for elderly and paediatric gastroenteritis patients. Several commercially significant species of whiteflies are among the 118 alien species that have invaded India. According to Dubey and Sundararaj (2015), there are currently 442 species of whiteflies that belong to 32 genera that are known to exist in India. Of these, two species have invaded the country: the rugose spiralling whitefly (RSW), *Aleurodicus rugioperculatus* Martin (Homoptera, Aleyrodidae), and the solanum whitefly, Aleurothrixus trachoides (Back).

The highly polyphagous and invasive rugose spiralling whitefly (RSW), *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae), was first discovered in Tamil Nadu in 2016 (Selvaraj *et al*., 2016; Sundararaj & Selvaraj 2017). Later, reports on coconut, banana, sapota, maize, oil palm, mango, cashew, and many more ornamental plants were received from many regions of India, including Kerala, Karnataka, Andhra Pradesh, Assam, Goa, West Bengal, Maharashtra, Telangana, Meghalaya, and Gujarat (Selvaraj *et al*., 2019). In addition to feeding aggressively on leaf sap,

A. rugioperculatus nymphs and adults produce wax and excrete sticky honeydew on infested areas, which leads to the extreme growth of black sooty mould and a reduction in photosynthetic efficiency in palms. This depletion of nutrients and water causes premature leaf drop and drying (Kumar *et al*., 2013). In India, it is becoming a common pest of coconut and oil palm, necessitating control efforts to prevent crop losses.

Origin of Rugose spiralling whitefly (RSW): *Aleurodicus rugioperculatus* Martin, a recent addition to the list of whitefly species found in Florida, is currently known as the rugose spiralling whitefly after formerly going by the term "gumbo limbo spiralling whitefly." It is an endemic pest to Central America that was brought to Florida and was first discovered in Miami-Dade County in 2009. It is found in Belize, Guatemala, and Mexico naturally (Martin, 2004). From there, it has spread to 22 other Central and South American nations, including Florida, USA. According to Sundararaj and Selvaraj (2017), the rugose spiralling whitefly, *A. rugioperculatus*, has been found in coconut palms in Pollachi, Coimbatore district, Tamil Nadu, Karnataka, Kerala, and Andhra Pradesh, India. In Changanassery, Kottayam districts of Kerala, Shanas *et al*. (2016) also documented a serious outbreak of RSW infestation in coconut palms, mango, and guava trees. According to Selvaraj *et al.* (2016), RSW caused serious damage to coastal areas in Karnataka, specifically in Mangalore and Udupi. The infection levels in coconut and banana were from 20–35% and 24–38%, respectively. Poorani and Thanigairaj (2017) reported seeing a severe infestation of this new invasive pest on banana leaves and fruits in Tamil Nadu.

Host plants of Rugose spiralling whitefly: With 118 hosts from 43 different plant families, including commercially significant crops in the US, the RSW is extremely polyphagous (Francis *et al*., 2016). In its natural habitat, it primarily infects broadleaved plants like coconut palms (Martin, 2008). Similar infestations were found on custard apple, hibiscus, sapota, bhendi, citrus, mango, guava, and jatropha (Selvaraj *et al*., 2016). Additionally, according to Stocks (2012), RSW infestation was observed in weeds, ornamentals, palms, and both native and alien plant species.

Furthermore, according to host plant data collected in Florida between 2009 and 2012, 22% of the rugose spiralling whitefly-affected hosts were palm species, followed by gumbo limbo (16%), avocado (9%), black olives (4%), and mango types (3%). In Florida, Stocks (2012) noted roughly 95 host plants. *A. rugioperculatus* has been found to favour 17 different plant species across 11 families in Kerala (Shanas *et al.,* 2016). 15 host plants from 13 botanical families were found in Tamil Nadu, according to Srinivasan *et al.* (2016). These plants included two each from the Euphorbiaceae, Malvaceae, and Arecaceae families as well as one each from the Annonaceae, Melliaceae, Asteraceae, Musaceae, Myristicaceae, Myrtaceae, Piperaceae, Rutaceae, and Sapotaceae.

Taxonomical characters: In Mound and Halsey's 1978 catalogue of the world's whiteflies, along with their host plants and natural predators, 1156 species of whiteflies (Aleyrodidae) in 126 genera were included. Subsequent to that time, a number of novel genera and species have been identified, while some have been merged with previously identified taxa. In Florida, *A. rugioperculatus* was initially reported by (Martin, 2004). *A. rugioperculatus* is a member of the family Aleyrodidae in the order Hemiptera, specifically the subfamily Aleurodicinae. *A. rugioperculatus* was characterized by distinctive compound and simple pores (Martin, 2004). *A. rugioperculatus* is commonly called as rugose spiralling whitefly because of the spiralling egg laying pattern and also having rugose (fluted/ irregularly corrugate) appearance of the puparial operculum.

Morphological details of different stages of *A. rugioperculatus*

Egg stage: RSW, *A. rugioperculatus* females cover their eggs with white waxy substance and place them in a concentric circular or spiral arrangement on the underside of leaves. The elliptical eggs range in colour from creamy white to dark yellow, and they are bigger than the eggs that *A. disperses.*

Nymphal stage: There are five stages of RSW development. There are four immature instars; the first three are continuous feeders and are called nymphs. As the only mobile juvenile stage of RSW, the first instar, often referred to as the crawler stage, emerges from the egg, searches for a spot to start eating using its needle-like mouth parts, and sucks plant sap. As their life cycle progresses, crawlers moult into immature stages that are initially flat, oval, and stationary but eventually become more convex (Mannion, 2010). Nymphs range in size from 1.1 to 1.5 mm, depending on the stage of development. The nymphs are pale to golden yellow in hue, and they will create long, thin filaments of wax in addition to a dense, cottony wax.

Adults: Adult rugose spiralling whiteflies are naturally languid and nearly three times larger than regular whiteflies. Rugose spiralling whitefly adults can be identified by their huge size and the presence of two irregular light brown bands across their wings, however taxonomic identification is necessary for species confirmation (Stocks and Hodges 2012). Males' abdomens end features are lengthy, pincer-like structures.

Pupal stage: Generally, the pupa has a broadly cordate vasiform orifice, an operculum ventro that is dorsally characteristically rugose and basally spinulose, with two ventro median fine setae; additionally, it has a lingula head that protrudes beyond the vasiform orifice and is finely spinulose, apically acute, with its four setae located in close proximity to the apex. First abdominal, cephalic, and anterior marginal setae are

absent; 12 pairs of outer sub marginal setae, including a nominal caudal pair, are present; pro-, meso-, and meta-throacic setae and the eighth abdominal setae are arranged in single sub median pairs and are fully anterior to the vasiform orifice; the operculum's opposite anterior corners are present (Martin, 2004).

A head and an anterior two pairs of much smaller pores are present on abdominal segments VII and VIII, and there are four separate pairs of compound pores in the abdomen. The pore band is broken right posterior to the lingular apex, and the submarginal is characterised by a zone of densely packed, broader immed pores that protrude from the puparial surface. The inner edge of the zone forms mesally-directed lobes. Selvaraj and Sundararaj (2017)

Damage Symptoms: It feeds on the cell sap of leaves with its needle-like mouth parts. It depletes the plant of nutrients and water, causing stress. Its leaves exude a glossy, sticky liquid similar to honeydew, which makes a perfect growing medium for sooty moulds. The accumulation of sooty mould on leaves has the potential to cause physiological diseases by interfering with the host's photosynthetic process. Affected palms can occasionally suffer from immature nut fall, stunted vegetative and reproductive growth, or even stop producing nuts entirely.

$$\text{Infestation Index} = \frac{\begin{array}{l}(\text{No. of palms under Scale } 0 \times 0) + \\ (\text{No. of palms under Scale } 1 \times 1) + \ldots , \\ + (\text{No. of palms under Scale } 3 \times 3)\end{array}}{\text{Total no. of palms observed}}$$

Damage rating scale for the infestation of *A. rugioperculatus*

No. of egg spirals	Grade	Category	Infestation index
No egg spirals and sooty mold encrustation noticed	0	Nil	0.0
Fewer than 10 egg spirals per leaflet; the presence of sooty mold encrustation in 5- 6 lowermost fronds	1	Low	0.01 to 1.0
Ten to 20 egg spirals per leaflet; the presence of sooty mold encrustation in 10-12 fronds	2	Medium	1.01 to 2.0
More than 20 egg spirals per leaflet; presence of sooty mold encrustation in more than 12 fronds	3	High	2.01 to 3.0

In accordance with the infestation index formula created by Srinivasan *et al.* (2016). Rugose spiralling whitefly infestation was assessed by screening different species of coconut.

Management Practices:

Surveillance and monitoring: For the purpose of early pest detection and AESA-based decision-making, routine surveying and monitoring should be carried out at least once every week. Promote the natural parasitoid *Encarsia* sp. accumulation. It is advised to install five yellow sticky traps per acre to monitor the RSW. Adult RSWs are seen to be most active in the morning, from 6 a.m. to 10 a.m., and in the evening, from 6 p.m. to 10 p.m.

Cultural control: Keep damaged coconut seedlings from being transplanted. Observe the recommended distance between objects. Applying fertilizer at the best recommended dosages based on the results of soil testing (soil health card). Limit how sick seedlings can be moved from one location to another. Aim for 7.5 x 7.5 m planting spacing; stay away from dense planting. Optimal fertilizer dosages applied in accordance with soil test results. Intercrop plantings that boost parasitoid activity in infected fields, such as cumbu, cocoa, and nutmeg. Set up 2 yellow light traps per acre between 7 and 11 p.m. to watch and catch adult RSWs that are flying.

When yellow sticky traps were set up facing east and coated with castor oil, the greatest number of adults were drawn in 270.59 adults per trap per week. The quantity of RSW caught by the traps dropped as the distance from the coconut garden increased in all directions, according to a dispersal distance and direction research.

According to a report, tall coconut varieties are less likely to have severe infestation than dwarf coconut varieties and hybrids (Srinivasan *et al.*, 2016). The results indicated that there was a significant positive correlation between the length of the leaflet (0.923) and oil palm (0.952) with pest infestation, and a significant negative correlation with the thickness of the leaflet (-0.870) and oil palm (-0.892) as well as the width of the leaflet (0.978) in the case of oil palm and the rugose spiralling whitefly infestation.

Mechanical Control: Forced water spraying can be used to remove coconut leaflets by focusing on their undersides. To control the RSW, it is advised to install yellow sticky traps at a rate of fifteen per acre on the palm trunk. Setting up the yellow light traps. Position the yellow sticky trap (15/acre) 1.5 metres above the ground and apply castor or engine oil to it. Periodically burn the badly infected leaves from the field. Adult travel from one tree to another will be restricted if water is sprayed on the lower surface of the leaves.

Biological control:

Parasitoids and Predators: Several natural enemies have been documented in association with RSW in Florida by Taravati *et al.* (2013) and Francis *et al.* (2016). These include parasitoids like *E. guadeloupae*, *E. noyesi*, and *Aleuroctonus* spp.; predators like *Nephaspis oculata, Azya orbigera* orbigera*, Chilocorus cacti, Cryptolaemus montrouzieri, Delphastus pallidus, Harmonia axyridis, Hyperaspis bigeminata, Cybocephalus* sp., and chrysopids like *Ceraeochrysa* spp.

In the field, five insect groups belonging to three distinct orders have been discovered as natural enemies of RSW.

Cryptolaemus montrouzieri Mulsant, *Chilocorus nigrita* (Fabricius), *Menochilus sexmaculatus* Fabricius, *Curinus coeruleus* (Mulsant) from Coccinellidae, *Cybocephalus* spp. from Cybocephalidae, *Dichochrysa astur* (Banks), *Mallada desjardinsi* (Navas), *Chrysoperla zastrowi* sillemi (Esben - Petersen) from Chrysopidae, *Oecophylla smaragdina* Fab. from formicidae and *Encarsia guadeloupae* Viggiani, *E. dispersa* Polaszek from Aphelinidae were recorded in the fields. Release of 4000 eggs per acre of Chrysopids, including Mallada desjardinsi and *Chrysoperla zastrowi* sillemi.To control the RSW infestation, use a fortnightly spray of the entomopathogenic fungus *Isaria fumosorosea* at a concentration of 5 mg/l of water combined with detergent or Khadi soap at a concentration of 5 g/l. Stapling leaf bits carrying the RSWF puparia (parasitized by *Encarsia guadeloupae*) under the coconut leaflets at a rate of one leaf bit per ten trees results in the release of *Encarsia guadeloupae* parasitoids. Release the *Leiochrinus nilgirianus* Kaszab (Coleoptera: Tenebrionidae) sooty mould scavenging beetle to remove the sooty mould from the leaflets. You can also spray 2.5% of maida paste solution mixed with detergent/Khadi soap @ 5g/l or 1% starch solution mixed with detergent/Khadi soap @ 5g/l to flake out Capnodium infection in leaflets.

On the infected palms, it was found that the natural parasitism by *E. guadeloupae* varied from 4.5 to 78.2 percent (Taravati *et al.,* 2013). In Tamil Nadu, Andhra Pradesh, and Kerala, Sellvaraj *et al.* (2016) identified *E. guadeloupae*, *Mallada* spp., and *Cybocephalus* spp. as common natural enemies of RSW. Of these, *E. guadeloupae* was shown to be the most dominant and to have the highest parasitism (20.0-60.0%). It was discovered that 60–70% of the spiralling whitefly's parasitism is caused by the foreign, well-known parasitoid *Encarsia guadeloupae* Viggiani (Hymenoptera: Aphelinidae), which was brought to India in 1999 (Ramani *et al*, 2002; Evans, 2007).

This has already been documented in relation to *A. rugioperculatus* from Florida (Kumar *et al*., 2013; Taravati *et al*., 2013). Based on the observation of 50–60% natural parasitization of the pupae, it seems to be a promising biocontrol agent against RSW. *Encarsia dispersa* Polaszek was found parasitizing *A. rugioperculatus* in Tamil Nadu surveys, according to Poorani and Thanigairaj (2017). *E. guadeloupae* was shown to have a significant parasitization of between 40 and 70 percent on banana alone (Poorani and Thanigairaj 2017). However, a survey carried out in Tamil Nadu and Kerala by Selvaraj *et al.* (2016) found that 20–60% of coconuts had *A. rugioperculatus* parasitized by *E. guadeloupae*.

It is recommended that these plants be grown in oil palm farms as Banker plants, which are refuges for parasitoids, in order to conserve and enhance the parasitoid population. The aphelinid parasitoid *Encarsia guadeloupae* Viggiani naturally parasitizes the coconut rugose spiralling whitefly *Aleurodicus rugioperculatus.* These included *Pseudomallada* sp. (Neuroptera: Chrysopidae), *Cybocephalus* sp. (Coleoptera: Nitidulidae), *Diadiplosis* sp. (Diptera: Cecidomyiidae*), Menochilus sexmaculatus* (F.), and *S. coccivora* (Coleoptera: Coccinellidae) as common predators that were observed to be feeding. According to Ramami *et al.* (2002), the two most common predators were chrysopids and Cybocephalus species.

Entomopathogens: The utilization of entomopathogenic fungi, specifically *Isaria fumosorosea* (NBAIR- Pfu 5), for biological control of coconut rugose spiralling whiteflies has been proven to be effective. Additionally, the introduction of *Encarsia guadeloupae* parasite, along with its conservation and augmentation, has been welcomed by coconut farmers in the north coastal districts of Andhra Pradesh state. Rugose whitefly intensity was reported to be effectively reduced by 58.1 to 97.03% in coconut orchards during the 2018–19 season by using *Isaria fumosorosea* (NBAIR–Pfu–5) at 1×10^8 spores/ml (5 g/litre of water) in two sprayings spaced one month apart.

Combination of biological and chemical control: *Isaria fumosorosea* alone and in combination with insecticides *against Aleurodicus rugioperculatus* on coconut was studied. They found that the most effective combination was *I. fumosorosea* (ICAR-NBAIR Pfu-5) @ 5 ml/l + profenophos 50 EC @ 2 ml/l spray, which significantly reduced the percent infestation of RSW (82.97%).

Ecofriendly IPM. In order to develop environmentally friendly IPM, research was done on the natural enemy complex, infestation grade index, occurrence, and intensity of the rugose spiralling whitefly (RSW), *Aleurodicus rugioperculatus* Martin, infesting coconut palms. The treatments include installing light traps at a rate of 5 ha, attaching yellow sticky trap sheets at a rate of 25 ha, spraying three rounds of 0.5% neem oil on the underside of leaves at intervals of 15 days, spraying three rounds of jet water at a rate of 10 days, approximately 15 days after the neem oil spraying, and taping leaflets that contain puparia parasitized by *E. guadeloupae* on palm leaflets.

According to the findings, the incidence and intensity of palms treated with environmentally friendly IPM techniques in 2018–19 considerably decreased, going from 75.5 to 37.7% and 85.7 to 42.9%, respectively. When the aphelinid parasitoid *Encarsia guadeloupae* Viggiani was discovered on palms treated with environmentally friendly IPM techniques, nut yield and net return were also shown to be more in synergy with maximum parasitism (78.5%).

Botanicals. Teepol or Sandovit sprayed with neem oil at 0.5% or 5% NSKE will help prevent RSW from developing.

Chemical Control: Pesticides should only be used as a last resort because they can harm biological control agents and non-target pests. In order to effectively control the pest population in field settings, spraying Azadirachtin 10000 ppm (1.7 ml), Dinotefuran 20 SG (0.93 gm), Pymetrozine 50 WG (0.85 gm), and Thiamethoxam 25 WG (0.84 gm) is recommended.

I. fumosorosea with 100% mortality was considerably superior to dinotefuran 20 SG (97.23%), thiamethoxam 25 WG (95.02%), and azadirachtin 10000 ppm (94.98%) at 6 DAT. Profenophos 50 EC and buprofezin 25 SC similarly shown maximum ovicidal action in field conditions (Pradhan *et al*., 2020).

CONCLUSIONS

Systemic insecticides can be used to control rugose spiralling whiteflies, but they should only be used as a last resort because they can destroy the biological control agents. To discover the pest early and promote the natural parasitoid *Encarsia guadeloupae*, periodic surveys and monitoring should be carried out. Yellow sticky traps can be used to control the rugose spiralling whitefly. Apart from the entomopathogenic fungus, *Isaria fumosorosea* exhibits remarkable efficacy in controlling pests.

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