

Biological control: Success story of managing invasive Rugose Spiraling Whitefly in Kadiyam nurseries of Andhra Pradesh, India

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The increasing demand to gain more production by adopting new technologies and changing agricultural practices results in new hazards to environmental health that are readily able to cross borders. This free trade and movement of plant materials across political and geographical borders has led to the introduction of certain plant, insect and pathogen species to new localities. These species are causing enormous damage to biodiversity and the valuable natural agricultural systems upon which human kind depends. The direct and indirect health effects are increasingly becoming serious and the damage to nature and environment is often irreversible. The effects are often exacerbated by global change and chemical and physical disturbance to species and ecosystems.

Recently, Rugose Spiraling Whitefly (RSW), *Aleurodicus rugioperculatus* Martin (Hemiptera: Sternorrhyncha: Aleyrodidae) entered India infesting coconut plantations across Kerala, Tamil Nadu, Karnataka and Andhra Pradesh. Presently, infestation of RSW increased over the time and spread across the southern states and even spread too far-off states like Assam, Gujarat and extending its host ranges at greater level which could be due to its polyphagous nature (Fig. 1).

Immature stages of RSW produce profuse quantity of wax filaments. Furthermore, RSW produce honey dew which results in development of sooty mould. The severity of infestation ranged between 40-60 % in coconut and 25-40 % in banana (Selvaraj *et al.*, 2016). Rugose spiraling whitefly was initially reported from Miami-Dade County, Florida, United States of America from gumbo limbo, *Burera simaruba* (L.) as a pest. However, it was originally described from Belize in 2004 on coconut (Martin, 2004) where its natural population was reported. This whitefly is believed to have originated from Central America and distribution of this pest in Central and North America is limited to Belize, Mexico, Guatemala and the United States (Evans, 2008). In the continental United States, the first established population of RSW was reported from Florida in 2009, and since then its distribution range has expanded considerably within the state and subsequently, it has spread to 22 other countries in Central and South America, including Florida, USA. India is the only country in the Oriental region where the whitefly has been introduced. Initially, this whitefly was observed in several coconut farms in the Pollachi area of Coimbatore district, Tamil Nadu and first



Fig. 1. Eggs, Nymph and Adult RSW.

reported in Kottayam from Kerala during July – August 2016 (Sundararaj and Selvaraj, 2017). The pest has also been recorded at Kadiyam nurseries in Coastal Andhra Pradesh during October-November, 2016. The possible entry to Andhra Pradesh may be by coconut seedlings obtained from nurseries in Tamil Nadu and Kerala.

Kadiyam nurseries located in the coastal Andhra Pradesh in East Godavari district is credited with more than 100 years of antiquity. The nursery sector comprising 1555 hectares of land with about 1500 floriculture nurseries with an annual turnover of more than 200 crores has earned a brand value of floriculture nursery industry in Andhra Pradesh. Kadiyam nurseries are a combination of small, medium and large nurseries comprising of wide variety of indoor plants, outdoor plants, seasonal plants, ornamentals plants, medicinal plants, fruit crops, apart from the production of plants congenial to local situation, they also import plants from different parts of India and on the other side, the nursery owners also export the plants to different parts of the

world like Singapore, Malaysia, China, Thailand, Arabian and European countries. Growth and development of Kadiyam as a cluster of floriculture nurseries is not an individual effort, but it is an effort of all the stake holders involved in its bloom, primarily the floriculture nursery owners at Kadiyam (Uday Bhaskar *et al.*, 2020). The latest bottle neck in the form of RSW compounded the existing hurdles like operating as an unorganized sector, lack of control over the transactions, organizational disparities among the nurseries.

Host range of Rugose spiraling white fly

Rugose spiraling whitefly is a polyphagous pest feeding on a wide range of host plants including palms, woody ornamentals, and fruits (Mannion, 2010). Florida Department of Agriculture and Consumer Services (FDACS), Division of Plant Industry (DPI) records from 2009 to 2015 identified rugose spiraling whitefly on at least 118 plant species, which include a combination of edibles, ornamentals, palms, weeds, as well as native and invasive plant species (Stocks,

2012). Further, host plants recorded from 2009 to 2012 at Florida shows that 22% of RSW affected hosts were palm species, 16% were gumbo limbo, 10% were *Calophyllum* spp., 9% were avocado, 4% were black olive, and 3% were mango varieties (Francis *et al.*, 2016). Within the family Arecaceae (palms), 44% of host records were from coconut. Based on incidence records, these plant species can be considered as primary or preferred hosts of this pest. However, all plant species reported have not been documented as true hosts of the pest and may not require management. A total of 17 plant species under 11 families were recorded as preferred hosts of *A. rugioperculatus* at Kerala (Shanas *et al.*, 2016).

In Kadiyam nurseries the sale of various ornamentals and fruit plants belonging to different families is one of the prime activities and further majority of nursery plants are grown under coconut palms shade. The sooty mold produced due to whitefly feeding and its subsequent blackening of undersurface leaves is also a cause of concern as sooty mold deposited on ornamentals gives a poor appearance and not readily accepted by the consumer. The import and export of various plant material especially infested ornamentals and fruit plants is another cause of concern pertaining to spread of rugose spiraling whitefly to other parts of the state and the country. The host preference of *A. rugioperculatus* in Kadiyam region was recorded by scoring the presence of live egg spirals on leaf and categorized as low (10 egg spirals/ leaflet), medium (10-20 egg spirals/leaflet) and high intensity (>20 egg spirals/ leaflet) and the host range recorded as per its incidence is detailed below (Table 1).

Keeping in view the wide diversity of host plants and as hub of nursery activity sustaining lakhs of people a planned management strategy was formulated in consultation with Department of Horticulture, Government of Andhra Pradesh to educate, enlighten and adopt strategic mechanism to prevent spread the rugose infested plant material from Kadiyam nurseries and to successfully implement the pesticide free recommendations advocated. To show case the impact of pesticidal free management approach in rugose spiraling white fly management the following on farm research activities was carried out in Kadiyam nurseries itself to show and validate the package recommended against RSW.

An observation trail to study the efficacy of spraying of Azadirachtin 10,000 ppm @ 1ml on rugose spiraling white fly was carried out in coconut plantations in Kadiyam mandal. Three sprays were conducted on five palms with Azadirachtin 10,000 ppm @ 1ml at 20 days interval. The average number of spirals per 10 leaflets in 5 palms before spray was 65.37 ± 2.15 which was reduced to 29.52 ± 1.48 (medium intensity) after first spray, 12.63 ± 1.27 spirals per 10 leaflets was observed after 2nd spray and 9.45 ± 1.13 spirals per 10 leaflets after third spray. So, it clearly indicated that the regular spraying of Azadirachtin 10,000 ppm can reduce the intensity of whitefly incidence (Table 2) without resorting to chemical insecticides. This demonstration convinced nursery growers and large-scale spraying of coconut palms on borders and nursery plants at need-based interval with Azadirachtin 10,000 ppm @ 1ml was done.

Table 1. Incidence and intensity of *A. rugioperculatus* on various plants in Kadiyam nurseries of Andhra Pradesh

S. No	Common name	Scientific name	Spirals per leaflet/leaf	Intensity
1	Coconut	<i>Cocos nucifera</i>	>30	High
2	Oil palm	<i>Elaeis guineensis</i>	>30	High
3	Cocoa	<i>Theobroma cacao</i>	<10	Low
4	Banana	<i>Musa sp</i>	10 -20	Medium
5	Indian shot	<i>Canna indica</i>	10 -20	Medium
6	Seethaphal	<i>Annona squamosa</i>	Spirals on entire leaf	High
7	Curry leaf	<i>Murraya koenigii</i>	Spirals on entire leaf	Medium
8.	Jack fruit	<i>Artocarpus heterophyllus</i>	Lower no of spirals	Low
9	Papaya	<i>Carica papaya</i>	<10	Low
10	Yam	<i>Colacasia sp</i>	<10	Low
11	Mango	<i>Mangifera indica</i>	Lower no of spirals<10	Low
Ornamentals				
12	Bird of paradise	<i>Strelitzia reginae</i>	<10 (Low)	
13	Fish tail palm	<i>Wodyetia bifurcata</i>		
14	Spider lily	<i>Lycoris sp</i>		
15	Areca palm	<i>Chrysalidocarpus lutescens</i>		
16	Cabbage tree	<i>Pisonia alba</i>		
17	Rose apple	<i>Syzigium malaccense</i>		
18	Heliconia	<i>Heliconia stricta var. Iris Red</i>		

Table 2. Effect of Azadirachtin 1% EC on rugose spiralling whitefly:

Mean no. of egg spirals per 10 leaflets in 5 palms			
Before spray	After 1 st spray	After 2 nd spray	After 3 rd spray
65.37±2.15	29.52±1.48	12.63±1.27	9.45±1.13

Efficiency of yellow sticky traps in attracting rugose white fly

Use of locally made yellow sticky traps (yellow colour tarpaulin sheet used for fish pond bunds purpose available and

sufficient to prepare 10 traps of 1 m x 1 m size smeared with castor oil at seven to ten days interval) (Fig. 2) was promoted instead of commercially available A4 size yellow sticky traps. The locally prepared yellow sticky traps were durable and cost effective. These yellow sticky traps were wound around coconut palm trunks at 5 feet height (Fig. 3) and alternatively hung in between the lanes by tying to two poles. The adults, pupae and spirals of RSW per 20 leaflets in lower whorl coconut leaf were counted and compared to those on palms where sticky traps were absent. The observations from Vijaya Durga nursery, Kadiyapulanka, East

Godavari revealed that the palms with yellow sticky traps recorded 18.00 ± 1.81 , 37.90 ± 3.11 and 14.70 ± 0.91 number of adults, pupae and spirals per coconut leaf, respectively. While the palms without yellow sticky traps had a significantly high number of adults, pupae and spirals. The number of adults, pupae and spirals per leaf on yellow sticky trap installed palms at Sri Satyadeva nursery were 9.90 ± 1.45 , 42.15 ± 5.54 and 16.05 ± 1.91 , respectively. Further, the palms without yellow sticky traps recorded significantly high number of 69.10 ± 3.16 adults, 97.90 ± 3.50 pupae and 25.95 ± 1.05 egg spirals per leaf (Table 3).



Fig. 2. Indigenously developed yellow sticky trap with RSW

The results of these two experiments show that the azadirachtin 1% and yellow sticky traps had significantly reduced the number of whiteflies per palm than the control palms. However, the RSW infested palms have to be monitored continuously for the population buildup of RSW. The yellow sticky traps need frequent maintenance by cleaning and application of castor oil and the Azadirachtin sprays has to be given in 15 to 20 days interval.

Biological control

Field release of parasitoid *Encarsia guadeloupae* and its establishment

Parasitoids viz., *E. guadeloupae* Viggiani (Hymenoptera: Aphelinidae) was known to parasitise *A. rugioperculatus* while Poorani and Thanigairaj, 2017 reported *Encarsia dispersa* Polaszek parasitizing *A. rugioperculatus* in surveys conducted at Tamil Nadu. A heavy parasitisation ranging from 40 to 70% was recorded on banana alone by *E. guadeloupae* (Poorani and Thanigairaj, 2017). The survey conducted by Selvaraj *et al.* (2016) recorded 20–60% parasitism of *A. rugioperculatus* by *E. guadeloupae* on coconut in Tamil Nadu and Kerala. Among the two parasitoids, *E. guadeloupae* was more predominant, causing 60–70% overall parasitism while *E. dispersa* was found in much fewer numbers and the extent of parasitism was <5% (Poorani and Thanigairaj, 2017). The surveys in Andhra Pradesh and especially in Kadiyam nurseries revealed absence of this parasitoid. Hence, with special concentrated efforts the parasitoid consignments of *E. guadeloupae* were regularly obtained from ICAR- CPCRI, Kasargod, Kerala, ICAR-NBAIR, Bangalore and TNAU, Tamil Nadu and released in the white fly infested nurseries in 2017, 2018, 2019 and by 2019 this parasitoid established excellently and more than 50 per cent parasitisation of RSW pupae was recorded (Fig.4 & 5). The establishment of the parasitoid was very low in the initial years of release but by 2019-20 the rate of parasitisation increased.

Field evaluation of *Isaria fumosorosea* (NBAIR Pfu-5) against rugose spiraling whitefly carried out by ICAR-NBAIR, Bangalore in association with DRYSRHU

Field experiments were conducted in Madavaraidupalem in Kadiyam mandal, East Godavari district, and Kalavalapalli

village in West Godavari district, Andhra Pradesh (two gardens) during November-March, 2018-19



Fig. 3. Yellow sticky traps wrapped around the trunk of coconut palm

Table 3: Population of adult RSWF, Pupae and number of spirals in palms with and without yellow sticky traps.

Vijaya Durga Nursery, Kadiyapulanka , East Godavari			
	Adults	Pupae	Spirals
With Yellow sticky trap	18.00 ± 1.81	37.90 ± 3.11	14.70 ± 0.91
Without Yellow sticky trap	66.50 ± 4.32	88.20 ± 6.06	26.30 ± 1.08
Sri Satya Deva Nursery, Kadiyapulanka, East Godavari			
With Yellow sticky trap	9.90 ± 1.45	42.15 ± 5.54	16.05 ± 1.91
Without sticky trap	69.10 ± 3.16	97.90 ± 3.50	25.95 ± 1.05

(Average for 20 leaflets in lower whorl coconut leaf (Mean ± SE))

to field evaluate the efficacy of *I. fumosorosea* against RSW revealed that *I. fumosorosea* Pfu-5 reduced the egg hatching (62-78%), caused mortality on early nymphal instars (52-68%) and late nymphal instars (48-63%) with overall reduction upto to 60-79% at different location. The

fungus killed all the developmental stages of RSW under field conditions however during high temperatures there is a comparatively lower suppression of eggs (18.6%), nymphs (20.3%) and adults (9.45%) at a temperature of >35°C. The promising results with *I. fumosorosea* Pfu-5

spraying were obtained in Kadiyam region as regular sprays were carried out by all nursery men at 10 to 15 days interval with high jet sprayers and were adopted as a low cost alternative to Azadirachtin 10000 ppm. Especially the spraying operations were initiated very early in the season as and when initial RSW population was observed (below 5 spirals per plant) in the month of September itself and the initial sprays coupled with collective spraying operations created more impact and successfully arrested and reduced RSW population build up.



Fig. 4. Paralysed (blackish) and unparalysed (light brown) RSW Pupae

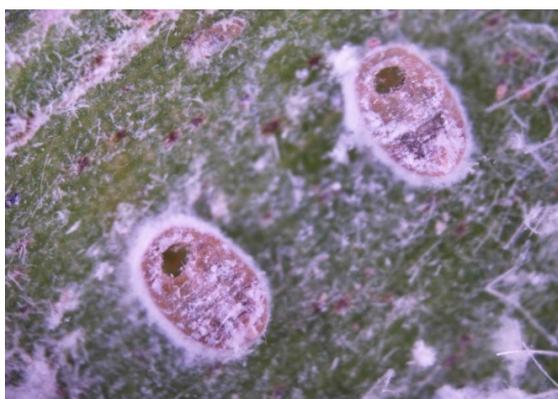


Fig. 5. Parasitoid emergence hole in RSW pupae

Predator *Pseudomallada astur* against Rugose spiraling white fly

The natural population of *P. astur* was observed feeding on the eggs and nymphs of RSW at Kadiyam and Kadiyapulanka villages of East Godavari, Andhra Pradesh. The *P. astur* grubs were collected from nursery at Kadiyapulanka. These grubs were reared at parasite breeding station, Horticultural Research Station, Ambajipeta using corcyra eggs. The grubs were reared in individual vials until pupation and then adults were transferred into the adult rearing cages. Adult insects were reared on artificial protein rich diet which is provided in semisolid paste. This diet consisted of equal parts of yeast, fructose, honey, Proteinex R and water. The adults lay eggs on the brown sheet provided on the lid of the rearing cage. The adults were collected on daily basis and transferred into fresh rearing cage with fresh food. From the old cages, the brown paper sheets along with *P. astur* eggs were removed and made into small pieces with 5-10 eggs. These small cuttings were clipped on the underside of RSW infested coconut leaves. The eggs of *P. astur* are available in the HRS, Ambajipeta and priced at Rs. 150 for 1000 eggs.

Though this predator is found in good numbers in field an augmentative release of this natural enemy is thought to provide a greater impact as the population of RSW was generally high during the favourable season with multitude of plant hosts. Accordingly, large scale multiplication of *P. astur* was carried out in bio control lab Ambajipeta and in 2018-19 about 3,47,000 eggs were supplied and in 2019-20 about 21.40 lakhs eggs were supplied to plantation farmers and nursery growers were also in forefront in taking consignments of this predator eggs and clipping them in their nurseries regularly. Good buildup of this predator population was observed over the

years in the nurseries strengthening the base of biological control.

Capacity building programs to nursery growers on farm production of *Isaria fumosorosea* (NBAIR Pfu-5)

As large-scale production of *I. fumosorosea* and field supply by the government institutes was very difficult hence, training programs on self-production of entomopathogenic fungus *I. fumosorosea* were conducted to progressive nursery growers of Kadiyam region on production of this fungus on broken rice in their own farm at a low cost. A nucleus culture of the fungus was supplied to the needy nursery farmers and the nursery growers were assured of quality check of the fungal stock produced by them. The nursery growers were provided with a production kit and pamphlet as ready reckoner to encourage them for producing these fungi. On farm training and demonstrations were also conducted on preparation of spray fluid, mode of spraying and precautions to be taken during spraying at regular intervals and the field impact of entomopathogenic fungus was also shown through sample collections

Strengthening extension network: Utilisation of the staff (Village Horticulture assistants and Agriculture assistants) working in Rythu Bharosa Kendras (RBKs)

The government of Andhra Pradesh has come up with a new concept of Rythu Bharosa Kendras (Farmer Assurance Centres) at village level to have a platform at the village level to improve the services of government in qualitative and quantitative terms especially to deliver the farm advisory services and have Dr. YSR Horticultural University as technical partner. The VHAs

and VAAs employed in Kadiyam region were thoroughly trained in promoting management of RSW in nurseries of Kadiyam region. The constant guidance to VHAs and VAAs by Assistant Director of Horticulture and local Horticultural officer along with scientists of research station brought the extension system more closely to nursery community of Kadiyam region. The Village Horticulture assistants and Agriculture assistants role was pivotal in monitoring the status of RSW and assisting in carrying out timely sprayings and supplying stock culture of entomopathogen *I. fumosorosea*. Their constant vigil and supervision was instrumental in managing the RSW incidence in this region effectively.

Awareness through print and electronic media

The local print and electronic media actively disseminated all information pertaining to the activities taken by University and Horticulture department in managing RSW and reached the unreached nursery growers.

The free movement of the plant material from one place to another is unavoidable accordingly the chances of introducing alien insect pests and diseases are also high posing threat to biodiversity of the introduced region. Against RSW the management strategies of spraying of Azadirachtin 1% EC, installation of yellow sticky traps, conservation biological control using *E. guadeloupae* coupled with need based releases of predatory insect *P. astur* and utilizing entomopathogenic fungi *I. fumosorosea* as another spraying option offered a integrated package for managing RSW. Ultimately awareness campaigns and programmes, including practical demonstrations conducted regularly showed

a tremendous impact at grass root level in effectively managing RSW in Kadiyam nurseries paving way and giving impetus for pesticide free management approach and showcasing strength of biological control once again.

Management strategies recommended for RSW in Andhra Pradesh

1. Avoid transportation of coconut seedling or any other ornamental plants from pest infested areas to new un infested areas
2. Release of *P. astur* @ 100 to 150 eggs / palm during low incidence and up to 300 eggs/ palm during medium incidence for at least 10 per cent of infested palms particularly in those plantation where spraying is not feasible
3. Re-distribution of *E. guadeloupae* in RSW infested areas
4. Avoiding Pesticides spray
5. Spraying Azadirachtin @ 1% @ 1 ml per litre along with detergent powder @ 10 gms two / three sprays at 15 -20 days interval.
6. Foliar application of entomopathogenic fungi *I. fumosorosea* @ 1×10^8 spores/ml (5 gm /litre along with sticker 2 ml/litre)
7. Intermittent Jet water spray at fortnightly intervals
8. Installation of yellow sticky traps on palm trunk to attract adult white flies and regular smearing with castor oil at 7 to 10 days interval
9. Community based approach for management.

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