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Research Article

BIOLOGY, DISTRIBUTION AND HOST RANGE OF NEW INVASIVE PEST OF INDIA COCONUT RUGOSE SPIRALLING WHITEFLY *ALEURODICUS RUGIOPERCULATUS* MARTIN IN TAMIL NADU AND THE STATUS OF ITS NATURAL ENEMIES

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Abstract: Intensive field survey was undertaken during August 2017 to February 2019 in major coconut growing districts of Tamil Nadu to study the distribution, host range and natural enemies of new invasive pest in India coconut, Rugose spiralling whitefly (RSW) *Aleurodicus rugioperculatus* Martin. The new invasive pest completed its life cycle in 59.00± 3.2 days in coconut with egg, nymphal, pupal and adult period of 6.9±0.88, 19.57±2.17, 10.9±0.78 and 22.7±3.48 days respectively. The RSW incidence were recorded in Coimbatore, Tiruppur, Erode, Theni, Pudukottai and Kanyakumari districts of Tamil Nadu. The rugose spiralling whitefly incidence was high in Coimbatore district followed by tiruppur and Erode. Survey carried out in Tamil Nadu showed the occurrence of rugose spiralling whitefly in21 hosts belonging to 15 botanical families. Among all host plants coconut and banana are the most preferable hosts to RSW. In this present study 9 predators (3 from Neuroptera, 5 from Coleoptera and one from hymenoptera) and one parasitoid belongs to the family Aphelinidae (*Encarsia guadeloupae* Viggiani) were observed. Among the natural enemies *E. guadeloupae* is the predominant parasitoid with the potential of parasitizing RSW upto70-80%. The field samples collected from Kanyakumari district had more parasitization (60.75%) by *E. guadeloupae* followed by Coimbatore (58.60%) and Tiruppur(56.06%) district.

Keywords: *Coconut, Encarsia, Invasive, Rugose, Whitefly*

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Introduction

The whitefly genus *Aleurodicus* Douglas encompasses 35 species, of which only the spiralling whitefly *Aleurodicus disperses* Russel was so far known to occur in India. The Rugose Spiraling Whitefly (RSW) (*Aleurodicus rugioperculatus*) was described by Martin from Belize in Central America in 2004 based on puparia collected under the leaves of Coconut [2]. The rugose spiraling whitefly, *Aleurodicus rugioperculatus* Martin (Hemiptera: Sternorrhyncha: Aleyrodidae) has been recently reported in India from Tamil Nadu, Karnataka, Kerala and Andhra Pradesh[8]. India is the only country in the Oriental region where the whitefly has been introduced. It is an invasive pest that attacks a wide range of host plants including palms, woody ornamentals and fruits. Coconut and banana are among the most preferred host plants. The RSW is highly polyphagous with 118 hosts belonging to 43 plant families including economically important crops in the United States [1]. It mainly infests coconut palms and other broad-leaved hosts in its native range [3]. Heavy sooty mould deposition and near total drying of leaves were observed on banana in some places. The pest is somewhat superficially similar in its habits and general appearance to spiralling whitefly (*Aleurodicus disperses* Russell), which itself is an invasive pest that came to India in the mid-1990s. Rugose whitefly feeding causes stress to the host plant by removing water and nutrients and also by producing honeydew, which covers the lower leaves and results in the growth of sooty mold. Although sooty mold is not a plant disease, its presence on the upper surface of the leaf can potentially reduce photosynthesis of the plant. Hence studying the biology, distribution, host range and association of natural enemies of new invasive pest in Tamil Nadu is essential.

Materials and Methods

Survey for distribution of *A. rugioperculatus* and occurrence of its natural enemies Intensive field survey was undertaken during August 2017 to February 2019 in major coconut growing districts of Tamil Nadu viz., Coimbatore, Tiruppur, Erode, Theni, Pudukottai and Kanyakumari (132 locations from 6 districts) [Fig-1]. To study the intensity damage of *A. rugioperculatus*. A standard evaluation system was formulated based on the percent intensity of damage as follows:

$$Intensity\ of\ damage\ (\%) = \frac{No\ of\ fronds\ infested/Tree}{Total\ no\ of\ fronds\ observed/tree} \times 100$$

During the survey in different districts of Tamil Nadu, the host range of *A. rugioperculatus* was also observed. The predators and parasitoids were collected during the survey and identified at biosystematics laboratory, Department of Agricultural Entomology, Tamil Nadu Agricultural University. The distribution of important predators and parasitoids were also studied in Tamil Nadu.

Biology of *A. rugioperculatus* on coconut

Biology of *A. rugioperculatus* was studied on dwarf coconut trees at 25 to 30°C with relative humidity of 70 to 85 percent at coconut farm, Tamil Nadu Agricultural University. The observations were made as detailed below.

Egg period

Ten leaves with egg spirals were tagged with date of egg laying and the clip cages were removed after egg laying by female. The leaves with egg spirals were collected and kept in a plastic container for the emergence of nymphs from the eggs. The leaves were examined every 24 h. for the nymphal emergence.

Incubation period was calculated from date of egg laying to till the nymphal emergence.

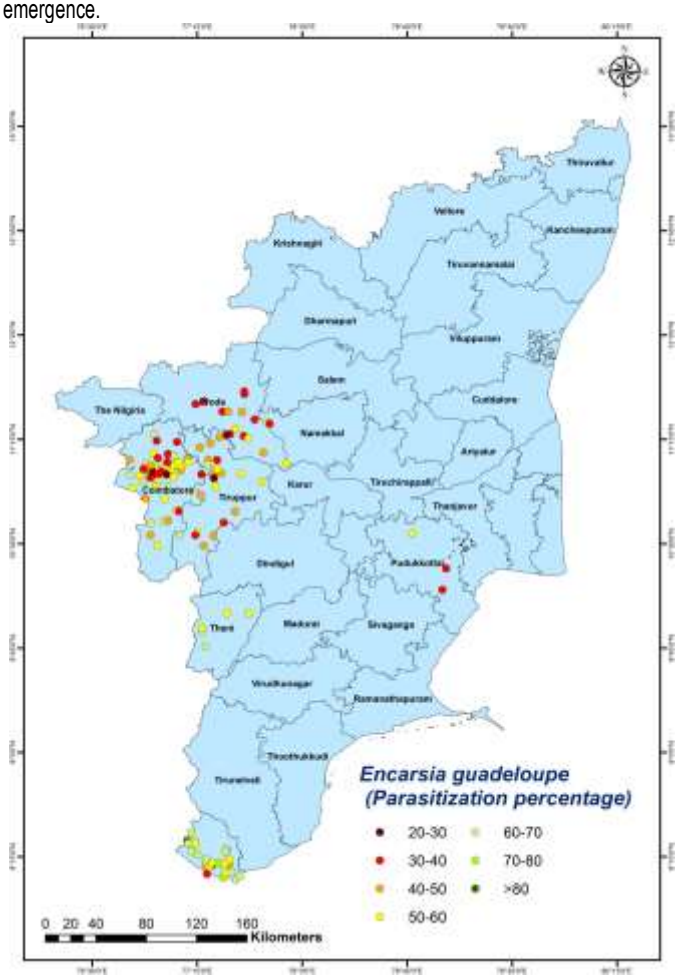

Fig-1 Natural parasitisation potential of *Encarsia guadeloupe* on RSW from different district of Tamil Nadu

Nymphal period

Observations were made on the nymphal period from the respective leaves. Ten leaves with first instar nymphs were tagged with date of emergence. The leaves were examined using a hand magnifier (15x) on every 24 h. to study the nymphal growth and development. The period of each instar from first to fourth instar nymphs and the total developmental time were recorded.

Pupal period

Ten leaves with fourth instars were tagged to study the pupal duration. The leaves were examined using a hand magnifier (15x) on every 24 h. for the emergence of adults from the pupae. The pupal duration was recorded on various host plants.

Adult emergence

Ten leaves with pupae were covered with respective cages to trap the adults that emerged from pupae. The pupae were examined on every 12h. for emergence of adults and percent adult emergence was calculated.

Adult longevity

Five freshly emerged males and females were released on respective host plants confined within in a small leaf clip-cage. Ten replications were maintained. The caged adults were observed daily for mortality. Survival of adults was recorded daily till all the adults died. The period between the release of adults and the adult mortality was recorded as the adult longevity.

Total developmental period

Total developmental period was calculated from date of egg laying to adult emergence on the respective host plant.

Analysis of natural parasitization potential of *Encarsia guadeloupae*

During the survey rugose spiraling whitefly infested samples were collected from the field were kept under laboratory condition to observe emergence of parasitoids. The number of puparial cases with and without emergence home made by the parasitoids was examined under microscope to analysis the percent natural parasitism by *Encarsia guadeloupae*. The overall distribution map of *A. rugioperculatus* in Tamil Nadu was prepared along with parasitisation potential of *Encarsia guadeloupae* [Fig-1].

Percent of parasitization

$$Percent\ parasitization = \frac{Number\ of\ parasitized\ whitefly\ nymphs}{Total\ number\ of\ whitefly\ nymphs} \times 100$$

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

Table-1 *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; presence of sooty mold encrustation in 5- 6 lowermost fronds	1	Low	0.01 to 1.0
Ten to 20 egg spirals per leaflet; 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

$$Infestation\ Index = \frac{(No.\ of\ palms\ under\ Scale\ 0\ X\ 0) + (No.\ of\ palms\ under\ Scale\ 1\ X\ 1) + \cdots . + (No.\ of\ palms\ under\ Scale\ 3\ X\ 3)}{Total\ no.\ of\ palms\ observed}$$

Based on this infestation index formula developed by Srinivasan *et al.*(2016). The coconut varieties were screened for the assessing the infestation of rugose spiralling whitefly.

Statistical analysis

The data were analyzed using analysis of variance (ANOVA) using AGRES 3.01 and AGDATA software. Data in the form of percentages were transformed to arcsine values and those in numbers were transformed to $\sqrt{x}$+0.5 and analyzed. The mean values of the treatments were compared using DMRT at 5 percent level of significance

Results and Discussion

Biology of *A. rugioperculatus* on coconut

Egg stage

Eggs were smooth, elliptical, whitish to yellow, translucent and deposited mainly on under surface of the leaves of coconut. Eggs were 0.3426 ± 0.0027 mm length and 0.1720 ± 0.003 mm width. Eggs were laid in characteristic spiral manner covered with waxy coat. It is having incubation period of 6.9±0.88 days.

Nymphal stage

There were four distinct nymphal instars. The first instar nymphs called crawlers had functional walking legs and antennae. They were translucent, yellowish green, elliptical with a convex dorsum. The first instar nymphs were 0.3730 ± 0.0068 mm length and 0.2132 ± 0.0045 mm width. The mean duration of first instar nymph is 5.8±0.78 days. The second instar nymphs were oval, translucent and had many marginal fringes of wax covering the body of dorsum. The second instar nymphs were 0.3839±0.0475 mm length and 0.2387 ± 0.0203 mm width. The developmental duration of second instar nymphs is 5.40±0.50 days. The third instar nymphs were oval with 0.6227 ± 0.0518 mm length and 0.4148 ± 0.0494 mm width. They had numerous evenly spaced waxy rods on the margin of the body produced from abdominal pores with more wax secretion covering the body. The duration of third instar nymph is 8.37±0.89 days. The fourth instar nymphs were 0.6667 ± 0.0804 mm length and 0.4317 ± 0.0334 mm width. The body was covered entirely with copious amount of white waxy materials.

Pupal stage

Puparia of *A. rugioperculatus* are characterized by an apically acute lingual that is exerted and slightly short of the posterior margin of the pupa and a quadrate operculum with wrinkled or 'rugose' texture. The marginal pores are arranged laterally and posteriorly into clusters that occur between the marginal compound pores. It is having developmental period of 10.9±0.78 days.

Table-2 Biology of Rugose spiralling whitefly on coconut

SN	Life stages of Rugose spiralling whitefly	Period (Mean ± SD*)
1	Egg	6.9±0.88 days
2	I Instar	5.8±0.78 days
3	II Instar	5.40±0.50 days
4	III Instar	8.37±0.89 days
5	IV Instar	10.9±0.78 days
6	Adult	22.7±3.48 days
	Total life period	59.00± 3.2 days

Table-3 Intensity of damage of *A. rugioperculatus* in Tamil Nadu

SN	Districts	Intensity of damage (%)*
1	Coimbatore	62.86(52.45)[a]
2	Tiruppur	56.06 (48.48)[b]
3	Erode	54.43 (47.54)[b]
4	Pudukottai	47.06 (43.41)[c]
5	Theni	52.94 (46.68)[b]
6	Kanyakumari	40.96 (39.79)[d]
	SEd	2.2795
	CD (P = 0.05)	4.7550

*Mean of five locations; significant at 1%; figures in parentheses are arc sine transformed values; in a column, means followed by a common letter(s) are not significantly different by DMRT (P = 0.05)

Adult stage

Adults emerged from the pupae through a 'T' shape exit slit on the dorsal surface of the pupae. The wings of newly emerged adults were clear after unfurling, later covered with a coat of white waxy powder. The eyes were dark reddish brown and each forewing had two characteristic dark spots. The adult longevity range is 22.7±3.48 days. Still now there is no biology and lifecycle studies related rugose spiralling whitefly [Table-2].

Survey on intensity of damage by *A. rugioperculatus*

The results on the distribution and intensity of damage of *A. rugioperculatus* in in Tamil Nadu coconut rugose spiralling whitefly incidence were recorded in Coimbatore, Tiruppur, Erode, Theni, Pudukottai and Kanyakumari districts of Tamil Nadu. The rugose spiralling whitefly incidence was high in Coimbatore (62.86%) district followed by tiruppur(56.06%) and Erode (54.43%).

Host ranges of *A. rugioperculatus*

In the present study, a total of 21 plant species from 15 families were recorded as hosts of *A. rugioperculatus*. Among the host plants 8 hosts were infested by *A. rugioperculatus* in which all the life stages of whitefly were noticed whereas in other 12 host plants only the eggs stages were documented [Table-4]. In this host ranges coconut and banana plant species are having heavy infestation by *A. rugioperculatus*. A total of 17 plant species under 11 families were recorded as preferred hosts of *A. rugioperculatus* at Kerala [6].

Table-4 Host ranges of rugose spiraling whitefly

Table-4a Hosts in which all life stages of rugose spiraling whitefly noticed

SN	Common Name	Botanical Name	Family
1	Coconut*	*Cocos nucifera* L.	Arecaceae
2	Banana	*Musa paradisiaca* L.	Musaceae
3	Custard apple	*Annona squamosa* L.	Annonaceae
4	Citrus	*Citrus limon* (L.)	Rutaceae
5	Nutmeg	*Myristica fragrans* (Houtt.)	Myristicaceae
6	Guava	*Psidium guajava* L.	Myrtaceae
7	Cacao	*Theobroma cacao*	Malvaceae
8	Tapioca	*Manihot esculanta* Crantz	Euphorbiaceae

Table-4b Hosts subjected to oviposition by rugose spiralling whitefly

SN	Common Name	Botanical Name	Family
1	Arecanut	*Areca catechu* L.	Arecaceae
2	Neem	*Azadirachta indica* A. Juss.	Meliaceae
3	Jatropha	*Jatropha curcas* L.	Euphorbiaceae
4	Mango	*Mangifera indica* L.	Anacardiaceae
5	Bhendi	*Abelmoschus esculentus*	Malvaceae
6	Black pepper	*Piper nigrum* L.	Piperaceae
7	Sapota	*Achras zapota*	Sapotaceae
8	brinjal	*Solanum melongena*	Solanaceae
9	Cotton	*Gossypium hirsutum*	Malvaceae
10	Maize	*Zea mays*	Gramineae
11	bajra	*Pennisetum glaucum*	Poaceae
12	Hibiscus	*Hibiscus rosasinensis* L.	Malvaceae

Natural enemies of *A. rugioperculatus*

In the present study we were recorded one species of aphelinid parasitoid and 9 species of predators against this new invasive pest [Table-5]. Which are naturally available in rugose spiralling whitefly affected coconut gardens and also in other host plants. Among all-natural enemies *Encarsia guadeloupae* plays a major role in controlling of new invasive pest the natural parasitisation range is from 20 to 80% [Table-6]. Parasitisation range of *E. guadeloupae* is 40 to 70% in banana crop ecosystem [5]. 20-60% parasitism of *A. rugioperculatus* by *E. guadeloupae* on coconut in Tamil Nadu and Kerala [7].

Table-5 Natural enemies of *A. rugioperculatus*

Predator groups	Scientific Name	Order and Family
I. Chrysopids	*Malladaastur* (Banks)	Neuroptera, Chrysopidae
	Mallada boninensis Okamoto	Neuroptera, Chrysopidae
	Chrysoperla zastrowi sillemi (Esben - Petersen)	Neuroptera, Chrysopidae
II. Cybocephalid	*Cybocephalus* spp.	Coleoptera, Cybocephalidae
III. Coccinellids	*Cryptolaemus montrouzieri* Muls.	Coleoptera, Coccinellidae
	Chilocorus nigrita (Fabricius)	Coleoptera, Coccinellidae
	Menochilus sexmaculatus Fab.	Coleoptera, Coccinellidae
	Curinus coeruleus (Mulsant)	Coleoptera, Coccinellidae
IV. Red ant	*Oecophylla smaragdina* Fab.	Hymenoptera, Formicidae
Parasitoid group		
I. Aphelinid	*Encarsia guadeloupae* Viggiani	Hymenoptera, Aphelinidae

Table-6 Natural parasitization of RSW by *Encarsia guadeloupe*

SN	Districts	Natural parasitisation (%)*
1	Coimbatore	58.60
2	Tiruppur	56.06
3	Erode	47.06
4	Pudukottai	54.43
5	Theni	52.94
6	Kanyakumari	60.75

*Mean of twenty samples

Table-7 Damage of *A. rugioperculatus* in different coconut verities

Coconut variety	No. of palms under the Grade*				Infestation index	Category
	0	1	2	3		
Chowghat Orange Dwarf (COD)	0	13	10	27	2.28	High
West Coast Tall (WCT)	36	10	4	0	0.64	Low
Malayan Yellow Dwarf (MYD)	0	11	15	24	2.23	High
Malayan Green Dwarf (MGD)	2	17	12	20	2.02	High
Kenthali Dwarf (KTD)	17	11	22	0	1.76	Medium
Arasampatti Tall (ART 1)	32	16	2	0	0.76	Low
COD X WCT hybrid	0	18	13	29	2.32	High

Infestation index of *A. rugioperculatus*

Based on the rating scale we observed that the dwarf coconut palms were more susceptible for rugose spiralling whitefly comparing to tall palms. Chowghat Orange Dwarf (COD), Malayan Yellow Dwarf (MYD), COD X WCT hybrid and Malayan Green Dwarf (MGD) showing more damage (High) with infestation index of 2.28,2.23, 2.32 and 2.02 respectively [Table-7].

Kenthali Dwarf (KTD) having 1.76 infestation index with medium level damage followed by West Coast Tall (WCT) and Arasampatti Tall showing minimum infestation index 0.64 and 0.76. Likewise, chowghat orange dwarf and Malayan yellow dwarf are most susceptible for rugose spiralling whitefly [6]. These results will strengthen our present results.

Application of research: Coconut rugose spiralling whitefly is a new invasive pest of India. So, the survey and status of the natural enemies and their alternative host study is needed

Research Category: Agricultural Entomology

Abbreviations: RSW- Rugose spiralling whitefly

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University: Tamil Nadu Agricultural University, Coimbatore, 641003, Tamil Nadu
Research project name or number: PhD Thesis, Bioecology and bio intensive pest management of Rugose spiralling whitefly

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Tamil Nadu *viz*., Coimbatore, Tiruppur, Erode, Theni, Pudukottai and Kanyakumari (132 locations from 6 districts)

Cultivar / Variety name: Nil

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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