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FULL–LENGTH RESEARCH ARTICLE

Distribution, Host Range and Status of Invasive Rugose Spiralling Whitefly, *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae) in Karnataka

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Abstract Rugose spiralling whitefly (RSW), *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae), an invasive pest to the Oriental region was found infesting several plantation crops like coconut, banana, guava, Indian almond, sapota, oil palm, mango, cashew, custard apple and several ornamental plants in southern states of India as well as Assam, West Bengal, Maharashtra, Meghalaya, Odisha, Chhattisgarh and Gujarat. Intensive surveys across different agroclimatic zones of Karnataka revealed that infestation of the pest was severe in coastal and southern region of Karnataka compared to northern region. Molecular characterization of partial mitochondrial cytochrome c oxidase–I gene (658 bp) and morphological characters of the pest and its natural enemies confirms its identity. During the study, 35 host plants were recorded, and several natural enemies viz., parasitoids, *Encarsia guadeloupae*, *Encarsia dispersa* (Hymenoptera: Aphelinidae), predators, *Pseudomallada astur* (Neuroptera: Chrysopidae), *Jauravia pallidula, Cheilomenes sexmaculata* (Coleoptera: Coccinellidae) and *Cybocephalus indicus* (Coleoptera: Cybocephalidae) were also observed feeding on RSW. The parasitoid *E. guadeloupae* was the major parasitoid associated with the pest. Natural parasitism by the parasitoids was ranging from 7–80% in the study area.

Keywords Parasitoids · Predators · *Encarsia* · *Pseudomallada* · *Jauravia* · *Cheilomenes* · *Cybocephalus* · Plantation crops · Ornamental plants · Agroclimatic zones · Invasive pest · Mitochondrial cytochrome c oxidase–I gene

Introduction

Rugose spiraling whitefly (RSW), *Aleurodicus rugioperculatus* Martin, an invasive species was first time reported feeding on gumbo limbo, *Bursera simaruba* in South Florida in 2009. It was first reported on coconut (*Cocos nucifera*) from Pollachi, Tamil Nadu, India during August, 2016 [19, 22], subsequently found feeding on banana, Indian almond, sapota, maize, oil palm, mango, cashew, custard apple and several other ornamental plants in Karnataka, Kerala, Andhra Pradesh, Telangana, Goa, Assam and recently its occurrence was observed in West Bengal, Lakshadweep, Maharashtra, Gujarat, Odisha, Chhattisgarh and Meghalaya. Continuous feeding by nymphs and adults of whitefly leads to water and nutrient loss from its host plants, and release honeydews on the upper surface of the lower leaves that encourages growth of sooty mould which reduces photosynthesis efficiency of the plant [1]. In Indian subcontinent, this invasive pest has spread to several locations and colonizes on several host plants. Earlier workers reported the infestation ranged from 40–60% and 25–40% on coconut and banana, respectively, and even complete drying of banana leaves was also noted in several places of Tamil Nadu and Kerala [19].

Several natural enemies viz., *Encarsia guadeloupae* Viggiani (Hymenoptera: Aphelinidae), *Encarsia dispersa,*

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chrysopids and coccinellids were recorded feeding on RSW. There is a considerable degree of shared parasitism between coconut and intercrop herbivores. Pest populations could thus be suppressed by indirect interactions. Due to its rapid spread, there is a need to study the intensity of damage by the pest across different agroclimatic zones of Karnataka and to understand its favourable hosts, natural enemies and coexistence pattern to develop an effective management strategy against this pest. Keeping in view these, the present study on distribution, host range and status of invasive rugose spiralling whitefly, *Aleurodicus rugioperculatus* in Karnataka was conducted.

Materials and Methods

Study area: Intensive surveys and in situ sampling were carried out once in a week for seven months in plantations, ornamental gardens, kitchen gardens and in field crops, both in rural and urban areas of different districts of Karnataka viz. Mandya, Ramanagara, Chikkamagaluru, Davanagere, Mysuru, Shivamogga, Hassan, Chamarajanagar, Bengaluru rural, Tumakuru, Kolar, Bengaluru urban, Kodagu, Dakshina Kannada, Uttara Kannada, Belgavi, Bagalkote, Bidar, Bellary, Chitradurga, Dharwad, Raichur and Udupi from October, 2018 to April 2019. All these locations are categorized under the ten agroclimatic zones of Karnataka. At least five locations were chosen in each agroclimatic zone for sampling. Intensity of damage and sooty mould growth status in the survey area were categorized into different grades from 0–5 by visual observation (Table 1). Percentage infestation was estimated from the mean sooty mould growth status grades divided by highest grade (five) and multiplied by 100. The leaflet samples were observed under 40 × stereozoom microscopes. The intensity of damage by *A. rugioperculatus* was calculated from the range of egg patches, nymphs, pupae, adults, active stages and parasitized pupae per leaflet (Table 2 and 3) and was presented in the map (Fig. 1).

Table 1 Rating scale adapted to record *Aleurodicus rugioperculatus* infestation during survey

Intensity of Damage (%)	Damage Category	Grade
0	Nil	0
1–20	Very Low	1
21–40	Low	2
41–60	Moderate	3
61–80	High	4
81–100	Very High	5

(Geetha, 2000)

Table 2 Agroclimatic zones of Karnataka state

Zone No	Zone name	District
Z1	North–Eastern Transition Zone	Bidar, Kalaburgi
Z2	North–Eastern Dry Zone	Kalaburgi, Yadgir, Raichur
Z3	Northern Dry Zone	Koppal, Gadag, Dharwad, Belgavi, Vijayapura, Bagalkot, Bellary, Davanagere, Raichur
Z4	Central Dry Zone	Chitradurga, Davanagere, Tumakuru, Chikkmagaluru, Hassan
Z5	Eastern Dry Zone	Bengaluru rural, Bengaluru urban, Ramanagar, Kolar, Chikkaballapur, Tumakuru
Z6	Southern Dry Zone	Mysuru, Chamarajanagar, Mandya, Tumakuru, Hassan
Z7	Southern Transition Zone	Hassan, Chikkamagaluru, Shivamogga, Mysuru, Davanagere
Z8	Northern Transition Zone	Belgavi, Dharwad, Haveri, Gadag
Z9	Hilly Zone	Uttara Kannada, Belgavi, Dharwad, Haveri, Shivamogga, Chikkamagaluru, Kodagu, Hassan
Z10	Coastal Zone	Udupi, Dakshina Kannada, Uttara Kannada

Morphological and molecular identification of whitefly and natural enemies: The identification of whiteflies is mainly based on the fourth larval instar, the so–called puparium. Infested host plant leaves with puparium were collected and wrapped in paper envelope [2] and adult whiteflies were collected in 70% ethanol along with relevant collection data for morphological and molecular identification, respectively. Part of the collected host plant leaves/ parts infested with immature stages and puparium were placed in rearing jar (21 × 10 cm) up to 10–15 days to check the emergence of parasitoids. The parasitoids emerged were collected using aspirator and preserved in vials containing 70% ethanol for further identification. Assessment of parasitism was determined based on the number of pupae parasitized as against unparasitized pupae in the host leaves.

Identification of the species was carried out at ICAR–National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru. Permanent mounts of the puparium were prepared [14]. Taxonomy of the natural enemies was confirmed and its host plants were identified. Molecular characterization of partial mitochondrial cytochrome c oxidase I (COI) (658 bp) gene of adult RSW was carried out from samples of five different locations of Karnataka. The extracts were subjected to PCR amplification of 5' terminus of the *COI* gene by following standard protocols.

Table 3 Infestation of *Aleurodicus rugioperculatus* and natural parasitism in different agroclimatic zones of Karnataka

Zone No	Avg. egg patches/ leaflet	Avg. nymphs /leaflet	Avg. pupae /leaflet	Avg.adults /leaflet	Avg. active stages/ leaflet	Avg parasitized pupae/ leaflet	Avg parasitoid adult emerged	Parasitization (%)	Parasitoid adult emergence (%)	Mean sooty mould status	Mean infestation (%)
Z1	4.0	33.5	11.6	12.2	2.8	1.9	0.6	17.5	40.8	2	40 (Low)
		(29.2–37.8)	(10.7–12.5)	(11.8–12.7)	(2.7–3.0)	(1.8–2.1)	(0.6–0.7)	(16.7–18.3)	(38.3–43.3)		
Z2	2.65	19.5	11.7	10.7	2.1	1.7	0.5	15.2	33.3	2	30 (Low)
	(1.6–3.7)	(16.1–22.9)	(10.7–12.7)	(9.6–11.8)	(1.5–2.7)	(1.7–1.8)	(0.5–0.6)	(13.8–16.7)	(28.3–38.3)		
Z3	3.0	29.7	17.1	17.8	3.5	3.4	1.3	20.1	40.0	2	30 (Low)
	(1.9–4.1)	(27.7–31.7)	(14.0–20.2)	(17.2–18.4)	(3.0–4.0)	(2.3–4.5)	(0.8–1.8)	(17.7–22.6)	(36.7–43.4)		
Z4	4.8	71.6	58.5	43.2	5.7	38.1	14.9	8.5	41.2	2	35 (Low)
	(1.6–8.0)	(17.4–125.8)	(9.7–107.4)	(8.5–77.9)	(1.7–9.7)	(0.9–75.3)	(0.4–29.5)	(6.7–10.4)	(30.0–52.5)		
Z5	7.7	133.8	106.1	58.3	7.0	80.6	37.8	39.6	45.6	3	50.59 (Moderate)
	(1.6–13.9)	(16.2–251.4)	(9.2–203.0)	(9.4–107.2)	(1.6–12.5)	(1.3–159.9)	(0.3–75.3)	(7.2–72.0)	(11.7–79.6)		
Z6	7.6	166.05	117.7	61.3	9.1	83.4	37.9	51.6	47.5	4	73.33 (High)
	(2.7–12.6)	(60.4–271.7)	(33.0–202.4)	(27.0–95.6)	(4.7–13.6)	(8.3–158.5)	(3.4–72.5)	(23.4–79.9)	(23.4–71.6)		
Z7	14.7	303.3	281.2	200.4	21.4	220.2	151.9	70.7	62.0	5	100 (Very high)
	(11.7–17.8)	(281.7–325.0)	(238.2– 324.2)	(98.0– 302.8)	(14.7–28.2)	(150.7–289.7)	(80.0–223.8)	(63.6–77.8)	(54.6–69.4)		
Z8	1.8	14.5	6.5	10.7	2.0	1.8	.7	18.1	30.5	1	20 (Very low)
	(1.6–2.1)	(13.4–15.6)	(6.5–6.6)	(10.6–10.8)	(1.4–2.7)	(1.6–2.1)	(0.5–1.0)	(16.1–20.2)	(28.3–32.8)		
Z9	4.4	62.4	48.0	29.7	4.6	65.1	43.9	37.6	33.6	2	35 (Low)
	(0.0–8.9)	(0.0–124.9)	(0.0–94.1)	(0.0–59.4)	(0.0–9.3)	(0.0–130.3)	(0.0–87.8)	0.0–75.2	(0.0–67.3)		
Z10	9.7	187.6	48.7	6.3	10.6	96.1	66.4	48.9	53.1	4	71.43 (High)
	(6.0 –13.5)	(74.7–300.5)	(62.1–235.4)	(49.8–122.8)	(6.0–15.3)	(13.2–179)	(8.2–124.6)	(21.5–76.4)	(36.8–69.4)		

Numbers in the parentheses indicate the range of different life stages, parasitization (%) and parasitoid adult emergence (%)

Note: Sooty mould growth status

0= Nil; 1= Very low; 2= Low; 3= Moderate; 4= High; 5= Very High

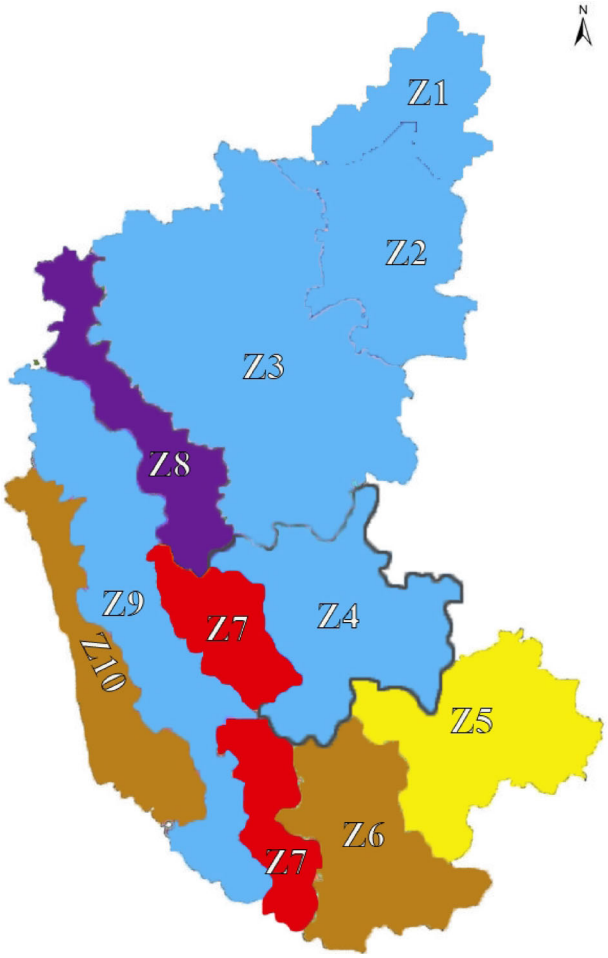

Fig. 1 Distribution and intensity of damage of *Aleurodicus rugioperculatus* in different agroclimatic zones of Karnataka. (Different agroclimatic zones are: Z1: North eastern transition zone, Z2: North eastern dry zone, Z3: Northern dry zone, Z4: Central dry zone, Z5: Eastern dry zone, Z6: Southern dry zone, Z7: Southern transition zone, Z8: Northern transition zone, Z9: Hill zone, Z10: Coastal zone). (Colour notations are: Purple: Very low infestation (1–20%), Blue: low infestation (21–40%), Yellow: Moderate infestation (41−60%), Brown: High infestation (61–80%), Red: Very high infestation (81–100%))

The amplified products were sequenced by M/s Chromous Biotech Pvt Ltd, Bengaluru and the same were uploaded to GenBank after annotation. The sequences were submitted to the NCBI GenBank.

Results

Species identification and confirmation: The assigned accession numbers for the sequences submitted to GenBank were MK883218, MK883219, MK883220, MK926750 and MK926751. Our sequences matched > 90% with the available sequence of *A. rugioperculatus* (accession number KP032219) submitted from Florida, USA (Dickey et al. 2015), thereby confirming the identity of the pest.

Distribution and intensity of damage of *A. rugioperculatus*: The incidence was high on host plants like coconut palm, banana, Indian almond, ornamental palms etc. The level of infestation was very low in Northern transition zone (Z8) and low in North–eastern transition zone (Z1), North–eastern dry zone (Z2), Northern dry zone (Z3), Central dry zone (Z4) and Hilly zone of Karnataka (Z9). The level of infestation was moderate in Eastern dry zone of Karnataka (Z5). The level of infestation was high and very high in Southern dry zone (Z6) and Southern transition zone of Karnataka (Z7), respectively. In very low level of infestation zones, the egg patches, nymphs, pupae and adults per leaflet were ranging from 1.6–2.1, 13.4–15.6, 6.5–6.6 and 10.6–10.8, respectively. The mean sooty mould status was 1, and the infestation level was 20%. In low level of infestation zones, the egg patches, nymphs, pupae and adults per leaflet were ranging from 0–8.9, 0–125.8, 0–107.4, 0–77.9, respectively. The mean sooty mould status was 0–4, and the infestation level was 30–40%.

In moderate level of infestation zones, the egg patches, nymphs, pupae and adults per leaflet were ranging from 1.6–13.9, 16.2–251.4, 9.2–203.0, 9.4–107.2, respectively. The mean sooty mould status was 1–5, and the infestation level was 50.59%. In high level of infestation zones, the egg patches, nymphs, pupae and adults per leaflet were ranging from 2.7–13.5, 60.4–300.5, 33–235.4, 27–122.8, respectively. The mean sooty mould status was 1–5, and the infestation level was 71.43–73.33%. In very high level of infestation zones, the egg patches, nymphs, pupae and adults per leaflet were ranging from 11.7–17.8, 281.7–325.0, 238.2–324.2 and 98–302.8, respectively. The mean sooty mould status was 5, and the infestation level was 100%.

Coexistence with other whiteflies: As many as four exotic whiteflies viz., rugose spiralling whitefly, *Aleurodicus rugioperculatus* Martin; Bondar's nesting whitefly, *Paraleyrodes bondari* Peracchi; nesting whitefly, *P. minei* Iaccarino; palm infesting whitefly, *Aleurotrachelus atratus* Hempel have been reported from different regions in India in rapid succession. During the present study, *A. rugioperculatus*, *P. bondari*, *A. dispersus* and *P. minei* were observed to simultaneous coexistence on many of the host plants (Table 4). We observed *Aleurodicus rugioperculatus* co–existing with *Aleurotrachalus atratus, P. bondari*, *A. dispersus* and *P. minei* on coconut. Infestations of *A. atratus* and *A. rugioperculatus* along with *Aleurocanthus arecae,* a native whitefly species were commonly observed on coconut.

Discussion

Intensive surveys conducted across the state of Karnataka revealed that the level of infestation was quite high in southern and coastal regions (71.43–100%) as compared to northern regions (20–40%). Hot and humid climate along with suitable host plants favoured proliferation of the pest in coastal regions of Karnataka. The pest was reported on several ornamental and commercial plants in Kerala, Karnataka and Andhra Pradesh causing death of the plants in severe cases. The spread to different states might be due to neighbouring state boundaries [5]. If it is unchecked, the pest may spread to other regions of the country.

Host range of *Aleurodicus rugioperculatus*: Invasive pests pose a great threat to natural environment. Strategic management of the pest through the knowledge about host range is quintessential for formulating integrated pest management strategy. A wide range of host plants including palms, woody ornamentals and fruits were found infested with *A. rugioperculatus* [12]. There were around 118 plant species recorded [21]. As per the record from 2009 to 2012 in Florida, 22% of RSW infected hosts were palm species, 16% were gumbo limbo, 10% were *Calophyllum* spp., 9% were avocado, 4% were dark olive and 3% were mango varieties [3]. Inside the family Arecaceae (palms), 44% of host records were from coconut. A sum of 17 plant species under 11 families was recorded as preferred hosts of *A. rugioperculatus* in Kerala [20]. Severe leaf infestation 25–40% was witnessed on banana and total drying of infested leaves in several places in Tamil Nadu and Kerala [19].

During survey, 35 plant species were found infested with *A. rugioperculatus. Cocos nucifera* (coconut), *Musa* sp. (banana) and *Terminalia catappa* (Indian almond) were found heavily infested by *A. rugioperculatus*. Sugarcane, cashew and maize were recorded as host plants for the first time in Karnataka. Plants belonging to the family Arecaceae are mostly favoured by *A. rugioperculatus* infestation. Severe infestation was found on *Dypsis lutescens, Manilkara zapota, Annona squamosa, Annona reticulata.* Moderate infestation was found in *Psidium guajava, Strelitzia reginae, Magnolia champaca, Roystonea regia, Calophyllum inophyllum, Terminalia arjuna, Anacardium occidentale, Mangifera indica, Canna indica, Syzigium cumini, Citrus aurantiifolia, Areca catechu, Artocarpus heterophyllus.* Negligible infestation was found on *Zea mays, Anacardium occidentale, Syzygium samarangense, Piper betle, Ficus elastic, Dypsis lutescens, Licuala grandis, Syzygium cumini, Elaeis guineensis, Thespesia populnea, Combretum indicum, Hibiscus rosasinensis, Ficus religiosa* and *Saccharum officinarum.*

The invasions on various hosts were seen in plantations, kitchen garden and avenue plantations along the interstates and highways. The spread of nuisance was an indication that it might be due to transport of planting materials which harbour the pest and human interventions. Prevailing wind and climatic factors were also additionally assumed to be an indispensable factor in spreading the pest. During the survey, it was observed that intercropping practices was the reason for widespread of the pest to various host plants. Epigenetic changes might help the insect to feed on different host plants having different surface characteristics. When the plants had thick leaf lamina as compared to thin lamina in previous host plants, it tried to change its feeding behaviour in order to sustain in that new host plant.

Pattern of Coexistence: Within a span of two years, four Neotropical non–indigenous, exotic whiteflies were reported from India [7]. The coexistence of these whiteflies in the same palms/ leaves indicates mutual survival of these competing insect species by novel mechanism. Synchrony of coexistence and mutual survival of these competing insect species could be due to the marked time partitioning of the resource use among the species except that they are demographically nearly equivalent and need detailed study. Such co–occurrence has been observed among these invasive species, in which one species occupies the breeding and feeding niche of another species under optimum weather parameters and attempts to displace one or more of its competitors gradually which leads to temporal variation. Further, this mutual survival of more than one species indicates deferred its existing pest management options in various crop plants.

Natural enemies of *A. rugioperculatus:* During the surveys, several parasitoids viz*., Encarsia guadeloupae*, *Encarsia dispersa*, and predators like *Pseudomallada astur*, *Jauravia pallidula, Cheilomenes sexmaculata* and *Cybocephalus indicus* were observed to be feeding on RSW. Among the natural enemies, parasitoids were found most abundant as compared to predators. During the study, parasitism by *E. guadeloupae* was found higher as compared to *E. dispersa.* Adults of *E. guadeloupae* and *E. dispersa* lay their eggs by piercing ovipositor into early instar nymphs of *A. rugioperculatus* preferably on second instar nymphs.

The parasitoid may face the host's venter side during pupation but before emerging as an adult, it turns its face to dorsum side through a hole that is chewed in the dorsum of the host [6]. Upon emergence from the host, the parasitoid species *Encarsia* performs different activities like walking, drumming, turning, mounting on nymphs and preening during host selection, host feeding and oviposition [9]. Host discovery and its suitability were ascertained by antennae movement (antennation) and ovipositor probing. Mass production of *E. guadeloupae* under laboratory

Table 4 Host plants of *Aleurodicus rugioperculatus* in Karnataka

Sl. No	Plant species	Infestation level	Coexistence
1	Coconut palm, *Cocos nucifera* (Arecaceae)	Very severe	*A.dispersus, A. atratus, P. minei, P. bondari*
2	Banana, *Musa* spp. (Musaseae)	Very severe	*A.dispersus, P. minei, P. bondari*
3	Indian almond, *Terminalia catappa* (Combretaceae)	Very severe	*A.dispersus*
4	Sapota, *Manilkara zapota* (Sapotaceae)	Severe	*P. minei, P. bondari*
5	Butterfly palm, *Dypsis lutescens* (Arecaceae)	Severe	*P. minei, P. bondari, A. atratus,*
6	Custard apple, *Annona squamosa* (Annonaceae)	Severe	*P. minei, Pealius nagercoilensis*
7	Ram phal, *Annona reticulata* (Annonaceae)	Severe	*P. minei*
8	Guava, *Psidium guajava* (Myrtaceae)	Moderate	*A.dispersus, P. minei, P. bondari*
9	False bird of paradise, *Strelitzia reginae* (Strelitziaceae)	Moderate	*P. minei, P. bondari*
10	Mango, *Mangifera indica* (Anacardiaceae)	Moderate	–
11	Champak, *Magnolia champaca* (Magnoliaceae)	Moderate	*A.dispersus*
12	Royal Bottle palm, *Roystonea regia* (Arecaceae)	Moderate	–
13	Indian shot, *Canna indica* (Cannaceae)	Moderate	*P. minei*
14	Areca nut, *Areca catechu* (Arecaceae)	Moderate	–
15	Jackfruit, *Artocarpus heterophyllus* (Moraceae)	Moderate	–
16	Jamun, *Syzigium cumini* (Myrtaceae)	Moderate	*P. minei*
17	Citrus, *Citrus aurantiifolia* (Rutaceae)	Moderate	*P. minei*
18	Indian–laurel, *Calophyllum inophyllum* (Calophyllaceae)	Moderate	*P. minei, P. bondari*
19	Arjun, *Terminalia arjuna* (Combretaceae)	Moderate	–
20	Cashew, *Anacardium occidentale* (Anacardiaceae)	Moderate	–
21	Maize, *Zea mays* (Poaceae)	Minor	–
22	Sugarcane, *Saccharum officinarum* (Poaceae)	Minor	–
23	Rose apple, *Syzygium samarangense* (Myrtaceae)	Minor	–
24	Betel vine, *Piper betle* (Piperaceae)	Minor	–
25	Rubber fig, *Ficus elastica* (Moraceae)	Minor	*P. minei*
26	Areca palm, *Dypsis lutescens* (Arecaceae)	Minor	–
27	Ruffled fan palm, *Licuala grandis* (Arecaceae)	Minor	–
28	Malabar plum, *Syzygium cumini* (Myrtaceae)	Minor	*P. minei*
29	Oil palm, *Elaeis guineensis* (Arecaceae)	Minor	*A. atratus, P. minei*
30	Indian tulip, *Thespesia populnea* (Malvaceae)	Minor	*P. minei*
31	Rangoon creeper, *Combretum indicum* (Combretaceae)	Minor	–
32	China rose, *Hibiscus rosasinensis* (Malvaceae)	Minor	*A.dispersus*
33	Ficus *Ficus religiosa* (Moraceae)	Minor	*Singhiella simplex*
34	*Frangipani, Plumeria alba* (Apocynaceae)	Minor	*A.dispersus*
35	*Akashmoni, Acacia auriculiformis* (Fabaceae)	Minor	–

Low = less than 10 live egg spirals or adults/leaflet; Medium = 11–20 live egg spirals or adults/leaflet); Severe = above 20 live egg spirals or adults/leaflet)

conditions was quite a difficult task because of higher sensitivity of nymphs. The nymphs showed mortality when taken out from its natural conditions. Collection of parasitoid adults from heavily parasitized area and releasing in the highly infested area will facilitate decline in the pest population after establishment of the parasitoid in that location. Mass production and release of *Cheilomenes sexmaculata, Pseudomalla astur* will help in reduction of the pest as they are voracious feeder of eggs and nymphs.

Natural enemy complex of *A. dispersus* was earlier documented by several workers in several countries [14–24] of which many are known to feed on *A. rugioperculatus.* Commonly observed natural enemies were *Pseudomallada astur*, *Cybocephalus indicus, Cheilomenes sexmaculata*, *Cryptolaemus montrouzieri* and *Jauravia pallidula*. In case of *C. sexmaculata* and *C. montrouzieri*, both the adult and larval stages fed on the eggs and immature stages of the *A. rugioperculatus*. Continuous feeding by the predators in large numbers showed

subsequent decline in whitefly population. *C. montrouzieri* was also recorded on *A. dispersus* in India and Hawaii [18].

Predatory efficiency of the *C. sexmaculatus* and *Scymnus* sp. was observed on *A. dispersus* on cassava [17], on *Dombeya spectabilis* [4] and mulberry [13] in Tamil Nadu. The adult and grubs of the predator *C. montrouzieri* were also known to feed on other whiteflies like *B. tabaci* [23]. Other predators like *Pseudomallada astur* Banks, *Cybocephalus indicus* and *Jauravia pallidula* were also found feeding on eggs and nymphs of *A. rugioperculatus*. Infestation started from Tamil Nadu, Kerala and its spreading. Receding of pest damage was observed in coastal Karnataka. Parasitization percentage in receding pest damaging regions was very high. The major factors which may be attributed are monsoon, parasitoids and natural infection by *Isaria fumosorosea.* Collection of parasitoid adults from heavily parasitized areas and releasing in the highly infested areas will show decline in the pest population after natural enemy establishment. Mass production and release of *C. sexmaculata* and *P. astur* will help in the reduction of the pest as they are voracious feeders of eggs and nymphs.

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Declarations

Conflict of interest No conflict of interest among authors.

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