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Invasion and escalation of *Aleurodicus rugioperculatus*: An alarming pest in east coast region of India

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Biological invasions by exotic species are of major concern to the native ecosystems, biodiversity and livelihood security. These frequent invasions are causing nearly 25% of economic loss globally. So far, more than 110 exotic insect species have been reported from India (Mandal 2011). Among these insects, exotic whitefly, *Aleurodicus rugioperculatus* (Martin) (Hemiptera: Aleyrodidae), commonly known as the rugose spiraling whitefly (RSW), is one of the worst species causing frequent losses in agriculture, horticulture and forestry (Naveena *et al.* 2020). Although the species origin occurred from Belize, South America (Martin 2004), it was first reported on coconut plantations in Pollachi, Tamil Nadu, India in 2016 (Sundararaj and Selvaraj 2017). Further, it spreads to many parts of the country, wrecking direct and indirect damages (Sumalatha *et al.* 2020). Data on Climate Match Index (CMI, 0.62–0.73) predicted through CLIMEX based modeling by Chakravarthy *et al.* (2017) revealed that the eastern region of India, Odisha, Andhra Pradesh, West Bengal, in particular, is the potential area for the incursion of the RSW. This pest wreaks severe havoc and worries over 5000 coconut farmers in Cuttack, Odisha (2020). Later, it affected the *Acacia auriculiformis* plantation in India drastically (Sundararaj *et al.* 2021). Reports on the occurrence of RSW on various host ranges in east coastal region of India are scarce. Therefore, the present studies aimed to document and assess the expansion of host range, nature and intensity of damage caused with the economic impacts of this cryptic invasive species in coastal tract of India particularly in Odisha. This study could provide awareness to various stakeholders and help to develop a sustainable management strategy for the upcoming time.

A continuous and systematic roving survey was conducted during January-May 2021 in Bhubaneswar (20°24'05.13'' N and 85°78'17.62'' E at 62.37 meter amsl) and its surrounding areas. Fruit orchards, coconut plantations, vegetable cultivated areas, ornamental and avenue areas, and wild germplasm resources were focused for the survey. The infested host plants were collected along with whitefly adults and preserved with 70% ethanol. The nature and extent of damage were examined critically on each host plant species. The intensity of damage was assessed on randomly selected five leaves (leaflets) per plant. An assessment of their population level (intensity) was carried out following the scale described by Sundararaj *et al.* (2021) (Low, less than 10 live egg spirals or adults/leaflet; moderate, 11–20 live egg spirals or adults/leaflet; severe, more than 20 live egg spirals or adults/leaflet). In addition, the dissimilarity index was estimated using XLSTAT statistical software (XLSTAT Premium 2020.2.1, Adinsoft, NY)

The RSW was identified based on the descriptions given by Martin (2004) and Stocks and Hodges (2012). It could be easily identified under field conditions by its larger size (compared to commonly found species in the real world), the spiral pattern of occurrence and sluggish nature. In general, RSW mostly noticed on the abaxial surface of the leaf with white flocculent matter dispersed in a spiraling pattern. Close observation under microscope 10X (Olympus CX21i, India) depicted brown patches on the forewings. A pair of sword-like pincer structures was noticed at the tip of the abdomen in male species. The investigation revealed the whole body of the adult was white and appeared like a tiny moth. The study also explored that nymph were oval with waxy material all over the body, whereas the pseudopuparium was considered the final nymphal stage. The RSW was found to feed on 27 plant species, including economically important cultivated plants and palms in the covered study area (Fig 1). The natural infestations on various host plants are in accordance with the earlier reports (Stocks and Hodges 2012, Selvaraj *et al.* 2016, 2017, Anonymous 2017). The present study explored the expansion of its host plant (Table 1). Our study found two

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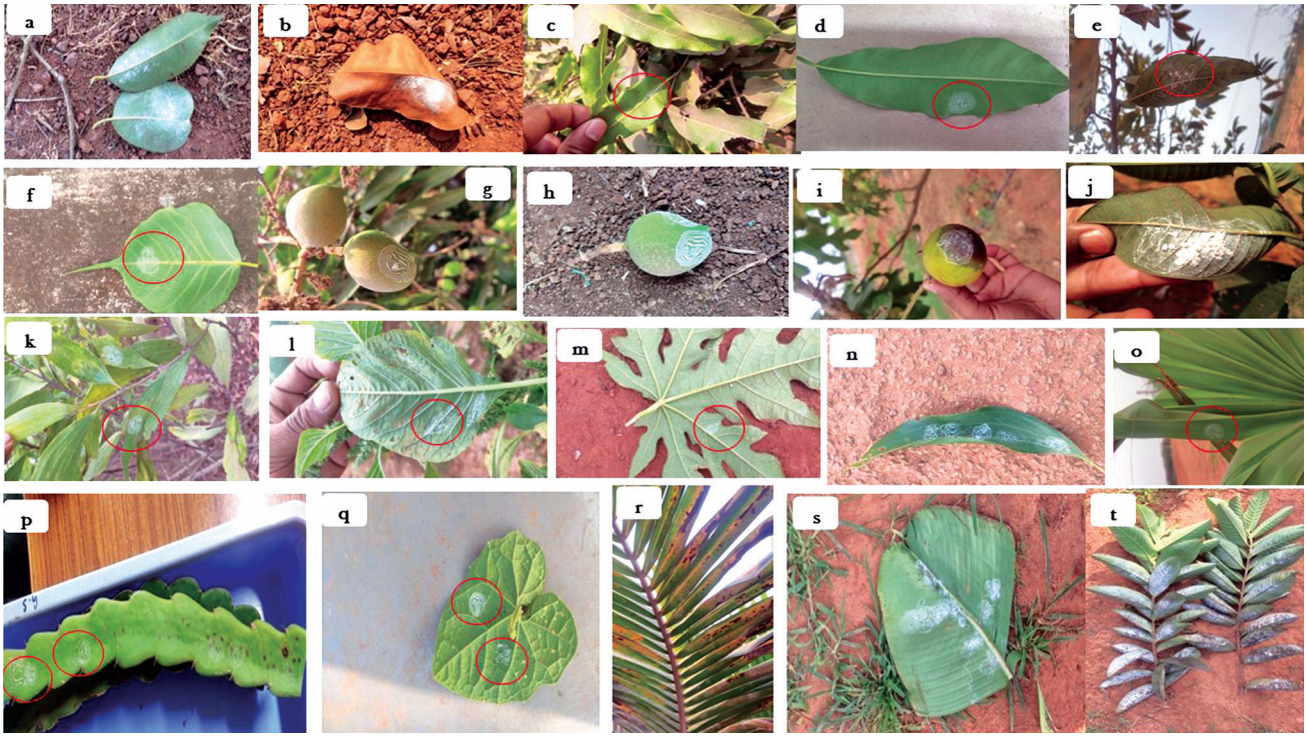

Fig 1 Infestation of RSW on different host crops (both vegetative and reproductive part). a, b, infestation on jamun (back side of leaf and fallen leaf); c, ashoka leaf; d, Khirni leaf; e, custard apple leaf; f, peepal leaf; g, h, fruits of mango affected; I, infestation on fruits of wild brinjal; j, guava leaf; k, acacia leaves; l, amaranthus leaf; m, papaya leaf; n, acacia leaf covered with RSW; o, royal palm; p, dragon fruit; q, pointed gourd leaf; r, coconut leaf covered with RSW; s, banana leaf; t, guva leaf covered with RSW.

new host crops i.e. *Amaranthus tricolor* (L.) and *Solanum torvum* (Swartz) invaded by RSW, that reported firstly to the scientific society. The present findings agree with the observations of Sundararaj *et al.* (2021). Hierarchical clustering was performed based on RSW incidence on different host plants (Table 1). The 27 host plants (Table 1) were grouped into two clusters (20 host plants in cluster I and 7 host plants in cluster II). In cluster II, 4 host plants i.e. coconut, banana, guava and jamun showed severe levels, and 3 host plants i.e. areca nut, custard apple and royal palm exhibited moderate to severe levels of infestation (Fig 2).

Both nymphs and adults were usually found crowded on the abaxial surface of leaflets causing direct damage by driving phloem sap. Indirectly, larger excrement of honeydew facilitates the growth of black fungus, *Capnodium* sp. (sooty mold), which affects normal photosynthesis and disrupts leaf configuration. Further, it caused leaf drooping and wilting. Moreover, in jamun and wax apple (Fig 1b), leaf litter was also covered with a heavy infestation of the sooty mold with white mealy matters along with RSW infestation. The infestation was also not exempted from reproductive parts i.e., mango, guava, wild brinjal, etc (Fig 1g-i). The initial feeding and colonization of RSW were observed on amaranthus, wild brinjal, ashoka, custard apple, ber, and other ornamental plants. Still, it found that the insect failed to feed continuously and establish successfully in those plants. As RSW is a highly polyphagous pest on more than a hundred hosts (Stocks and Hodges 2012), frequent monitoring is essentially required from further havoc.

RSW poses a serious challenge to the agricultural sector and economy as the biologist and public witnessing and recognizing the damage caused. Despite the severe ecological damage and economic loss caused by the RSW, the factors contributing to its success remain elusive. Further, the ongoing dispersal and establishment of RSW are some of the most remarkable biological outcomes of climatic variability (Gao and Reitz 2017). In addition to that, the prediction report revealed an increase in the number of invasive species like RSW increase number for India (Bellard *et al.* 2013) and particularly eastern part of the country, including Odisha (Chakravarthy *et al.* 2017) and across the world indeed. Interestingly the current study reveals that although the climate of east coast of India is favourable for many major and minor fruit crops, the host preference of RSW towards coconut, banana, jamun and guava is more (Fig 2). Our study claims that its establishment on these host plants and spreading in this region is highly conducive.

The invasive RSW is indeed an alarming threat and is now well established on 27 species of host plants in east coast region of India. Although intensity level varies from low to severe in the focused area, regular monitoring is necessary to check its further spread and timely management. A holistic approach is the need to adopt for rapid response strategies against its invasion, which could be possible by educating farmers and creating awareness among various

Table 1 Host plant distribution for the invasive RSW and its infestation level

Plant species	Common name	Family	Infestation level	Remarks
Mangifera indica (L.)	Mango	Anacardiaceae	Low to moderate	Colonize on fruits and under surface of leaves
Anacardiun occidentale (L.)	Cashew	Anacardiaceae	Low	
Annona squamosa (L.)	Custard apple	Annonaceae	Moderate to severe	Infestation on lower surface of leaves
Psidium guajava (L.)	Guava	Myrtaceae	Severe	Infestation on lower surface of leaves and black sooty mould on upper surface
Syzygium aqueum (Alston)	Watery rose-apple	Myrtaceae	Moderate	
Syzygium jambos (L.) (Alston)	Rose apple	Myrtaceae	Moderate	
Syzygium cumini (L.) (Skeels)	Jamun	Myrtaceae	Severe	Colonize on lower surface of leaves and black sooty mold on upper surface also traced on leaves litter on soil
Averroha carambola (L.)	Carambola	Oxalidaceae	Low	
Cocos nucifera (L.)	Coconut	Arecaceae	Severe	Coverage on backside of leaf with sooty mold on upper surface
Areca catechu (L.)	Arecanut	Arecaceae	Moderate to severe	
Roystonea regia	Royal palm	Arecaceae	Moderate to severe	
Acacia auriculiformis	Acacia	Fabaceae	Low to moderate	
Solanum torvum (Swartz)	Wild brinjal	Solanaceae	Low	On fruits and leads to rotten
Amaranthus tricolor (L.)	Amaranthus	Amaranthaceae	Low to moderate	
Polyalthia longifolia	Ashoka tree	Annonaceae	Low	
Zea mays (L.)	Maize	Poaceae	Moderate	
Trichosanthes dioica (Roxb.)	Pointed gourd	Cucurbitaceae	Low	
Musa sp.	Banana	Musaceae	Severe	Severe colonization on below surface of leaves and black sooty mold on upper surface
Aegle marmelos (L.) Correa	Bael	Rutaceae	Low	
Ficus religiosa	Peepal/ aswatath	Moraceae	Low	
Hylocereus undatus	Dragon fruit	Cactaceae	Low to moderate	
Ficus benghalensis	Banyan	Moraceae	Low	
Carica papaya (L.)	Papaya	Caricaceae	Low	
Zizyphus mauritiana (Lam.)	Indian jujube/ ber	Rhamnaceae	Low to moderate	
Artocarpus heterophyllus (Lam.)	Jackfruit	Moraceae	Low	
Codiaeum variegatum (L.)	Variegated Croton	Euphorbiaceae	Low	
Manilkara hexandra (Roxb) Dubard	Khirni	Sapotaceae	Low	

Low, less than 10 live egg spirals or adults/leaflet; moderate, 11-20 live egg spirals or adults/leaflet; severe, more than 20 live egg spirals or adults/leaflet.

stakeholders and field entomologists.

SUMMARY

In nutshell, invasive species causes serious threat to the natural ecosystem. Severe and up surging phenomenon of exotic rugose spiraling whitefly (RSW), *Aleurodicus rugioperculatus* (Martin) became a major concern in global crop production. The present study aimed to document and assesses the host range, nature and intensity of damage caused by this cryptic species. The roving survey was conducted to study the occurrence of RSW in the fruit orchards, vegetable gardens, ornamental crops and avenues trees plantation in the east-coast region of India. Hierarchical clustering was performed based on its incidence on different host plants and correlated with the dissimilarity index. The RSW was identified based on morphological characteristics and the nature of the damage. RSW infested a total of 27 crops. Four host plants, viz. *Cocos nucifera* (L.), *Musa* sp.

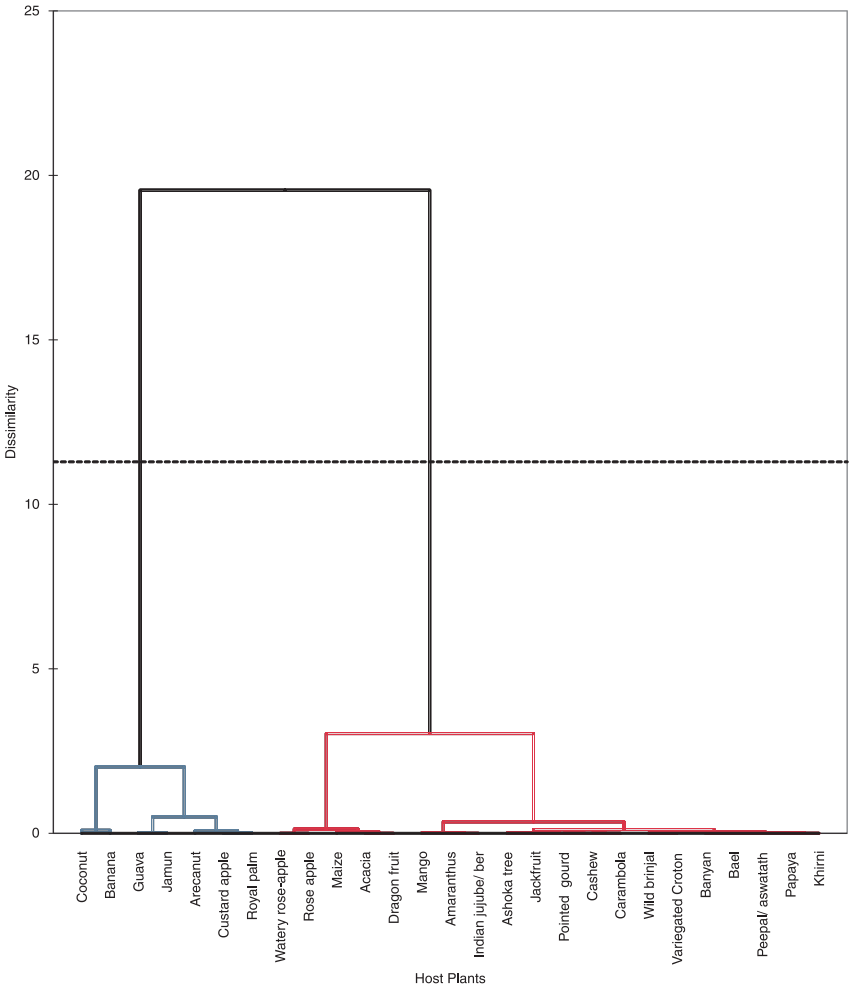

Fig 2 Hierarchical clustering of 27 host plants based on infestation of RSW.

Psidium guajava (L.) and *Syzygium cumini* (L.) (Skeels) showed severe levels of infestation. An important implication from the current study is the occurrence of its incidence on the two new host crops, viz. *Amaranthus tricolor* (L.) and *Solanum torvum* that was envisaged firstly to the scientific world. This study provides baseline information about RSW among various stakeholders, helps to develop a sustainable management strategy for timely mitigation of RSW menace.

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