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Incidence, hosts and potential areas for invasion by Rugose Spiraling Whitefly, *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae) in India

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ABSTRACT: Surveys were conducted to assess the incidence of Rugose spiraling whitefly (RSW), *Aleurodicus rugioperculatus* Martin, in Karnataka, Kerala, Tamil Nadu, Maharashtra, Gujarat, Himachal Pradesh and Sikkim in India. In Kerala and Tamil Nadu cocount fronds were severely infested with rugose whitefly. In Karnataka, RSW infestation is just beginning to attack Guava, Jamun, Teak and Tropical almond (Indian almond), trees. With the onset of pre-monsoon showers, the RSW infestation considerably came down in Tamil Nadu, Karnataka and Kerala. Although RSW has not spread into North India presently, potential areas identified for its establishment include parts of South Indian states, Odisha, Uttar Pradesh, Bihar, Chattisgarh, Uttarkhand and West Bengal where regular monitoring and preventive measures need to be stepped up.

Keywords: *Aleurodicus rugioperculatus,* invasive pest, survey

INTRODUCTION

The Rugose Spiraling Whitefly (RSW), *Aleurodicus rugioperculatus* Martin was first described from Belize, Central America by Martin in 2004. This species has been found in Mexico, Guatemala, USA and is suspected to be distributed in eight other countries (Sundararaj and Selvaraj, 2017) on more than 100 plant species (Taravati *et al.,* 2013; Sundararaj and Selvaraj, 2017; Selvaraj *et al.*, 2017). The whitefly was recorded as a serious pest in Florida in 2009 on gumbo limbo (*Bursera simaruba*) leaves, black olive (*Bucida buceras*) leaves and underside of coconut fronds. The infestation of the Rugose whitefly on coconut palm in the Orient and in India for the first time was recorded in 2016 in Coimbatore district, Tamil Nadu (Sundararaj and Selvaraj, 2017).

The RSW was recorded and its occurrence was limited only to Kerala and Tamil Nadu on coconut (Sundararaj and Selvaraj, 2017). The RSW is supposed to have originated in Central America but how it gained entry to India in 2016 is not known. RSW was recorded on coconut from Pollachi, Tamil Nadu and from Palakkad, Kerala during July-August 2016 (Anonymous, 2017). The pest has also been recorded from Coastal Andhra Pradesh during October-November, 2016 (Bhagavan, Pers. Comm., 2017). The possible entry to Andhra Pradesh may be via coconut seedlings from nurseries in Tamil Nadu. The occurrence and distribution of the whitefly on wild and cultivated plants across different states during 2016-17 is reported in this publication.

MATERIALS AND METHODS

Surveys were conducted during December 2016 and January 2017 in Pollachi (10° 39' and 26.19" N 77° 00' and 38.41" E) and surrounding areas of Tamil Nadu. Coconut gardens, fruit orchards, teak plantations, avenue and forest trees and other cultivated areas and gardens were surveyed for RSW. In order to assess the infestation of RSW on palms, shrubs, herbs, trees and cultivated crops in and around Hassan (12° 13′ and 13° 33′ N and 75° 33′ and 76° 38′ E), Karnataka, South India were observed during second week of February 2017. Roving surveys were carried out in thirty two villages of Hassan district, selected randomly for RSW presence. To create awareness among coconut growers, information on RSW was circulated among Coconut Federations, Associations and growers in Hassan district.

In another survey during last week of March 2017 in nineteen taluks of six districts *viz*., Ramanagara (12° 42' and 35.12" N 77° 16' and 50.51" E), Mandya (12° 33' and 51.82" N 76° 44' and 01.15" E), Mysore (12° 17' and 44.92" N 76° 38' and 21.77" E), Chamarajanagara (12° 03' and 09.52" N 77° 17' and 11.36" E), Mangaluru (12° 15' and 13.19" N 74° 40' and 12.21" E) and Bengaluru (12° 58' and 17.76" N 77° 35' and 40.43" E) in Karnataka. Entomologists from Central Integrated Pest Management Centre (CIPMC) (12° 49' and 35.32" N 77° 39' and 07.98" E), Bengaluru, ICAR-Indian Institute of Horticultural Research (ICAR-IIHR) (12° 07' and 53.49" N 77° 29' and 51.17" E), Bengaluru, V. C. Farm, Mandya, Nagenahalli Farm, Mysore, Krishi Vigyan Kendra (KVK), Chamarajanagara, Department of Horticulture, Government of Karnataka, Mandya and Malvalli (12° 23' and 07.03" N 77° 03' and 12.89" E) participated in the survey. Observations were recorded on the RSW infestation on wild and cultivated plants, natural enemies of RSW and effect of crop protection measures on RSW populations on select crops were sampled from four twigs each from bottom, middle and top (from each direction) tree canopies and the numbers from the three levels of canopy were averaged/tree and recorded (Table 1).

RSW was sampled on plants following the a forementioned procedures. Surveys were also conducted in East Sikkim (27° 18' and 30.11" N 88° 40' and 20.49" E), Kolkata (22° 34' and 21.53" N 88° 21' and 50.02" E) and Himachal Pradesh (31° 06' and 17.33" N 77° 10' and 24.25" E) for the RSW. At each location, the plants infested, degree of severity and natural enemies of RSW were recorded. Entomologists working on horticultural crops were also contacted in Assam (27° 17' 12.63" N and 89° 49' 07.92" E), Punjab (31° 08' 49.67" N and 75° 20' 28.38" E), Lucknow (26° 50' 48.10" N and 80° 56' 46.20" E), Shivamogaa, Karnataka (13° 55' 47.75" N and 75° 34' 05.16" E), Junagadh, Gujarath (21° 30' 35.26" N and 70° 33' 11.43" E) for the status of RSW on mango, jamun, guava, *Terminalia catappa*, papaya, Ficus, coconut, custard apple.

Prediction of Future distribution of RSW using CLIMEX, a bioclimatic model

CLIMEX is a bioclimatic software which uses responses of an organism to its surrounding climatic conditions and is useful for predicting the potential hot spots for the organisms establishment and distribution. CLIMEX (version. 4), was used to develop a model for identifying potential areas for the establishment of RSW in India, based on its existing geographical distribution (Sutherst *et al.,* 2004). The meteorological data used in CLIMEX was taken from CliMond. Using "Match Climate Function" option in CLIMEX, for predicting the locations in India that can support favourable climatic conditions for the establishment of *A. rugioperculatus*. For this purpose, select locations from North America where the pest was more prevalent and considered as "home locations" and Climate Match Index (CMI) was assessed for Indian locations *i.e.*, "away locations", where it can establish as a potential pest. The degree of climate similarity is considered as the factor governing the spread and establishment of the pest *i.e.,* higher the CMI value, higher the chances of establishment of RSW in that particular locality.

RESULTS AND DISCUSSION

Pest Identification

RSW was identified based on descriptions given by Martin (2004). The RSW could be easily identified under field conditions by its larger size (compared to commonly found whitefly species in India) and sluggish nature. RSW colonized underside (abaxial) of the leaves with white waxy matter dispersed in a spiraling pattern. Thirdly, RSW colonized, infested and established on broad - leaved plants. This doesn't however, meant that all broad leaved plants were colonized by RSW and all narrow- leaved plants were free from RSW. On close examination, under 10x lens, brown patches on the forewings similar to color of the cinnamon bark could be observed. In some individuals, however, the patches

were not clearly indistinguishable. In males, at the tip of the abdomen, a pair of sword - like pincer structures could be noticed (Fig. 1).

Selvaraj *et al.* (2017) carried out molecular identification of RSW (A Gene bank Acc. No. KY209909) and its parasitoid, *Encarsia guadelopae* Viggiani (B-Gen Bank, Acc. No. KY223606) based on cytochrome oxidase I Barcodes were also generated.

Adults under microscope (Nikon SMZ25, 1x, WD: 60) revealed deposition of waxy materials in almost spiraling manner, with grayish eyes. The whole body of the adult is white and appeared like a small moth. Further examination of underside of leaves revealed that elliptic, yellowish eggs were laid in a spiral pattern. Nymphs were oval shaped with white waxy material all over the body. Pseudopuparium represented the final stage of the nymphs, white in colour covered with much waxy material (Fig. 1).

Nature of Damage

In Pollachi, Tamil Nadu, heavy infestation of the RSW was observed in several coconut gardens, the infestation could be identified by the thick deposition of black sooty mould fungus, *Capnodium* sp. on different parts of coconut palms leading to dropping of fronds and wilting symptoms. Underneath the affected coconut palms, all the herbs and ground vegetation was completely littered with the black sooty mould fungus because of the copious amounts of honeydew excreted by adults and nymphs. Both nymphs and adults were found sucking the plant sap from underside of the plant leaves and tender parts. The reproductive parts of the coconut palm were also heavily covered with whiteflies and mealy matter. Affected palms experienced immature nut fall, stunted vegetative and reproductive growth and palms severely affected ceased nut production. The RSW infestation was also observed on the leaves of Indian almond (*Terminalia catappa*), teak (*Tectona grandis* L.), Purple butterfly tree (*Bauhinia purpurea* L.) wherein the RSW colonized leaves showed dropping and drying symptoms with the underside of leaf largely covered with nymphs and adults with white mealy matter. Interestingly, on Jamun tree, *Syzygium cumini* (L.) the RSW colonized upper surface of the leaves and brown secretion of honey dew could be seen laden on green leaves (Fig. 2).

Table 1. Details of the locations and crops surveyed for RSW in South India

Taluk	Name of village	Crops surveyed	Status of RSW *	Extent of infestation **	Remarks
District: 1. Ramanagara, Karnataka, India					
1. Ramanagara	Vondaraguppe, Kengal	Coconut, Mango, Teak Teak	+	Trace on coconut and teak	
2. Channapatana	Voderahalli, Settihalli, Belekere, Nidagatta	Coconut, Guava, Jamun	+	Trace on underside of the leaves	
3. Kanakpura	Sathnur, Harohalli,	Coconut, Banana Halegabadi	+	Trace on coconut	
District: 2. Mandya, Karnataka, India					
4. Maddur	Sompura, Nidagatta	Coconut, Banana, Teak	+	Trace on coconut	
5. Mandya	Hale Budanur, Konnahalli, Holalu, VC Farm	Coconut, Guava, Jamun, Teak	+	Trace on Jamun	Colonizes upper surface of the leaves
6. Pandavapura	Yeliyur, B.R.Koppal	Coconut, Mango	+	Trace on leaves of coconut	
7. Srirangapatana	Srirangapatana, Nagenahalli	Coconut, Mango, Guava, Jamun, Teak	-	-	

8. Malavalli	Kodipura, T.K. Halli, Halaguru	Coconut, Arecanut, Maize, Sugarcane	-	-	
District: 3. Mysuru, Karnataka, India					
9. Mysore	Chikkali, Varuna	Coconut, Papaya, Arecanut, Guava, Mango, Teak	+	Traces on guava and teak	
10. H.D. Kote	Rayanakere, Doddundi, Hampapura, Yarahalli, Kanakana halli	Coconut, Banana, Cassava, Tomato, Chilli, Teak	+	Colonies established underside of the teak and cassava	
11. Nanjanagudu	Hediyala Hiregowdanahundi	Coconut, Tomato, Banana, Teak	+	Negligible on teak	
12. Gundalapete	Biradevanapura Kurubarahundi	Coconut, Tomato	-	Absent	
District: 4. Chamarajanagara, Karnataka, India					
13. T. Narasipura	Gargeshwari, Madrahalli, Banahalli	Coconut, Paddy, Sugarcane, Maize, Papaya, Banana	-	Absent	
14. Chamaraja nagara	Basavahatti, Tagarpura	Coconut, Arecanut, Banana, Papaya, Sapota, Jamun, Teak	+	Traces on Guava, underside of leaves, coexisting with two tailed mealybug	
15. Kollegala	Terambali, Sathegala, Hosahalli	Coconut, Arecanut, Banana, Mango, Sugarcane, Maize	-	Absent	
District 5: Mangaluru, Karnataka, India					
16. Mulki	Mulki	Coconut, Banana & Guava	+	Low to moderate	
17. Karnad	Karnad	Coconut, Banana & Guava	+	Low to moderate	
18. Kolnad	Kolnad	Coconut, Banana & Guava	+	Low to moderate	
19. Dharmastala	Dharmastala	Coconut, Banana & Guava	+	Low to moderate	
District: 6. Tumakuru, Karnataka, India					
20. Dobaspet	Dobaspet and surrounding villages	Coconut, Guava, Mango, Banana, Bauhimia, Anona, *Ficus* sp..	+	Negligible on guava	-
21. Hirehalli	Hirehalli and surrounding villages	Coconut, Guava, Mango, pappay, sapota etc.	+	20-25% incidence	Moderate level of infestation on guava
District: 7. Chitradurga, Karnataka, India					
22. Hiriyur	KVK, Hiriyur and surrounding villages	Citrus, Pomegranate, Gauva, Sapota, Mango, Banana etc.	+	10% incidence	On few trees of guave
23. Holalkere	Adanur and surrounding villeges	Pomegranate, Guava, Mango, Banana, Bauhimia.	+	-	Moderate infestation

District: 8. Hassan, Karnataka, India					
26. Beluru	Beluru and surrounding villages	Guava, wild almond	+	<2% on Guava)	
27. Karekere	Agriculture college, Hassan	Guava, wild almond	+	<5% on wild almond)	Underside of leaves
28. Hassan	Hassan and surround villages	Bauhimia	+	1-2% on Bauhimia	Underside of leaves
District: 9. Coimbatore, Tamil Nadu, India					
29. Pollachi	Pollachi and eight surrounding villages	Coconut, Arecanut, Guava, Wild Almond, Pepper, Cocoa, Mango, Teak, Banana, *Bauhimia*, Anona, *Ficus* sp. Squmosa, Fish-tail palm, etc.	+	Estimated yield losses over 10% incurred on an average on Coconut and over 10% on Guava	Initial feeding and severe colonization on areca, pepper and banana but colonies did not develop & established.

*** + = present; - = absent; 88 traces /negligible = few colonies of RSW established underside of leaves. Low= more than 3-4 colonies established underside of the leaves. Moderate = 5 colonies of RSW established; affected leaves showing yellowing or dried, brown symptoms accompanied with leaf-fall.**

Table 2: Surveyed locations in other states of India where RSW was not found

State	Place
1. Gujarat	Jungadh
2. Himachal Pradesh	Solan, Shimla, Kulu & Manali
3. Sikkim	Gangtok, East Sikkim

Extent of damage

About 25% of estimated 2 lakh palms were infested in Pollachi incurring on an average 38 per cent nut yield loss (n=50,000 palms). The probable reason for RSW flare up might be due to prolonged warm dry weather conditions. On an average, Pollachi receives 1200 mm annual rainfall (RF) but during 2015 received only 600 mm and in 2016, rainfall was significantly low. So, due to prolonged dry and warm conditions, high populations of RSW were observed on host plants. Apart from coconut, Indian almond, Teak (*T. grandis* L.), *B. purpurea etc* recorded severe infestation of RSW. Recently, Pollachi received slashing rains (4 cm) during I and II fortnights of May 2017, that resulted in reduction of the incidence of RSW on coconut plantations (Pers, Commn., Vishak, 2017). Observations in Bengaluru on guava tress also revealed that due to slashing rains, the RSW was wiped out from the trees and fresh, healthy sprigs of foliage.

The initial feeding and colonization of RSW was observed on pepper, cocoa, coffee banana and other shrubs and herbs but continuous feeding and population establishment was not observed on the above plants. The RSW population failed to build-up on some of these plants. During the observational period, the prevailing warm weather conditions, 28-31°C temperature with 40-50% RH and no rain favored RSW. At many locations, the two-tailed mealybug, *Ferrisia virgata* Cockerell was found co-existing with RSW. It seems that the mealy bug and RSW have a partial niche overlap and population regulation is governed by several sets of determinate and indeterminate factors. In Tumakuru and Chitradurga districts several gardens of coconut, arecanut, banana, sapota, guava, citrus, jackfruit *etc.*, were surveyed. Except on guava, RSW was not recorded on any other wild and cultivated plants. Similarly none of the wild and cultivated plants were infested with RSW, in Hasan district.

(a) (b)

Fig. 1. Incidence of RSW on (a) Guava and (b) Jamun

In Channapatna and Ramanagar districts, trace infestation of RSW was found on guava. In Mandya, Halebidu and Belur trace infestation of RSW was observed on Jamun tree and other plants were free from RSW infestation. In Mangaluru district, low to moderate incidence was noticed on coconut, banana and guava. Surveys for RSW in North-West and North-East India revealed that there was no RSW infestation on any plant including coconut, guava, teak, almond, banana and others (Table 2).

Survey revealed that RSW infestation was found on guava, teak and *Bauhinia* plants and few trees of each species were severely infested. Recently CPCRI, Kasargod (Anonymous, 2017) reported Coconut as the major host in Kerala and *Psidium guajava; Musa* sp., *Myristica fragrans*; *Colacasia* sp., *Garcinia* sp., *Annona muricata; Murraya koenigii; Spondia smombin; Mangifera indica* and *Artocarpus heterophyllus* as alternate hosts of *A. rugioperculatus*. But this needs to be confirmed under artificial infestation conditions.

At Rahuri, Maharashtra, the RSW infestation was recorded on certain forest species *viz., Trichosanteus femeta, Terminalia belerica, Butea monosperma, Tectona grandis* and fruit crop, *Psidium guajava*.

Identifying potential areas for the pest using CLIMEX

CLIMEX based modelling predicted South West coastal regions of India comprising parts of Kerala, Karnataka, Goa, Maharashtra and extended up to Maharashtra - Gujarat border. Within South India, interior parts of Karnataka *viz*., Bengaluru, Mysuru, Tumakuru, Hassan, Belagavi, Shikaripura and Birur showed higher CMI (0.6-0.8) indicating favourable climatic conditions for the pest. In south India, Coimbatore (Tamil Nadu), Palakkad (Kerala) showed CMI of 0.6-0.8 in the present predictions which is favourable for the establishment of *A. rugioperculatus*. Sundararaj and Selvaraj (2017) reported the pest from these regions in India, confirms the validity of the model developed. Similarly parts of other states like Andhra Pradesh, Odisha, Madhya Pradesh, Bihar, Uttar Pradesh, Uttarakhand, Chhattisgarh, and West Bengal also showed a CMI of 0.62-0.73, indicating favourable climatic conditions for the establishment of this pest. All other regions of India showed CMI of >0.43<0.62, which are relatively less suitable for the establishment of the pest (Fig.3).

As RSW is a highly polyphagous pest on more than hundred hosts including edible plants, palms and weeds (Stocks and Hodges, 2012), the places where the suitability is predicted as risk prone, needs to be monitored regularly for containing or eradicating the pest in case it enters new areas from the infested ones.

Management practices

Field observations revealed that Chawcat Orange Dwarf (COD), variety of coconut was found highly susceptible to RSW *i.e.,* more than 80 per cent of

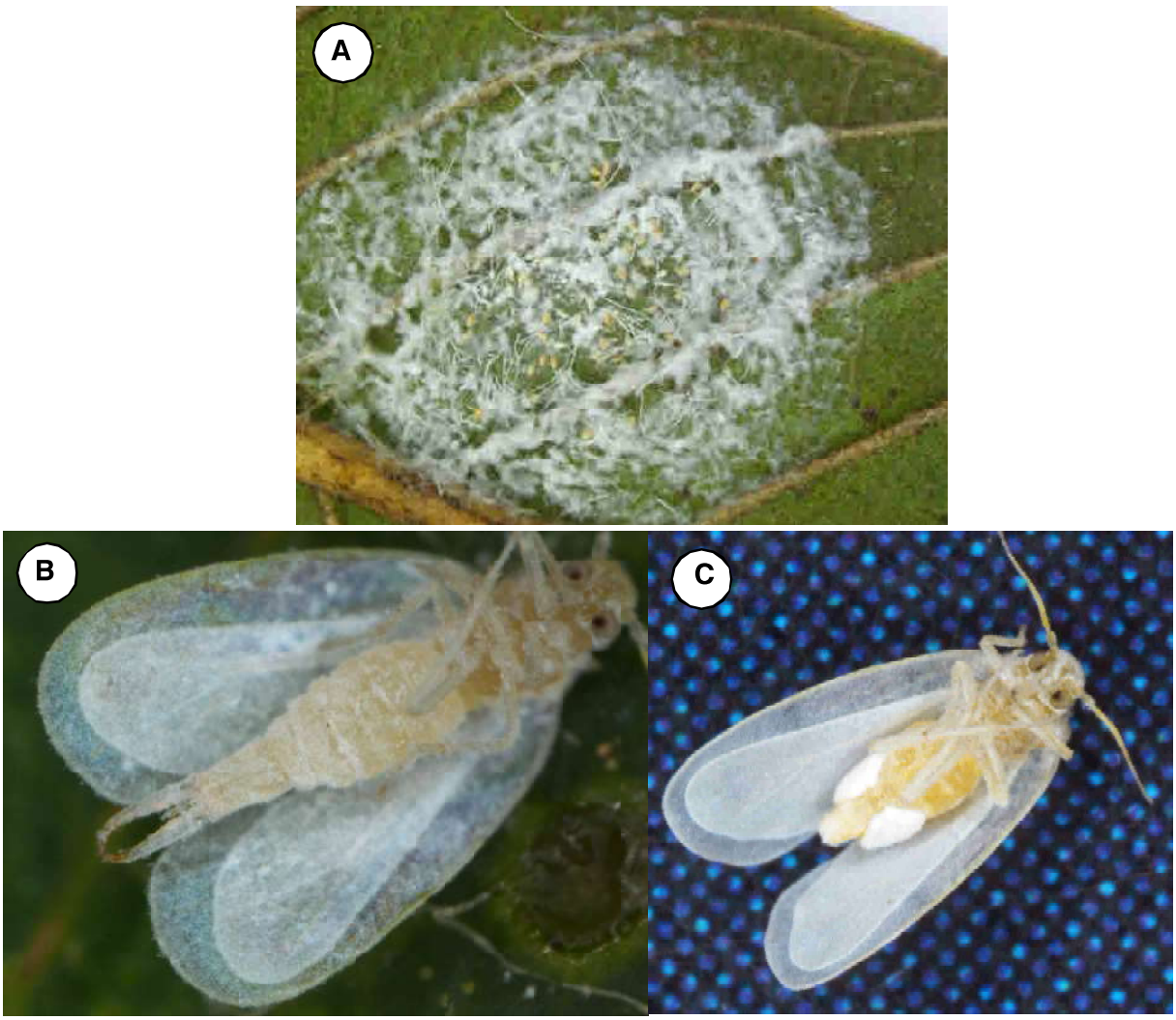

Fig. 2. A. Colonization of Rugose spiraling whiteflies, B. male with pincer like structure on last abdomen segment and C. female without pincer like structure

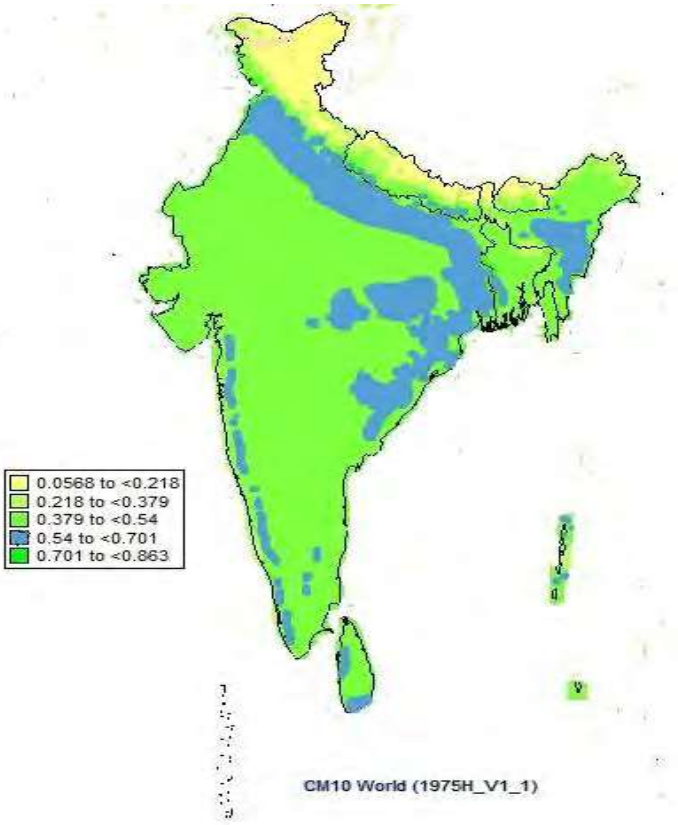

Fig. 3. Map showing regions favourable for establishment of *A. rugioperculatus* (CMI: 0.05 to <0.24–Not favourable, 0.24 to <0.43- Less favourable, 0.43 to <0.62- Slightly favourable, 0.62 to <0.81- Favourable, 0.81 to <1- Highly favourable, where CMI= Climate match index)

palms were severely affected in Pollachi. In contrast, Tall x Dwarf (green coloured coconut) variety had very low infestation.

A herbal preparation (kg) that contained cinnamon oil (30%) + emulsifier (10%) + buffer (16%), was sprayed @1ml/lit of water and was found not effective. The Center for Agriculture at Adyar, Tamil Nadu was distributing *Encarsia* sp. parasitoids @500-700 to each farm but population suppression of RSW was very slow in action . One percent starch solution was recommended against black sooty mould. Under field conditions in Kerala, Karnataka, Andhra Pradesh and Tamil Nadu, India, the populations of *E. guadeloupae* released in coconut and banana ecosystems recorded significant reduction of RSW population. Green lace wings, *Chrysoperla zastrowi* and coccinellids were recorded under field conditions, but in negligible numbers in South India. With the advent of monsoon rains, the RSW population is expected to decline rapidly. Taravati *et al.,* (2013) developed an injection method with IMA-jet at the recommended label rate (Imidacloprid 17.8SL) based on the tree diameter. This method proved effective and could be suitably combined with releases of two proven biocontrol agents, *viz*., lady bird beetle, *Nephaspis oculata* and the parasitoid wasp, *E. guadeloupae.*

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