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COMPETITIVE REGULATION OF DOMINANT EXOTIC WHITEFLIES ON COCONUT PALMS AS INFLUENCED BY BIOTIC AND ABIOTIC FACTORS

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ABSTRACT

In the recent past, exotic whiteflies viz., *Aleurodicus rugioperculatus, Paraleyrodes bondari, Paraleyrodes minei* and *Aleurotrachelus atratus* are infesting coconut plantations in India. Based on the damage potential, the predominant species are the rugose spiralling whitefly, *A. rugioperculatus* and the Bondars nesting whitefly, *P. bondari.* A study was undertaken to determine the seasonal incidence and population dynamics of these in the new invasion region at Karungalakudi block of Madurai district from 33rd standard meteorological week (SMW) of 2021 to 32nd SMW of 2022. The results indicated that *A. rugioperculatus* incidence rose considerably from the first week of April (10.9 adults/ leaflet) to third week of May (8.3 adults/ leaflet; while *P. bondari* reached maximum during the third week of March (71.99 adults/ leaflet) and extended up to first week of June (67.57 adults/ leaflet) coinciding with summer months with high temperature and limited precipitation. Subsequently, their incidence declined with the onset of north east monsoon coupled with parasitism by *Encarsia guadeloupae* and predation by chrysopids from third-week of August to fourth-week of December in 2021. The extent of parasitism by *E. guadeloupae* on *A. rugioperculatus* nymphs was positively correlated and ranged from 40% (third week of August, 33rd SMW, 2021) to 84% (second week of June 2022, 24th SMW). Chrysopids revealed a highly significant positive correlation with the incidence.

Key words: *Aleurodicus rugioperculatus*, *Paraleyrodes bondari*, invasive whiteflies; weather factors, parasitism, predation, *Encarsia guadeloupae*, green lacewings

Currently, many species of exotic whiteflies have invaded and caused heavy damage to coconut plantations in India. During 2016-2019, four non-native whiteflies namely rugose spiralling whitefly (*Aleurodicus rugioperculatus* Martin) (Shanas et al*.,* 2016; Selvaraj et al., 2016; Srinivasan et al*.,* 2016); Bondars nesting whitefly (*Paraleyrodes bondari* Peracchi) (Josephrajkumar et al., 2019); Neotropical nesting whitefly (*P. minei* Iaccarino) (Chandrika Mohan et al., 2019) and Neotropical palm whitefly (*Aleurotrachelus atratus* Hempel) (Selvaraj et al*.,* 2019; Josephrajkumar et al., 2020) were predominantly observed on coconut palms in southern states of Tamil Nadu. Climax modeling was performed for *A. rugioperculatus* to predict its invasiveness and the damage inflicting zones which included coastal regions of Maharashtra, Karnataka, Goa, parts of Kerala extending up to Gujarat border. In south India, Karnataka (Bengaluru, Mysuru, Tumakuru, Hassan, Belagavi, Shikaripura and Birur) and Tamil Nadu (Coimbatore) had favourable weather conditions to expand the invasive potential of the pest (Chakravarthy et al., 2017).

MaxEnt studies further revealed that Eastern coastal parts of Tamil Nadu, North-Eastern parts of Andhra Pradesh, Eastern coastal belts of Odisha, north-western coastal belts of Kerala, south-western coastal parts of Karnataka and western coastal belts of Maharashtra and Gujarat were predicted for highest habitat suitability regions for *A. rugioperculatus* (Selvaraj et al., 2022). Maruthadurai et al. (2023) also highlighted MaxEnt model that forecasted a possible *A. rugioperculatus* distribution with the yearly mean temperature (Bio 1, 28.9%), mean diurnal range (Bio 2, 19.5%) and annual precipitation (Bio 12, 19.1). India's coastal and southern states were found as the most ideal places for *A. rugioperculatus* establishment. Though, *A. rugioperculatus* sustained well in hot humid weather, the tropics, subtropics and temperate zones were found as the best places to proliferate and invade. In Kerala, deficit in south-west monsoon during 2016 increased the *A. rugioperculatus* population whereas subsequent heavy rains subdued the whitefly population. Furthermore, increase in the temperature up to 2°C was found as a pre-disposing factor and 7% decline in the relative humidity favoured the *A. rugioperculatus* population (Chandrika Mohan et al., 2016). As the invasion of *A. rugioperculatus* and *P. bondari* is relatively new to the Indian lands there is a need to understand the pestiferous nature of these exotic whiteflies in relation to the biotic (parasitoids and predators) as well as abiotic factors (temperature, rainfall and relative humidity). In this research paper the population dynamics of these whiteflies as influenced by biotic and abiotic factors were observed and presented.

MATERIALS AND METHODS

The population variation and seasonal modulation of *A. rugioperculatus* and *P. bondari* were studied in Karungalakudi block of Madurai district, Tamil Nadu on four-year-old highly susceptible Dwarf x Tall coconut trees. Surveillance was done at weekly interval for a year starting from August 2021 to August 2022, which coincided with 33rd standard meteorological week (SMW) of 2021 to 32nd SMW of 2022. Ten coconut trees were randomly selected. In each selected tree, five mature bottom fronds were chosen in which five leaflets were marked to collect data on the population dynamics of *A. rugioperculatus* and *P. bondari*. Number of nymphs and adult whiteflies were recorded on the selected leaflet and inter-related with weather factors. The coconut trees were maintained in pesticide-free environment as well as the trees were supplied with recommended dose of macronutrients, micronutrients and irrigation as per recommended package of practices. The correlation studies of exotic whiteflies population with biotic and abiotic factors was taken up. Biotic factors included natural parasitism of *A. rugioperculatus* by *Encarsia guadeloupae* (X1), predation by chrysopids (X2), coccinellids (X3) and spiders (X4) while the abiotic factors included were maximum temperature (X5), minimum temperature (X6), minimum relative humidity (X7), maximum relative humidity(X8) and rainfall (X8). In case of *P. bondari*, excluding the parasitoid (X1) all other factors were observed and correlated. The weather parameters were collected from the Google earth engine software (Satellite derived data). Multiple regression analysis was also performed for *A. rugioperculatus* and *P. bondari* relationship with predators, parasitoid and weather parameters. Using the SPSS 16.0 statistical software, simple correlation and multiple regression analyses were done between both dependent and independent variables to know the significant relationship.

RESULTS AND DISCUSSION

The population of exotic whiteflies on coconut was maximum during summer season i.e., March, 2022 to April, 2022. *A. rugioperculatus* population was high from fourth week of April, 2022 (10.9 adults/leaflet) concurred with 12th SMW of 2022. Later, *A. rugioperculatus* population was moderate throughout the study period and it ranged from 5.4 to 10.9 adults/leaflet. *P. bondari* was found maximum from third week of March, 2022 (71.99 adults/leaflet) to second week of June, 2022 (67.49 adults/ leaflet) and coincided with 11th to 23rd SMW of 2022. Among these two exotic whiteflies, the population of *P. bondari* was seven-fold higher when compared to *A. rugioperculatus* (Fig. 1). Similar results were observed in Kerala where *P. bondari* increased to four-fold with less numbers of *A. rugioperculatus* during July, 2020 (CPCRI, 2020). Further no two species cannot exist in the same limiting ecosystem and our study clearly states the increasing phase of *P. bondari* and receding phase of *A. rugioperculatus* due to higher parasitism rates of *E. guadeloupae* as reported by Chandrika Mohan et al. (2019). Chavan et al. (2022) reported peak population of *A. rugioperculatus* during 9th April to 15th April, whereas, Elango and Jeyarajan Nelson (2020) reported maximum population during July. Maximum temperature showed a strong positive correlation for both *A. rugioperculatus* (r=0.495**) and *P. bondari* (r=0.774**) population. Maximum *A. rugioperculatus* population was noticed during first week of April, 2022 when the maximum temperature prevailed at 36.2°C whereas *P. bondari* was highest

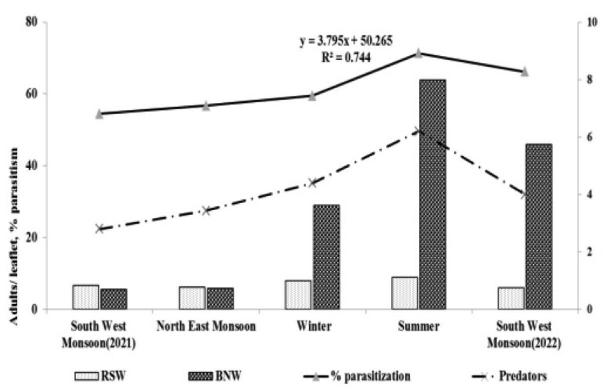

Fig. 1. Population dynamics of *A. rugioperculatus* and *P. bondari* and its natural enemies

Table 1. Popultion dynamics of *A. rugioperculatus and P. bondari*

		Adult	Parasitoid	Chrysopid	Coccinellids/ Cybocephalids	Spiders	Max. temp.	Min. temp	Min. RH	Max.RH	Rainfall
		Y	X1	X2	X3	X4	X5	X6	X7	X8	X9
		Biotic Factors					Abiotic factors				
		A. rugioperculatus									
Y	Adult	1	0.328*	0.699**	0.162	0.437**	0.495**	0.010	-0.508**	-0.518**	-0.394**
X1	Parasitoid		1	0.442**	0.285*	0.249	0.385**	0.230	-0.382**	-0.418**	-0.101
X2	Chrysopid			1	0.372**	0.182	0.571**	0.202	-0.623**	-0.614**	-0.364**
X3	Coccinellids/ Cybocephalids				1	-0.036	0.298*	0.157	-0.347*	-0.315*	-0.314*
X4	Spiders					1	0.144	-0.142	-0.089	-0.166	0.051
X5	Max. temp.						1	0.724**	-0.833**	-0.904**	-0.287*
X6	Min. Temp.							1	-0.364**	-0.546**	0.172
X7	Min. RH								1	0.940**	0.542**
X8	Max. RH									1	0.379**
X9	Rainfall										1

P. bondari

		Adult	Chrysopid	Coccinellids/ Cybocephalids	Spiders	Max. temp.	Min. temp	Min. RH	Max. RH	Rainfall
			X1	X2	X3	X4	X5	X6	X7	X8
		Biotic factors					Abiotic factors			
Y	Adult	1	0.759**	0.366**	0.246^{NS}	0.774**	0.458**	-0.785**	-0.825**	-0.362**
X2	Chrysopid		1	0.372**	0.182^{NS}	0.558**	0.202^{NS}	-0.623**	-0.614**	-0.364**
X3	Coccinellids/ Cybocephalids			1	-0.036^{NS}	0.293*	0.157^{NS}	-0.347*	-0.315*	-0.314*
X4	Spiders				1	0.144	-0.142^{NS}	-0.089^{NS}	-0.166^{NS}	0.051
X5	Max. temp					1	0.724**	-0.830**	-0.901**	-0.281*
X6	Min. temp						1	-0.364**	-0.546**	0. 172
X7	Min. RH							1	0.940**	0.542**
X8	Max. RH								1	0.379**
X9	Rainfall									1

*significant at p=0.05; **at p=0.01

during third week of March when the temperature was 36.0°C on 11th SMW. With regard to the minimum temperature, *A. rugioperculatus* population had a non-significant correlation (r=0.010), whereas it was positively correlated (r = 0.458**) for *P. bondari* (Table 1). Mane (2019) revealed a positive correlation between *A. rugioperculatus* and maximum temperature. Similarly, maximum temperature and relative humidity had positive correlation for cotton whitefly (Ahmad et al., 2018).

Both *A. rugioperculatus* and *P. bondari* population with maximum relative humidity had a highly significant negative correlation of r = -0.518**** and r = -0.825** respectively. Similarly, Elango and Jeyarajan Nelson (2020) reported the negative correlation between relative humidity and whitefly populations. Rainfall had a negative correlation (r = -0.394**) with *A. rugioperculatus* population (Table 1), whereas during northeast monsoon period the population of *P. bondari* was very low (Fig. 2), 1.50 adults/leaflet (46th SMW, fourth week of November, 2021). According to Ranjith et al. (1996), in Kerala *A. dispersus* rebounded throughout the summer and dropped off after severe pre-monsoon showers. Among the abiotic factors, rainfall was the predominant factor which helped in the reduction of *A. rugioperculatus* population.

The aphelinid parasitoid *Encarsia guadeloupae* had a positive correlation (r = 0.328*) with *A.rugioperculatus* population which helped in regulating the population of *A. rugioperculatus* (Table 1). The activity of *E. guadeloupae* coincided with the occurrence of *A. rugioperculatus* all through and the highest parasitism of 84% on nymphal stage was recorded in 24th SMW of June, 2022 and the lowest parasitism of 40% was recorded during 33rd SMW of August, 2021. Mani and Krishnamoorthy (2000) reported nearly 95.68% parasitism by *E. guadeloupae on Aleurodicus dispersus* which is in line with our study, thus it could be a probable

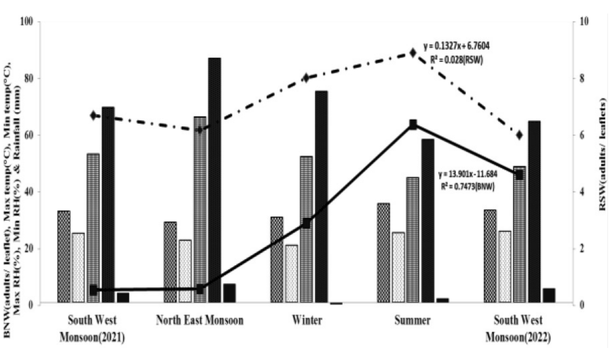

Fig. 2. Seasonal incidence *A. rugioperculatus* and *P. bondari*

reason for low population density of *A. rugioperculatus* compared to *P. bondari.* Among the chrysopids, *Mallada* sp. was found throughout the study period feeding on the immature stages of *A. rugioperculatus* as well as *P. bondari* and its population ranged from 1 to 4 grubs/ frond. Chrysopid population had a highly significant positive correlation with both the whiteflies population i.e., *A. rugioperculatus* (r = 0.699**) and *P. bondari* (r = 0.759**) (Table 1). The *P. bondari* population alone had positive correlation (r=0.366**) with predatory colepterans (Table 1). The ladybird beetles observed were *Cryptoleamus montrouzieri* and *Scymnus coccivora* along with predatory cybocephalid beetles. Ballal et al. (2021) reported a positive link of coccinellid predator larvae with adults and the immature stages of *Aleurotrachelus trachoides* (Back). Furthermore, spider population had a positive correlation (r = 0.437**) with *A. rugioperculatus* population besides it was not significant for *P. bondari* population (Table 1). Naik et al. (2009) stated a major positive connection between whitefly, coccinellids and spiders populations in brinjal crop and alike to our findings.The coefficient of determination (R^2) between *A. rugioperculatus* and the parasitoid was found to be 74.4% of total variation (Fig. 1), whereas for the abiotic factors it was found as 0.02. Thus, it is clear that *A. rugioperculatus* population was suppressed only by *E. guadeloupae.* In case of *P. bondari* the total variation was 74.73 for abiotic factors in population regulation (Fig. 2).

The fixed plot analysis on the exotic coconut whiteflies revealed that *A. rugioperculatus* was very minimal throughout the study when compared to Bondars nesting whitefly, due to the higher rates of parasitism by *Encarsia guadeloupae*. High temperature favoured whitefly outbreak as observed in high numbers during the summer months. Rainfall drastically reduced the population of both the whiteflies. Thus, weather factors and parasitism by *E. guadeloupae* played a critical role in the population regulation of *A. rugioperculatus* in the surveyed area. Innundative release of *Apertochrysa* sp. is advised in coconut plantations to suppress pest outbreak. The farmers are advised a pesticide holiday approach as well as to release the predators during the months of April and May so as to reduce the flaring whitefly population. Adoption of conservation biological control program helps in reducing the cost of plant protection for the coconut growers and safeguard the environment as well.

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CONFLICT OF INTEREST

No conflict of interest.

AUTHOR CONTRIBUTION STATEMENT

P.L: For collection, analysis, interpretation of data and drafting the manuscript. R. N: Advisor for the research work and for drafting the manuscript. A. J: Advisor for the research work and for drafting the manuscript P.C: Advisor for the research work. M.L.M: Advisor for the research. R.D: Advisor for the research. M.M: Advisor for the research. K.S: Advisor for the research.

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