Journal of Agrometeorology 23 (2) : 194-199 (June 2021)

Incidence forecasting of new invasive pest of coconut rugose spiraling whitefly (*Aleurodicus rugioperculatus)* in India using ARIMAX analysis

K.ELANGO*, S. JEYARAJAN NELSON and P.DINESHKUMAR[1]

Department of Agricultural Entomology, TNAU, Coimbatore, India.
[1]Department of Agricultural statistics, BCKV, Mohanpur, India
**Corresponding author: elaento@gmail.com*

ABSTRACT

The rugose spiraling whitefly (RSW), *Aleurodicus rugioperculatus* Martin is a new invasive pest occurring in several crops including coconut since 2016 in India from Tamil Nadu, Karnataka, Kerala and Andhra Pradesh. The population dynamics of new invasive whitefly species, *A. rugioperculatus* study indicated that RSW was found throughout the year on coconut and the observation recorded on weekly interval basis shows that *A. rugioperculatus* population escalated from the first week of July 2018 (130.8 nymph/ leaf/ frond) reaching the maximum during the first week of October (161.0 nymph/ leaf/ frond) which subsequently dwindled to a minimum during April. Due to variation in the agro-climatic conditions of different regions, arthropods show varying trends in their incidence also in nature and extent of damage to the crop. Influence of weather parameters on rugose spiralling whitefly incidence is lacking, which is essential for developing management strategies. The forecasting model to predict rugose spiralling whitefly incidence in coconut was developed by ARIMAX model of weekly cases and weather factors. In exploring different prediction models by fitting covariates to the time series data, ARIMA (0,2,1) with Maximum temperature was found best model for predicting the rugose spiralling whitefly incidence and all covariates were found non-significant predictors except maximum temperature.

Key words: *Aleurodicus rugioperculatus,* ARIMAX, coconut, incidence forecasting

Coconut (*Cocos nucifera*) is one of the most important crops in tropical areas. It is usually referred as ‘tree of heaven’ or ‘kalpavriksha’ because it provides more useful and diverse product to the people. Coconut is grown in more than 93 countries in the world in an area of 12 million hectares, with an annual production of 59.98 million tonnes of nuts. India occupies third position in the world level with an annual production of 10.56 million tonnes of coconuts. In India, Kerala, Tamil Nadu, Goa, Karnataka, Maharashtra, Orissa, West Bengal and Assam are the major coconut producing states in India. India consumes 50% of annual production for their culinary and religious purpose, 35% used as copra, 2% for manufacturing of value added products, 11% for tender uses and 2% for seed purpose. More than 900 species of pests are associated with coconut palm. This includes both invertebrates and vertebrates. Of these, red palm weevil, (*Rhynchophorus ferrugineus* Olivier) rhinoceros beetle (*Oryctes rhinoceros* L.) and coconut black-headed caterpillar (*Opisina arenosella* Walker) are the most important devastating insect pests of coconut in major coconut-growing areas of India (Kumara *et al*., 2015). In Tamil Nadu, the incidence of rugose spiraling whitefly, *A. rugioperculatus* (Hemiptera: Sternorrhyncha: Aleyrodidae) on coconut was first observed in Anaimalai block, Coimbatore during August, 2016 (Sundararaj and Selvaraj, 2017). Rugose spiraling whitefly (RSW) is a new invasive pest and also polyphagous which is likely to expand the host range as the species becomes more established. The RSW has been reported in India from Tamil Nadu, Karnataka, Kerala and Andhra Pradesh (Sundararaj and Selvaraj, 2017). It mainly infests coconut palms and other broad-leaved hosts in its native range. The pest is somewhat superficially similar in its habits and general appearance to spiralling whitefly *A. disperses*, which itself is an invasive pest that came to India in the mid-1990s. RSW 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. Influence of weather parameters on rugose spiralling whitefly incidence is lacking, which is essential for developing management strategies. Current studies showed that though the infestation was recorded throughout the year, it was found low in rainy season, moderate during post rainy season and high in summer. Therefore, weather parameters also play an important role in the rugose spiralling whitefly incidence in coconut trees. The population buildup of any insect is very intimately related with the weather parameters (Boopathi *et al*., 2014). Forecasting enables to prevent outbreaks and epidemics of rugose spiralling whitefly incidence. Hence, this study also aimed at proposing a prediction model to use management practices well in advance

MATERIALS AND METHODS

Population dynamics of coconut rugose spiralling whitefly

The population density of *A. rugioperculatus* on five-year-old coconut trees was assessed from 2017 to 2019. An earlier report by Elango *et al.* (2019) showed more damage with infestation index of 2.28 in Chowghat Orange Dwarf (COD) compared to other varieties. Ten coconut trees were selected randomly in the orchard of Horticultural College and Research Institute, TNAU, Coimbatore. The coconut trees maintained under pesticide-free environment were selected for observation of population dynamics of RSW, and the trees were supplied with proper macro and micronutrients and irrigation. The study was carried out for 21 months from October 2017 to April 2019, which coincided with 40th standard meteorological week of 2017 to 17th standard meteorological week of 2019. In each tree, the bottom matured five fronds were selected, and from each frond, five leaflets were marked for taking observations on population dynamics of RSW as per the methodology of Elango and Nelson (2020). Weekly observations were made in selected leaflets of the coconut tree, and the number of nymphs of *A. rugioperculatus* per leaf was noted on these leaflets

Weather parameters

The population RSW of (dependent variable) recorded on coconut were correlated with weather factors (independent variable) *viz.,* maximum temperature (X_1), minimum temperature (X_2), maximum relative humidity (X_3), minimum relative humidity (X_4), and total rainfall (X_5) obtained from Agro Climate Research Centre (ACRC), Coimbatore for the entire study period. Totally 82 observations are collected from the 40th SMW for 2017 to 14th SMW of 2019. Multiple regression analysis was also performed with weather parameters.

Correlation

Simple correlation was performed using SPSS 16.0 statistical package to associate the incidence of *A. rugioperculatus* with various biotic factors.

Time series modeling

Along with the insect data, the above-mentioned climatological variables are also collected for the same time interval. So, Multivariate time series is employed for predicting the number of *A. rugioperculatus* nymphs per plant in the coconut.

The ARIMAX model (Bierens, 1987) is a generalization of the ARIMA model, which is capable of including an exogeneous variable (*X*) (Zhi *et al.*, 2020). Given a (*k*+1) time series process $\{(y_t, x_t)\}$, where y_t and *k*-components of x_t are real valued random variables, the ARIMAX model is given by the form

$$\left(1-\sum_{i=1}^{p}\varphi_i L^i\right)(1-L)^d y_t=\mu+\sum_{k=1}^{r}\beta_k' L^k x_t+\left(1+\sum_{j=1}^{q}\theta_j L^j\right)\varepsilon_t$$

where, *L* is the lag operator, $\mu,\varphi_i,\beta_k,\gamma_j\in R$ are the parameters unknown and ε_t are the errors.

Initially, the stationarity of the variables is tested using the Autocorrelation function (ACF) and Augmented Dicker Fuller (ADF) test. If the data is non-stationary, the data was differenced until it become stationary and the difference parameter *d* is selected. The ACF and PACF are computed to fix the lag parameters *p* and *q* for Autoregressive and moving averages respectively. After fitting the ARIMAX models with various combinations, Model selection criterions such as corrected Akaike information criterion (AICc) and Schwartz-Bayesian criterion (BIC) values was employed. The corrected Akaike information criterion (AICc) is given by (Cavanaugh, 1997),

$$AIC=-2\log(\text{Maximum likelihood})+2k \text{ ,where, } k=p+q+1$$

$$AICc=AIC+\frac{2(k+1)(k+2)}{n-k-2}$$

and the Schwartz-Bayesian criterion (BIC) is given by (Schwarz, 1978),

$$BIC=-2\log(\text{Maximum likelihood})+2k\log(n)\ .$$

The model with minimum AICc and BIC was selected as the best model for the prediction of *A. rugioperculatus* nymphs per plant.

Table 1: Correlation coefficient (r) among *A. rugioperculatus* population and its abiotic factors (weather parameters)

	Y	X1	X2	X3	X4	X5
Y	1	.299**	.101	.234*	.323**	-.081
X1		1	.493**	-.409**	-.582**	-.152
X2			1	-.229*	.345**	.213
X3				1	.292**	.187
X4					1	.496**
X5						1

Y: *A. rugioperculatus* population per leaf, X1: Maximum temperature (^{0}C), X2: Minimum temperature (^{0}C), X3: Morning relative humidity (%), X4: Evening relative humidity (%), X5: Rainfall (mm).
** Significant at 1%, * Significant at 5%, NS: non-significant.

Table 2: ADF test for stationarity of insect population

Augmented Dickey-Fuller Test	t Statistic	p value*
Original value	-0.869	0.952
First differenced	-3.013	0.161
Second differenced	-4.923	0.009
* p < 0.05 - Significant at 5 % level		

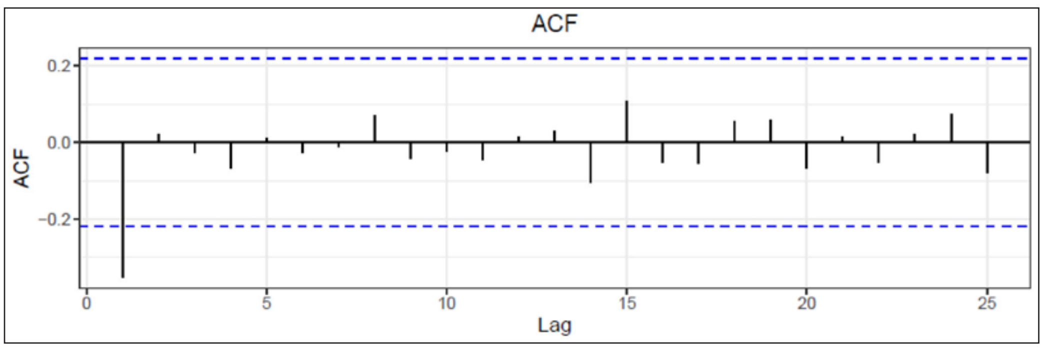

Fig. 1: Autocorrelation function for the Second order differentiation data

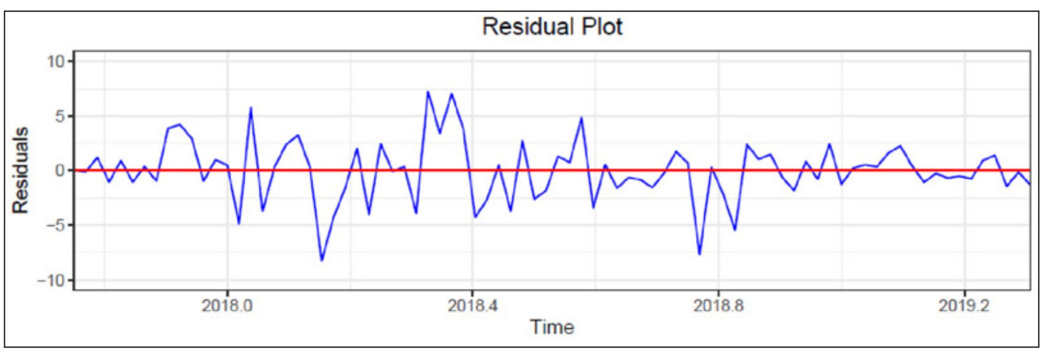

Fig. 2: Partial Autocorrelation function of the original series

RESULTS AND DISCUSSION

Correlation studies of population density of A. rugioperculatus

It was found that the infestation was low during the rainy season, moderate during post rainy season and high in summer. RSW population density was high during first week of October (161. nymph/ leaf/ frond). *A. rugioperculatus* population fluctuation was comparatively high from first week of July 2018 (130.8 nymphs /leaf/frond) till the last week of October 2018 (150.2 nymphs /leaf/frond) and then declined up to April. Correlation between abiotic factors and *A. rugioperculatus* population showed that maximum temperature (r = 0.299 *) and minimum temperature (r = 0.101) had significant positive correlations. There was a positive significant correlation between morning and evening relative humidity (r = 0.234*) and (r =0. 323**). However, rainfall (r = -0.181) showed negatively significant correlation

Table 3: Fitted models with its parameter estimates and the selection criterion

Sr. No.	Model	Parameter Estimates								AICc	BIC
		AR1	AR2	MA1	X1	X2	X3	X4	X5		
1	ARIMA(0,2,1)			-0.433*** (0.109)	-0.328* (0.162)	-	-	-	-	399.12	405.95
2	ARIMA(1,1,1)	0.827*** (0.086)		-0.301* (0.145)	-	-0.086 (0.168)	-	-	-	404.43	413.48
3	ARIMA(0,2,1)			-0.432*** (0.114)	-	-	-	-	-0.047 (0.061)	402.56	409.39
4	ARIMA(2,1,0)	0.468*** (0.114)	0.287* (0.116)	-	-0.369* (0.174)	-	-0.029 (0.079)	-	-	401.99	413.16
5	ARIMA(1,1,1)	0.834*** (0.081)	-	-0.307* (0.137)	-0.380* (0.182)	-	-	0.0243 (0.033)	-	402.61	413.78
6	ARIMA(1,1,1)	0.839*** (0.080)	-	-0.322* (0.136)	-0.304 (0.161)	-	-		-0.035 (0.060)	402.8	413.97
7	ARIMA(2,1,0)	0.469*** (0.116)	0.286* (0.119)	-	-0.368* (0.176)	-0.007 (0.169)	-0.028 (0.080)	-	--	404.32	417.55
8	ARIMA(2,1,0)	0.489*** (0.111)	0.267* (0.113)	-	-0.495* (0.232)	0.134 (0.242)		0.042 (0.049)		403.73	416.96
9	ARIMA(1,1,1)	0.829*** (0.083)	-	-0.292* (0.141)	-0.406* (0.182)	-		0.042 (0.036)	-0.071 (0.067)	403.82	417.06
10	ARIMA(1,1,1)	0.831*** (0.082)		-0.298* (0.141)	-0.406* (0.182)		-0.024 (0.077)	0.044 (0.037)	-0.075 (0.068)	406.12	421.35
11	ARIMA(2,1,0)	0.486*** (0.115)	0.271* (0.119)		-0.546* (0.236)	0.176 (0.246)	-0.049 (0.079)	0.069 (0.054)	-0.072 (0.067)	407.2	424.35

***, **, * Significant at 0.001, 0.01 and 0.05 levels; Values in the parentheses represents the Standard error of the coefficients
AICc - corrected Akaike's Information Criterion; BIC - Bayesian information criterion

Table 4: Normality tests for the residuals of the fitted model

Normality Test	Statistic	p value*
Box-Pierce test	3.944	0.950
Box-Ljung test	4.380	0.929
* $p < 0.05$ - Significant at 5 % level		

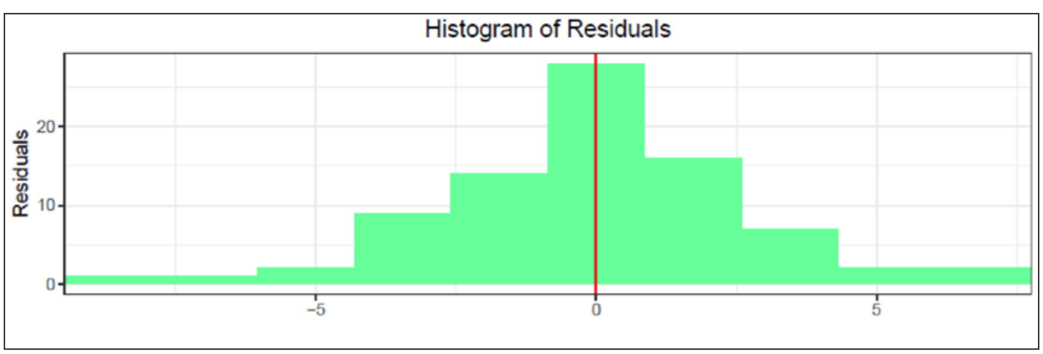

Fig. 3: Residual plot of the ARIMA (0,2,1) with maximum temperature

with *A. rugioperculatus* population. Similarly, deficit rainfall, increased temperature and reduced humidity were found to be the reasons for flare up and spread of the pest *A. rugioperculatus* (Josephrajkumar *et al.*, 2018). Elango and Nelson (2020) also reported that prolonged dry spell is the main reason for proliferation and quick dispersal of the rugose spiraling whitefly in Tamil Nadu. In case of *A. dispersus* also the population density was positively correlated with maximum temperature and negatively correlated with relative humidity on guava (Mallappanavar, 2000; Mani and Krishnamoorthy, 2000).

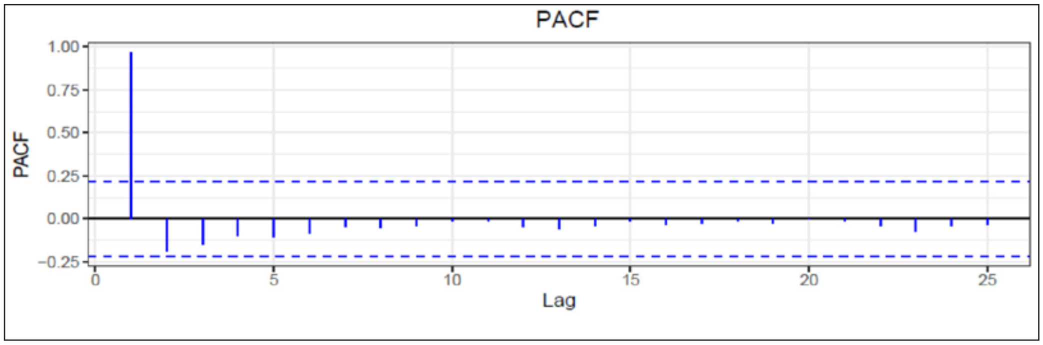

Fig. 4: Histogram for residual of the ARIMA (0,2,1) with maximum temperature

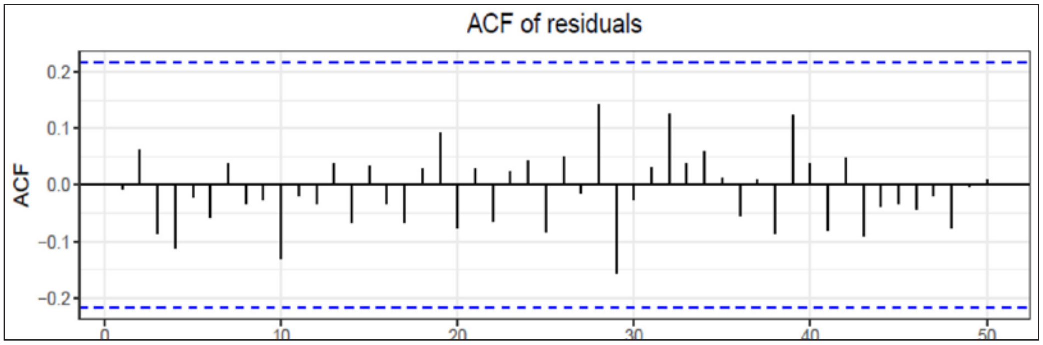

Fig. 5: ACF for residual of the ARIMA (0,2,1) with maximum temperature

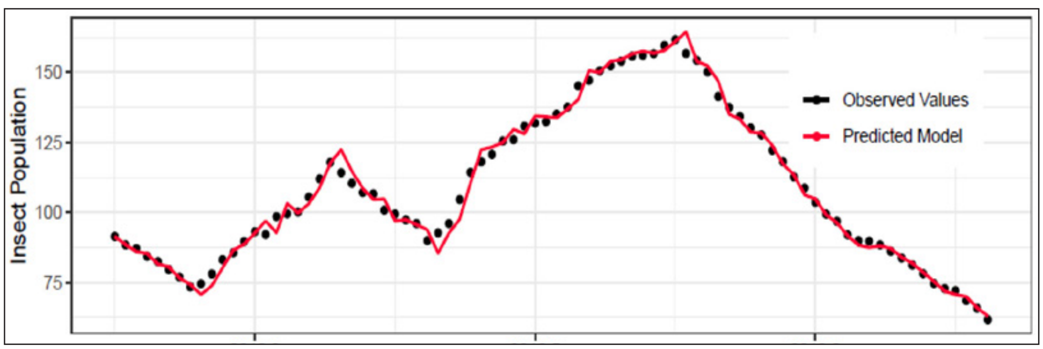

Fig. 6: Observed values and predicted values of ARIMA (0,2,1) with maximum temperature

ARIMAX modelling

Augmented Dickey-Fuller (ADF) Test and autocorrelation function (ACF) were used to test the stationarity of the insect population. From the Table 2, The *t*-statistic value of the Augmented Dickey-Fuller Test for the actual data shows that the data is non stationary (-0.869). So, the first differenced data was taken and tested for stationarity. The *t*-statistic of the ADF test in the Table 2 shows that it is non stationary (-3.013). Again, the second differenced data was taken and test for stationarity. The ADF *t*-statistic value (-4.923) shows that the second differenced data is stationary. Fig. 1 shows the ACF values of the second differenced data which confirmed that it is stationary. Using the ACF and PACF values as showed in Fig. 1 and 2, the optimum lags for the Moving average and auto regressive polynomials (p, q) were selected.

All the climatic variables were used with various combinations to fit the ARIMAX model. The parameter estimates of the fitted models and its significance were calculated. On the basis of minimum corrected Akaike information criterion (AICc) and Schwartz-Bayesian criterion (BIC) values, best 10 ARIMAX model was selected and presented in the Table 3. Among the fitted models, ARIMAX (0,2,1) with Maximum temperature have the least AICc and BIC values.

For validating the selected model, the normality of the residuals was tested. The simple residual plot in the Fig. 3 suggests that the residuals may be normal. To test that, Normality test such as Box-Pierce test and Box-Ljung test were used. The statistics of these two tests are presented in the table 4 which proved that the residuals are normally distributed. The histogram of the residuals (Fig. 4) is an added evidence for the residuals' normality. Fig. 5 which represents ACF of the residuals shows that none of the autocorrelation is significantly different from zero. From these evidences, we can conclude that the proposed ARIMAX model (Fig. 6) is the good fit and an appropriate model for the forecast of the insect population. Chattopadhyay (2021) stated that the management of weather and climate risks in agriculture has become an important issue due to climate change. Aishwariya *et al.* (2007) stated that whiteflies are present throughout the year in South India, with high population in summer (March-June) and low ones in winter (October January). Nymphal population was low in June to July and reached peak in November at Shimoga with this information, ARIMAX model was used to study the behavior of whitefly along with the abiotic factors. Only Maximum temperature has a significant impact with the whitefly population whereas the other abiotic factors were not significantly influencing the pest population.

CONCLUSION

ARIMAX model developed, it might be possible to predict a *A. rugioperculatus* incidence, since it is a new invasive pest of coconut in India. This model will further help to assess the incidence and population surge of rugose spiraling whitefly for its timely adoption of control measures by the growers. The model may further enables to prevent outbreaks and epidemics of rugose spiraling whitefly incidence in coconut ecosystem.

REFERENCES

Aishwariya, K.K., Manjunatha, M. and Naik, M.I. (2007). Biology and host range of spiralling whitefly. *Karnataka J. Agril. Sci.*, 20(1):149-152.

Bierens, H.J. (1987). ARMAX model specification testing, with an application to unemployment in the Netherlands. *J. Econom.*, 35(1):161-90.

Boopathi, T., S. B. Singh, T. Manju, S. K. Dutta, A. R. Singh, Samik Chowdhury, Y. Ramakrishna, and Vishambhar Dayal. (2017) Temporal modeling for forecasting of the incidence of litchi stink bug using ARIMAX analysis. *Indian J. Hortic.*, 74(4):604-607.

Cavanaugh, J.E. (1997). Unifying the derivations for the Akaike and corrected Akaike information criteria. *Stat. Probabil Lett.*, 33(2):201-208.

Chattopadhyay, N. (2021). Weather and climate based farm advisory services. *J. Agrometeorol., 23 (1): 1-2*

Cheng-Zhi, C., Wen-Fang, C., Xiao-Shan, Z., Jin, Z., Dan, X., Cong-Jian, L. and Waqar, K., (2020). Yield potential of world wheat based on ARIMA model under global warming. *J. Agrometeorol.*, *22*(4): 397-406.

Elango, K and Jeyarajan Nelson, S.(2020). Population dynamics of exotic rugose spiralling whitefly, *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae) on coconut as influenced by weather factors and natural enemies. *J. Plant. Crops,* 48(2):120-125.

Elango, K., Nelson, S.J., Sridharan, S., Paranidharan, V. and Balakrishnan, S. (2019). 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. *Int. J. Agric. Sci.,* 11(9): 8423-8426.

Josephrajkumar, A., Chandrika Mohan, P. S. Prathibha, T. Nalinakumari, and C. P. R. Nair. (2018). Pest Dynamics and Suppression Strategies. In The Coconut Palm (*Cocos nucifera* L.)-*Res. Develop. Persp.,* pp. 557-634.

Kumara, A. D. N. T., Chandrashekharaiah M., Subhash B. Kandakoor, and A. K. Chakravarth. (2015). Status and Management of Three Major Insect Pests of Coconut in the Tropics and Subtropics. In *New Horizons in Insect Science: Towards Sustainable Pest Manag.*, pp. 359-381.

Mallappanavar, M. C. (2000). Bioecology and management of spiraling whitefly, *Aleurodicus dispersus* Russell by *Verticillium lecanii (Zimm.)* on guava (Doctoral Dissertation, University of Agricultural Sciences, Dharwad; pp.76.

Mani, M., and A. A. Krishnamoorthy. (2000). Population dynamics of spiralling whitefly, *Aleurodicus dispersus* Russell (Aleyrodidae, Homoptera) and its natural enemies on guava in India. *Entomon,* 25(1):29-34.

Schwarz, G. (1978). Estimating the dimension of a model. *The Annals of Statistics*, 6(2):461-4.

Sundararaj, R and K. Selvaraj. (2017) Invasion of rugose spiraling whitefly*, Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae): a potential threat to coconut in India. *Phytoparasitica,* 45(1):71-74.

Received : March 2020 : Accepted : May 2021