Pest Management in Horticultural Ecosystems
Vol. 26, No.1 pp 11-17 (2020)

DOI number: 10.5958/0974-4541.2020.00002.8

Impact of weather parameters on *Raoiella indica* Hirst. (Acari: Tenuipalpidae) on coconut (*Cocos nucifera* L.)

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ABSTRACT: The red palm mite, *Raoiella indica* is a serious pest of several species of Arecaeae including *Areca catechu, Cocos nucifera* and *Phoenix dactylifera* as well as Musaceae (*Musa* spp.). It was first reported in the Caribbean islands in 2004 and has since spread throughout the region causing widespread damage to coconut in particular. The current study was designed to determine the relationship between several weather parameters (*viz.* minimum and maximum temperature, rainfall and relative humidity) and population levels of different life stages of *R. indica.* A series of stage-specific life tables were also constructed using the collected data. Multiple regression and correlation analyses indicated that collectively, all four weather parameters significantly influenced each life stage of *R. indica.* Sex ratio was significantly influenced by all weather parameters examined except rainfall. Graphical key factor analysis and regression of sub-mortalities (k) against total mortality (K) of the life tables generated indicated that mortality (k_2) in the nymphal stages (protonymph and deutonymph) contributed most to overall mortality (the key factor).

Keywords: *Raoiellaindica*, coconut, population dynamics, West Indies, weather factors

INTRODUCTION

Red palm mite, *Raoiella indica* Hirst (Acari: Tenuipalpidae) is commonly called the coconut red mite, red date palm mite and scarlet mite. It is widespread in the tropical and subtropical hemisphere and was first reported in the Caribbean region in 2004 in Martinique (Flechtmann and Etienne, 2004). In 2005, it was reported in the islands of Saint Lucia and Dominica (Kane *et al.,* 2005). In 2006, it was reported in the Dominican Republic, Guadeloupe, Puerto Rico, Saint Martin and Trinidad and Tobago (CABI, 2007). In 2007, the US Virgin Islands, Grenada, Haiti and Jamaica also reported red palm mite colonies (EPPO, 2014).

Various reports have stated that 32 palm species including coconut are host plants. In the Caribbean, it has also been observed to cause severe damage to bananas and plantains (*Musa* spp.), heliconias and gingers (*Heliconia* spp.) and bird of paradise (*Strelitzia reginae*) (CABI 2007). Both the fresh coconut and coconut oil industry has been severely affected as coconut production has declined drastically (Carrillo *et al.,* 2012). Several estates have been abandoned because it is uneconomical to maintain trees with severe attack by this mite especially during the dry season. Affected plant leaves turn from green to pale green then yellow and finally brown. Affected plants also abort flowers and small fruits and eventually entire crown of the plant dies (Carrillo *et al.,* 2012). These symptoms are frequently confused nutrient deficiencies or lethal yellowing, a non-related but very serious palm disease. Lethal yellowing also causes widespread chlorosis (browning and death of tissues) of the lower leaves. Red palm mite colonies establish on the underside of the leaves feeding through the stomata or by piercing the plant tissue with their stylet-like mouthparts (Rodriguez *et al.*, 2010). One of the major modes of dispersal appears to be through the transport of infected plant material or landscaping tools such as pruning shears. Additionally, dispersal through wind, as might occur with tropical storms, is also a possibility.

Raoiella indica is usually visible with the naked eye and appear as bright red dots with a round flat body, long body hairs and some water-like droplets at the tip. All life stages, including the eggs are red. Eggs become clear as they mature and nymphal eclosion occurs. Adult females frequently have dark markings on their dorsum after feeding. Females are slightly larger than males and occur in larger numbers in a population (Flores - Galano et al., 2010). They are also easily distinguished from males by having an oval body shape compared to the triangularly shaped body of males (Nageshachandra and Channabasvanna, 1984; Flores-Galano et al., 2010). Red palm mite can easily be distinguished from most spider mites by their bright red colour and absence of webbing as they do not produce silk, which is a common feature for most spider mites. Red palm mites are also relatively slow moving when compared with spider mites.

The objectives of the present study were to determine the correlation of weather parameters (*viz*. maximum and minimum temperature, rainfall and relative humidity) with different life stages of *R. indica* and develop life tables to identify the most vulnerable stage(s) in the mite's life cycle.

MATERIALS AND METHODS

Host plant culture

Twelve coconut seedlings (*var*. Cedros Green) with newly emerged shoots about a few centimeters from the drupe and no leaves present were collected from an estate in SWTrinidad. They were transported to a screen house and planted in 20L plastic buckets and allowed to continue growing. The plants were watered daily and fertilized with Blaukon® 12-12-17-2 at 2-week intervals to encourage leaf growth. Plants were placed in a semi-protected area where little rainfall or wind came into contact with the growing plants but were exposed to sunlight for the entire day. Plants were left to grow for a period of two months.

Mite culture

Field visits were made to Cedros, Trinidad and *R. indica* infected coconut leaves (30 – 60 cm long) were collected during the early morning period, placed in plastic bags and taken back to the screen house where the seedlings in the pots were actively growing. The infested leaf was attached to the young potted plants using paper clips to allow for migration of mites after which plants were placed outdoor under natural conditions. Mites were observed to have started oviposition several days after moving onto the fresh leaves and within two months the mite population increased rapidly.

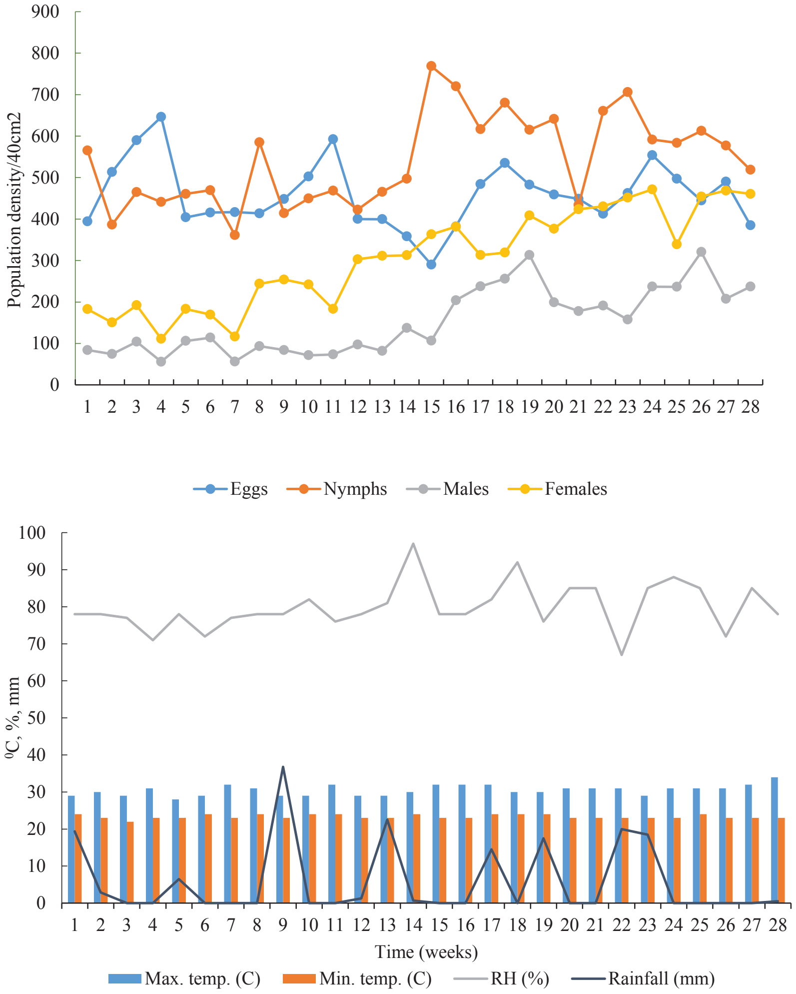

Fig. 1. Relationship between weather parameters and *Raoiella indica* egg, nymph and adult populations

Life tables

Stage-specific (vertical) life tables were constructed based on the mean values of the data collected and using the column headings: stage (x), initial number (N_x), number dead (d_x), mortality (q_x), survival (S_x) which was calculated as 1 – mortality(q_x) and k value (-ln[S_x]). Males were considered a mortality factor as females could reproduce via arrhenotokous parthenogenesis (unfertilized eggs develop into haploid males) (Nageshachandra and Channabasavanna, 1984) as well as sexually.

Data collection and analysis

Two coconut leaflets each 20cm long x 2cm width (= 40cm^2) were cut from randomly chosen growing plants and observed under a microscope. The number of eggs, nymphs, females and males of *R. indica* as well as the number dead in each stage were counted and recorded for each leaflet. This was done weekly over a 28-week period and each sample replicated five times. Weather and population data were analyzed using multiple regression and correlation analysis in SPSS ver. 24.

Life tables were analyzed using graphical key factor analysis (Southwood and Jepson, 1962). Sub-mortalities (k) for each stage was regressed against total mortality (K) and the linear regression and correlation coefficient (r^2) determined. The regression line with the greatest positive slope contributed most total mortality and was the key factor (Podoler and Rogers, 1975).

RESULTS

Population variation of *R. indica* with time and weather parameters

Data for four weather parameters *viz. m*inimum temperature (^{0}C), maximum temperature (^{0}C), relative humidity (%) and rainfall (mm) were collected from the University Field Station (UFS), Valsayn Trinidad and were used together with population data to develop multiple regression models for various stages of *R. indica.* Population densities of eggs, nymphs, males and females of *R. indica* were determined per 40cm^2 (from leaf dimensions 20cm x 2cm)) over the duration of the study and are presented Figure 1. Collectively, minimum temperature, maximum temperature, relative humidity and rainfall had significant effect on the egg ($F_{4,135}$ = 627.09, P<0.0001), nymphs ($F_{4,135}$ = 653.87, P<0.0001), female ($F_{4,135}$ = 152.83, P<0.0001) and male ($F_{4,135}$ = 127.58, P<0.0001) populations. However, maximum temperature had the greatest impact on all four stages of *R. indica* (Table 1). Sex ratios of *R. indica* were also determined and the data indicated that there were variations in the sex ratio during the study period with the mean male: female sex ratio being 1:2.19 (Fig 2). Maximum temperature (t_{54} = 96.098, P<0.0001), minimum temperature (t_{54} = 127.68, P<0.0001) and relative humidity (t_{54} = 64.203, P<0.0001) separately had significant effects on the sex ratio of *R. indica* while rainfall did not (t_{54} = 1.907, P = 0.0618). However, the combined effects of the four weather parameters did significantly affect the sex ratio.

Modeling

Several models were developed for *R. indica* using the weather parameters listed. A multiple regression model for eggs was developed for *R. indica*: Log_{10} Eggs = 3.159 + 0.000199* Temp(Min) – 0.002614*Temp(Max) + 0.0001398*RH – 0.001014*Rainfall – 0.1636*log_{10} nymphs – 0.01176*log_{10} adults. An insignificant amount of the variance in this model was accounted for through the combined effects of the other variables (r^2 = 6.94%) with only the constant in the equation making a significant contribution (t_{21} = 3.767, P = 0.0011). Overall the equation was not found to be statistically significant ($F_{1,22}$ = 0.2610, P = 0.9490).

The multiple regression model for nymphs was Log_{10}Nymphs = 1.557 + 0.02941*Temp (Min) + 0.002786*Temp(Max) - 0.00176*RH – 0.00022*Rainfall – 0.1162*log_{10}eggs + 0.3225*log_{10}adults.A significant amount of the variance in this model was accounted for through the combined effects of the other variables (r^2 = 53.21%) with log_{10}adults in the equation making a significant contribution to the total observed variance (t_{21} = 3.986, P = 0.0007). Overall the equation was found to be statistically highly significant ($F_{1,22}$ = 4.8242, P = 0.0082).

The model for male *R. indica* was Log_{10}Males = -4.411 + 0.05428* Temp (Min) + 0.004274* Temp (Max) - 0.00255*RH – 0.00257*Rainfall + 0.6396*log_{10}eggs + 0.4761*log_{10} nymphs + 0.9654*log_{10} females. The multiple regression equation for log_{10} males was found to be extremely significant ($F_{1,22}$ = 8.6545, P < 0.0001) with most of the variance being accounted for through the combined effects of the other variables (r^2 = 76.53%) with both the constant (t_{21} = 2.561, P = 0.0186) and log_{10} females (t_{21} = 4.570, P = 0.0002) in the equation making significant contributions to the total observed variance. The multiple regression model for Log_{10}Females was Log_{10}Females = 2.332 - 0.0671* Temp (Min) + 0.01144*Temp (Max) + 0.006443*RH + 0.003258*Rainfall - 0.4568*log_{10}eggs + 0.3302*log_{10}nymphs + 0.5292*log_{10}males.Most of the variance in log_{10} females was accounted for through the

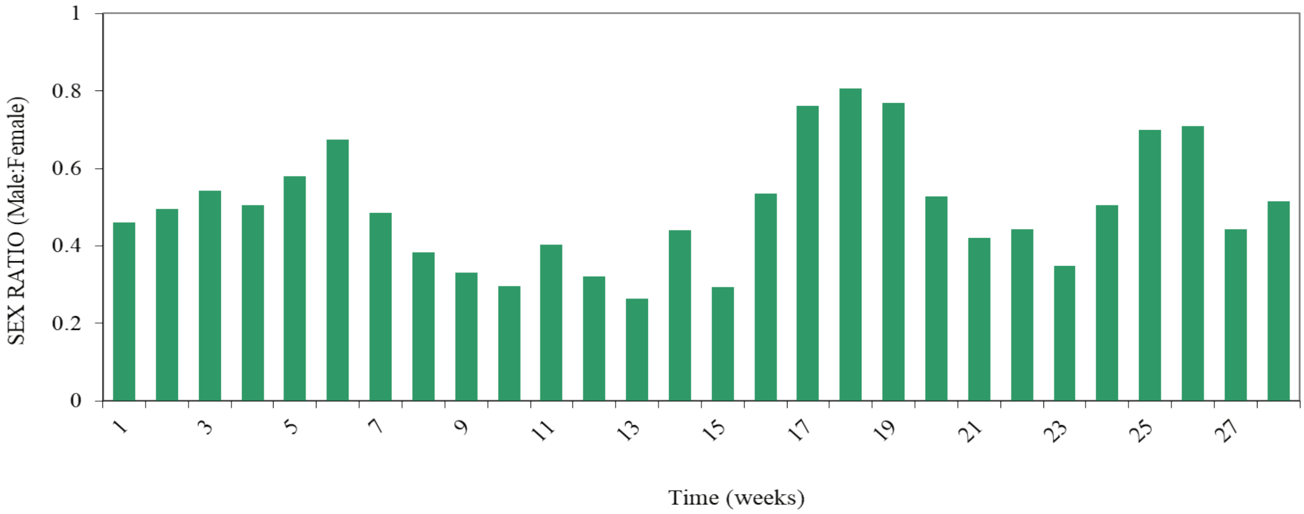

Fig. 2. Variation of sex ratio (male:female) of *Raoiella indica* during the period of study

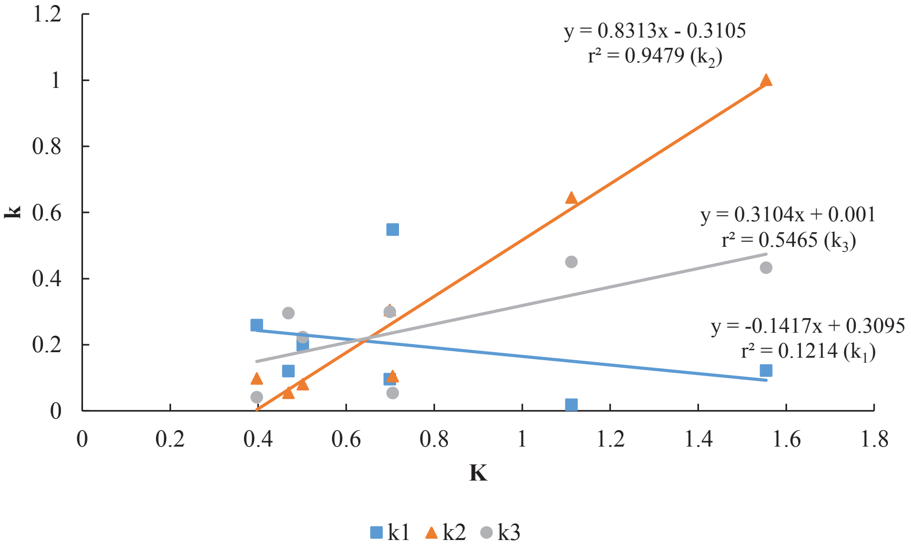

Fig. 3. Regression of sub-mortalities (k) against total mortality (K) for *Raoiell aindica*

Table 1. Correlation matrix for *Raoiella indica* with various weather parameters

Parameter	^{0}C (min)	^{0}C (max)	RH	Rainfall	Eggs	Nymphs	Females	Males	Total adults
^{0}C (min)	1	-0.0241	0.2332	0.0022	-0.0312	0.1152	-0.1449	0.1073	-0.0449
^{0}C (max)	-0.0241	1	-0.0436	-0.3784	-0.0354	0.2837	0.3572	0.3554	0.3780
RH	0.2332	-0.0436	1	-0.1721	-0.0124	0.1360	0.2831	0.1977	0.2634
Rain fall	0.0022	-0.3784	-0.1721	1	-0.1580	0.0206	0.0467	-0.0646	0.0015
Eggs	-0.0312	-0.0354	-0.0124	-0.1580	1	-0.2383	-0.2350	0.0134	-0.1421
Nymphs	0.1152	0.2837	0.1360	-0.0206	-0.2383	1	0.6221	0.5861	0.6442
Females	-0.1449	0.3572	0.2831	-0.0467	-0.2350	0.6221	1	0.7705	0.9615
Males	0.1073	0.3554	0.1977	-0.0646	0.0134	0.5861	0.7705	1	0.9160
Total adults	-0.0449	0.3780	0.2634	0.0015	-0.1421	0.6442	0.9615	0.9160	1

combined effects of the other variables (r^2 = 80.60%) with both $\log_{10}$males and maximum temperature in the equation making significant contributions to the total observed variance (t_{21} = 4.57, P = 0.0002). Overall the equation was found to be statistically significant ($F_{1,22}$ = 10.6562, P < 0.0001).

A multiple regression model of Log_{10}Total adults was developed for *R. indica*: Log_{10}Total adults = -1.189 - 0.05832*Temp(Min) + 0.02814*Temp(Max) + 0.009432*RH + 0.003073*Rainfall - 0.03458*$\log_{10}$eggs + 1.335*$\log_{10}$nymphs.A significant amount of the variance in $\log_{10}$Total adults was accounted for through the combined effects of the other variables (r^2 = 59.60%) with the two variables relative humidity (RH) (t_{21} = 2.095, P= 0.0485) and maximum temperature (t_{21} = 3.986, P = 0.0007) in the equation making significant contributions to the variance in this model. Overall the equation was found to be extremely significant ($F_{1,22}$ = 5.1643, P = 0.0021).The values in the correlation matrix support the multiple regression models derived (Table 1). Sex ratio (Figure 2) was not significantly affected by the weather parameters examined (r^2 = 13.24%, p=0.49) with sex ratio being represented by the model: sex ratio = 9.266 - 0.05719*[temp max] - 0.2721*[temp min]+ 0.01153*[RH] + 0.01672*[Rainfall]

Life tables

Graphical key factor analysis indicated that nymphal mortality most closely followed total mortality (K). This was confirmed by regression analysis of individual sub-mortalities (k) against total mortality (K) for *R. indica*. Based on the method of Podoler and Rogers (1975), the linear regression line with the greatest positive slope was sub-mortality k_2 (nymphs) (slope = 0.8313, r^2 = 0.9479) (Fig. 3).

DISCUSSION

The study revealed weather conditions apart from maximum temperature had little significance on the population over the period examined. Several studies have also found a positive correlation of spider mites with temperature (Fidelis *et al.,* 2019; Zhi Wen *et al*., 2018; Kaur and Zalom, 2018; Wen Hua *et al*., 2016). Additionally, the population of cassava mite (*Mononychellus tanajoa* (Bondar) (Acari:Tetranychidae) was greatly affected due to the washing away of nymphs and adults by rainfall (Yaninek*et al.,* 1989). Ahuja (2000) on the other hand mentioned that rainfall as well as maximum and minimum temperatures had negative and non-significant correlation to *P. latus* populations on *Sesamum indicum* L. Less *R. indica* eggs were oviposited at higher temperatures as there was a negative correlation between temperature and number of eggs in the present study. This is in agreement with a study by Ramani (2008) on *Tetranychus neocaledonicus* (Andre) (Acari:Tetranychidae) on *Moringa oleifera* Lam.

Some studies have indicated that rain generally has a negative influence on mites as most nymphs and adults are washed off during periods of heavy rainfall (Castilho *et al.,* 2015).However, Douglas *et al.* (2018) noted that the densities of two pasture mites, *Halotydeus destructor* (Tucker) (Acari: Penthaleidae) and *Penthaleus major* (Duges) (Acari: Penthaleidae) were not affected by rainfall. The current study also concludes that there was minimal influence of rainfall on populations of *R. indica* but this may have been due to the low rainfall recorded during the period of study. Leite *et al.* (2003) found that there were higher populations of mites where periods of low humidity occurred. The multiple regression model for total adults indicated that relative humidity made a significant contribution to the number of adults in the population. However, Gonzalez *et al.* (1983) noted that relative humidity played a negative role on the population of citrus rust mite (*Phyllocoptruta oleivora*) in Cuba while Kumar *et. al* (2015) observed no significant correlation between red spider mite and relative humidity.

The series of static (time-specific) life tables constructed for *R. indica* under field conditions has not been previously described in the available literature. Fidelis *et al.* (2019) only recently reported fecundity life tables for *R. indica* at various temperatures. They concluded that complete development of *R. indica* only occurred at temperatures between 20-30^{0}C and that eggs did not eclose at 15^{0}C while at 34^{0}C survival only occurred until the larval stage. Optimal reproduction was at 27^{0}C. The current study has identified that mortality (k_2) in the nymphal stages (protonymph and deutonymph) was the most significant contributor to the total mortality of *R. indica* observed during the study period. The mean nymphal mortality in this study was 24% which was similar to that obtained by Flores-Galano*et al.* (2010) for *R. indica* on *Areca catechu* L. of 24.4% (7.3% for protonymphs and 17.1% for deutonymphs).

We conclude that maximum temperature had the greatest impact and that relative humidity had a lesser but still significant impact on the population of *R. indica.* Additionally, peak periods were observed with the increase in egg production every 7-8 days and eclosion of nymphs every 8-9 days.However, there are unknown variables which were not considered in this study that may have an impact on the population dynamics of *R.indica* and further research is needed in this area.

REFERENCES

Ahuja, D.B. 2000. Influence of abiotic factors on the population of mite, *Polyphagotarsonemus latus* (Banks) infecting sesame (*Sesamum indicum*L.) in the arid region of Rajasthan (India). *Journal of Entomological Research,* **24** (1): 87-89.

CABI. 2007. *Raoiella indica.* In 'Distribution Maps of Plant Pests – Map 210" (1st Revision).CABI Wallingford, United Kingdom.

Carrillo, D., Amalin, D., Hosein, F., Roda, A., Duncan, R.E. and Pena, J.E. 2012. Host plant range of *Raoiella indica* (Acari:Tenuipalpidae) in areas of the invasion of the New World. *Experimental and Applied Acarology,* **57** (3/4): 271-289.

Castilho, R., Duarte, V., Moraes, G., Westrm, K., Trandem, N., Rocha, L., Delalibera, I. and Klingen, I. 2015. Two-spotted spider mite and its natural enemies on strawberry grown as protected and unprotected crops in Norway and Brazil. *Experimental and Applied Acarology,* **66** (4): 509-528.

Douglas, J., Umina, P., Macfadyen, S. and Hoffmann, A. 2018. Field associations of first generation densities of the pest mites *Halotydeus destructor* and *Penthaleusmajorin* in pasture. *Experimental and Applied Acarology,* **76** (4): 487 - 506.

EPPO. 2014. EPPO Global database. Available fro m https://gd.eppo.int/ Paris, France.

Fidelis, E., Reis, M., Negrini, M. and Navia, D. 2019. Life table parameters of the red palm mite *Raoiella indica* (Acari:Tenuipalpidae) at various temperatures and for sexual and asexual reproduction. *Experimental and Applied Acarology,* **78** (4): 535-546.

Flechtmann, C.H.W. and Etienne, J. 2004. The red palm mite, *Raoiella indica* Hirst, a threat to palms in the Anericas (Acari:Prostigmata:Tenuipalpidae). *Systematic and Applied Acarology,* **9**: 109-110.

Flores-Galano, G., Montoya, A. and Rodriguez, H. 2010. Biology of *Raoiella indica* Hirst (Acari:Tenuipalpidae) on *Areca catechu* L. *Revista de Protección Vegetal* 25 (1):11-16.

Gonzalez, N., Kalinin, V. and Diaz, E. 1983. Population dynamics of the rust mite during four years, related to the phenology of Valencia oranges. *Ciencia y Técnica en la Agricultura, Protección de Plantas* **6** (3): 35-62.

Kane, E.C., Ochoa, R., Mathurin, G. and Erbe, E.F. 2005. *Raoiella indica* (Hirst) (Acari:Tenuipalpidae): an island hopping mite pest in the Caribbean. Available from http://www.sel.barc.usda.gov/acari/PDF/Raoiella%20indica Kane%20et%20 al.pdf(Accessed 27th February 2020).

Kaur, P. and Zalom, F.G. 2018. Development of two spotted spider mite, *Tetranychusurticae* Koch at different temperatures. *Agricultural Research Journal* (Ludhiana), **55** (1): 172-174.

Kumar, D., Raghuraman, M. and Janardan, S. 2015. Population dynamics of the spider mite, *Tetranychus urticae*Koch on okra in relation to abiotic factors of Varanasi region. *Journal of Agrometerology,* **17(1):** 102-106.

Leite, G.L.D., Picanco, M., Zanuncio, J.C. and Marquini, F. 2003. Factors affecting mite herbivory on eggplants in Brazil. *Experimental and Applied Acarology* **31** (3-4): 243-252.

Nageshachandra, B.K. andChannabasavanna, G.P. 1984. Development and ecology of *Raoiellaindica* Hirst (Acari: Tenuipalpidae) on coconut. In 'Acarology VI' Griffiths, D.A. and Bowman, C.E.(Eds.) Ellis Horwood Publishers, Chicester, UK. 2:785 - 798.

Podoler, H. and Rogers, D. 1975. A new method for the identification of key factors from life tabledata. *Journal of Animal Ecology,* **48**: 85–115.

Ramani, N. 2008. Effect of temperature and relative humidity on oviposition and fecundity of *Tetranychus neocaledonicus*(Andre) (Acari:Tetranychidae) – a pest of *Moringa oleifera* Lam. *Journal of Experimental Zoology, India* **11** (2): 279-282.

Rodriguez, H., Montoya, A. and Flores-Galano, G. 2010. Feeding behaviour of *Amblyseius largoensis*(Muma) on *Raoiella indica*(Hirst). *Revista de Protección Vegetal* **25** (1)**:**26-30.

Southwood, T.R.E. and Jepson, W.F. 1962. Studies on the populations of *Oscinella frit* L. (Diptera: Chloropidae) in the oat crop. *Journal of Animal Ecology* **31**: 481–495.

Wen Hua, C., ChaoYu, L. and TsuiYing, C. 2016. Temperature dependent development and life history of *Oligonychus litchi* (Acari:Tetranychidae) on wax apple. *Journal of Asia-Pacific Entomology* **19** (1): 173-179.

Yaninek, J.S., Herren, H.R. and Gutierrez, A.P. 1989. Dynamics of *Mononychellustanajoa* (Acari:Tetranychidae) in Africa: Seasonal factors affecting phenology and abundance. *Environmental Entomology,* **18** (4): 625-632.

Zhi Wen, Z., JianFei, X., Ge, L., Shu Xian, S., Tian Rong, X. and Bin, X. 2018. Effect of temperature on development and reproduction of the carmine spider mite, *Tetranychus cinnabarinus*(Acari:Tetranychidae) fed on cassava leaves. *Experimental and Applied Acarology,* **74** (4): 383-394.

MS Recieved - 31 March 2020
MS Accepted -2 May 2020