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RESEARCH ARTICLE

Population dynamics of the coconut mite, *Aceria guerreronis* Keifer in Kerala, India

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ABSTRACT: The history of the invasion of the coconut mite, *Aceria guerreronis* Keifer of Kerala, India dates back to the early 1990s and within no time the pest took a toll on coconut farming and dependent industries of this state. The coconut trees as well as the economy of Kerala suffered a serious setback over the years. The current study evaluated the population dynamics of the mite on Chowghat green dwarf variety of coconut which is highly susceptible to mite infestation. The survey of coconut mite population was carried out on the Calicut University campus and surrounding areas from 2016-2018. The population density of the mite was estimated by counting the number of mites in the meristematic zone of the infested nuts at biweekly intervals. A seasonal fluctuation in the population density was observed as a normal trend annually with higher density during January to May and lower density during the period of June to August. Furthermore, an overall decline in the population density was recorded during the rainy season of the study period.

Keywords: Chowghat green dwarf, *Aceria guerreronis*, economic loss, seasonal fluctuation.

INTRODUCTION

Coconut is grown in many parts of the world, but it is mainly cultivated in tropical countries, more specifically in Asia. It is well known as a versatile cash crop serving domestic, commercial and industrial purposes. The plant is widely accepted for its excessive usage in an array of human needs. What is amazing is that no part of the plant need be discarded as extravagant. Probably this is one of the reasons for its versatility. It is grown in 93 countries by about 11 million farmers on 12 million hectares across the world. However, Asia comes first in production by attaining over 80%.This is jointly shared by Indonesia, Philippines and India with a total of 73% with India in the third position in the world production of coconut (Adkins et al., 2006). The credibility maintained by India in world coconut production took a dive by the introduction of the coconut pest, *Aceria guerreronis* in 1998 (Sathiamma et al., 1998).

Aceria guerreronis is a serious threat and like many invasive agricultural pests it displays dramatic population growth, leading to serious outbreaks. Within a short span, it spread to new areas making threat to the whole of Kerala and neighbouring states (Haq, 1999a; Mohanasundaram et al., 1999; Muthiah et al., 2001). Substantial loss of yield in coconut production along with further invasion of the mite pest into new areas resulted in undue decline in production (Haq, 2011). Control practices though followed promptly with invasion, it remained unsuccessful to a certain extent (Arie et al., 2003; Rethinam, 2003). The net result was the current drop of 50% in coconut production, rendering a great threat to mainly coconut farmers in Kerala.

The invasion, rapid spread, outbreak and associated economic loss have jeopardized the economy of people of all sectors connected with coconut, (Haq, 2006). The dynamics of this species are determined by various factors like temperature, RH, rainfall and wind velocity. The factors favourable to repeated invasion, subsequent crop loss and further control measures need to be taken as the most important requirements (Haq et al., 2000; Haq and Sobha, 2009). As far as Southern India is concerned, Kerala deserves special attention in coconut crop productivity (Haq, 1999 b). The climatic barriers in Kerala when compared with other states are more lenient and frequent, particularly the rain. Rain fall in Kerala is connected with seasons and 2-3 cyclic rainfalls are normal for the state. *A. guerreronis* reaches high population densities at 35°C. Therefore, these high population densities occur from the end of March – May which also precedes the onset of a period of high rainfall in Kerala. The latter can cause a substantial drop in the mite numbers depending on the intensity of the rain. Distribution of *A. guerreronis* occurs mainly during dry spells and it is also during these spells that it is more severe and prevalent (Zuluaga and Sanchez, 1971; de Souza et al., 2012). Rainy season prevents all chances of transfer of the colonies to new areas. Normally matured mites will move to the periphery of the tepal from the meristematic area to be transferred by the direction of the wind. Rain fall very often hinders their transfer rendering them to remain on the periphery of the tepals as dead ones. Therefore, the colony may perish during rainy season and this depends on the intensity of the rain too. The frequency of rainfall showed a negative significant correlation and drought length showed a positive significant correlation with the population densities (Haq, 1999a; Aratchige et al., 2012; Sobha and Haq, 2015). However in other localities there was no clear relationship between coconut mite population and dry or wet weather (Mariau, 1977; Howard et al., 1990; Ramaraju et al., 2000). Studies on the effect of abiotic factors on the population dynamics of *A. guerreronis* play an important role in the evaluation of effective control measures. Therefore, the aim of the present study was to assess the influence of climatic factors like temperature, RH and rain fall on the population density of *A. guerreronis* at Calicut University and nearby areas. Future studies will concentrate more on the economic importance of this mite.

MATERIAL AND METHODS

Aceria guerreronis being so minute and its feeding and breeding sites are effectively protected by the foliage of the host plants, it necessitates special techniques for its collection. Added to this, the comparatively tall, very erect and inaccessible nature of the plant, *Cocos nucifera* further creates problems of greater magnitude for its collection. However, success of sampling to a greater extend depends on regular and timely collection of materials without interruption. The study was carried out from July 2016- July 2018. Coconut plants of the common Chowghat green dwarf variety with plants between 20-30 years old, growing adjacent to residential quarters and nearby houses in and around the Calicut University campus, were chosen for the mite population assessment. The study area comprises three locations namely Chettiyarmad, University campus and Kohinoor. Coconut plants growing in these locations have spread out bunches (Figs 1A, B) carrying buttons ranging from 10-16 in a rachilla. Clear infection of nuts can be visible when the nut reaches 4-8 weeks onwards (Figs 2, 4B). After 8 weeks the infected nuts show dried up and clear symptom (Fig. 3) and eventually they become cracked (Fig. 4A). The mean of collected buttons from each locality has been considered for final assessment of the population. Sampling was done biweekly between 6-8 am by removing the button along with some portion of rachis. In the laboratory, the tepals of each button were carefully removed, one by one (Fig. 5A). The infested area of the meristematic tissue of the button (Fig. 5B) was observed under a stereo microscope and the number of adult and nymphal stages of mites (Fig. 6) present per square centimetre area of affected meristematic tissue were counted directly for population estimation. Severely infected nuts may promote falling off of tender coconuts leaving the tepals tightly adhered to the rachis (Fig. 7). Arithmetic mean of monthly meteorological data on temperature, relative humidity, rainfall and wind velocity during the study period have been obtained from meteorological centre of CWRDM, Calicut was taken into consideration in the present study.

For statistical analysis first scatter diagrams has been plotted to check the relation between the variables viz., temperature, rainfall, relative humidity and wind velocity with mite population. Accordingly, a correlation matrix was prepared and is presented in the table. A multiple regression model has been fitted for predicting mite population with all the climatic variables.

Figure 1. Spread out bunches of coconut - A) Nuts of 1-2 weeks without infection, B) Nuts of 2-4 weeks with rare symptoms of infestation.

Figure 2. Nuts of 4-8 weeks showing clear symptoms of attack by *A. guerreronis*.

Figure 3. Nuts of above 8 weeks showing dried up symptoms of attack in most of them by *A. guerreronis*.

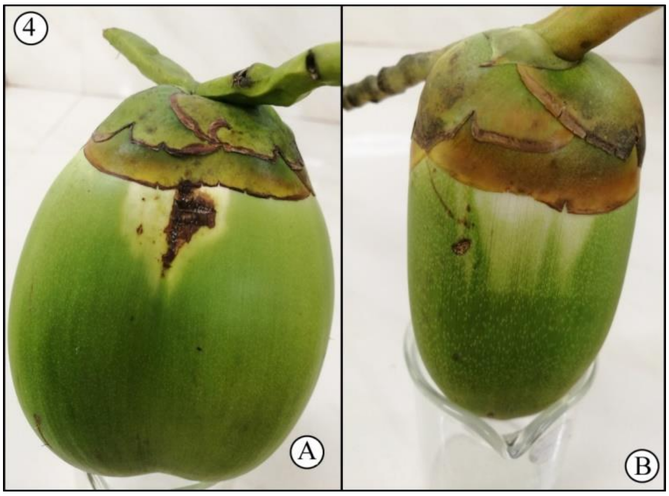

Figure 4. A) Nuts showing deep crack of infection after 12 weeks, B) Clear, broad and visible symptoms of mite infection below tepals.

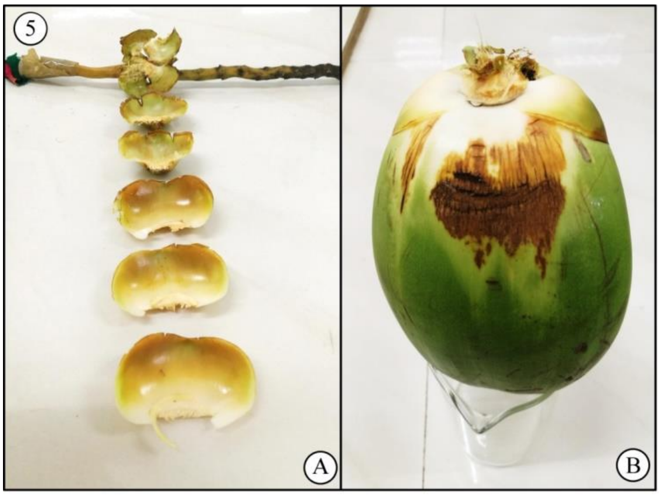

Figure 5. Removed tepals from meristematic area of the nuts for closer view of mite population - A) Two whorls of 6 tepals separated from the nut, B) Partly exposed meristematic area of the nut showing spread out symptom of attack.

Figure 6. Different life stages of *A. guerreronis* from the mite infected nut.

RESULTS

In the current study, sampling from the Chowghat green dwarf variety of coconut covering all seasons from 2016 - 2018 presented a varying degree of mite population. This trend considerably differs since the time of its invasion. The results of the study further revealed convincing evidence of population deterioration. All four climatic factors, namely temperature, RH, rainfall and wind velocity played a role in the fluctuation of the population. Temperature appeared to be the most striking along with rainfall and RH. Results of the study as shown in the correlation table also clearly indicate that among the 4 meteorological parameters, three of them, temperature, rainfall and RH have greater significance (Table 1).

Hence the effect of these variables on mite population was studied in detail with specified statistical analysis. The statistical study showed an overall performance of intermittent population fluctuation with respect to temperature and rain fall gradients.

Influence of temperature on mite population

The influence of temperature during the two-year survey disclosed a very convincing trend, namely, a successive increase in population from January to May for both the years (2017 and 2018) (Fig. 8). Further, it enabled strikingly to follow a receding pattern in population from higher levels to moderate and moderate to low levels in the succeeding months of June -October. In the years, 2016 and 2018, the impact of temperature on population density of the mite remained very striking, following a positive correlation trend. In 2016 to 2017, the population density of the mite showed a high degree of positive correlation (r=0.94) with temperature. During 2017-2018, the correlation between mite population and temperature was still higher (r=0.65). Considering all the climatic variables a multiple linear regression model is fitted for predicting the mite population. Eliminating the least significant variables using statistical techniques, we got the final regression model as Y= -1216.024 + 45.638 x X. where Y=mite population and X =temperature. Also, the R squared value is 0.871 which means that 87.1% of the variations in the response variable is explained by our linear model (Fig. 9). So from this regression equation we can predict the mite population for different known values of temperature. Predicted values from the above regression equation and observed values are plotted in Fig. 10. But when the temperature got raised above 35 ^{0}C, the population density of the mite decreased significantly.

Influence of rainfall on mite population

Despite the positive impact of temperature on the population density of the mite, rainfall exerted a negative impact namely a decline in population. The population density of the mite reached the minimum when rainfall reached its maximum. In 2016-2017 the population density of the mite showed a moderate degree of negative correlation with respect to rainfall. During 2017-2018 the degree of negative correlation between the mite population and the rainfall even increased.

Table. 1. Correlation between mite population and climatic variables

		Maximum Temperature	Maximum RH	Maximum Rainfall	Mite Population	Maximum Wind Velocity
Mite Population	**Pearson Correlation**	0.933	- 0.772	- 0.741	1	0.570
	Sig. (2-tailed)	0.000	0.000	0.000		0.003
	N	**25**	**25**	**25**	**25**	**25**

By a regression method we tried to analyse the effect of rainfall on mite population and got a linear relationship between the two variables. In 2016-2017 the correlation between rainfall and mite population with r = -0.67 .i.e. a moderate linear relationship can be seen (Fig. 11). Hence we fit the line of best fit (i.e. regression equation) which is of the form Y= -0.2976xX+349, where Y=mite population and X =rainfall. During 2017-2018 the correlation with rainfall and mite population with r= -0.76 i.e. much higher negative correlation can be noticed by comparing the r value of previous year (Fig. 12). Here also we fit the line of best fit which is of the form Y=-0.3158 xX+347.44. Hence from these two equations we can predict the mite population with corresponding values of rainfall during the years.

RH is also exerted a negative impact on the population. The population density of the mite reached the minimum when RH reached its maximum, though some exceptions were also observed. The population decreased drastically with respect to increase in rainfall coupled with prevalence of RH. The mite population followed a declining trend, even when the rainfall was very low, but the RH very high. Accordingly the mite could not revive its population density even when the temperature increased, leading to prevalence of the very low population in the field.

Figure 7. Intact tepals attached to the rachis after falling off highly infected tender coconuts.

DISCUSSION

The overall performance of *Aceria guerreronis* in the Chowghat green dwarf variety of coconut from 2016 to 2018 attempt to suggest that the plant is acquiring vigour to overcome the severe attack of the mite. Chowghat green dwarf variety of coconut is known to be very much amenable to attacks by *A. guerreronis* in Kerala (Haq, 2001), yet survival of this variety from such a strong and long-lasting impediment necessitates the developing of cultivars resistant against the attack of *A. guerreronis* and other mites. This is particularly important in view of the preference shown by the Indian and foreign tourists for coconut milk.

Population density of the coconut mite is greatly influenced by climate (Mariau, 1969; Otterbein, 1988). Among the climatic factors considered for the study, temperature, RH and rainfall have a stronger influence on population fluctuations in the study period. In a general observation it was found that the influence of all three parameters up to the optimum tolerance capacity is permissible for the survival of the mite species. But these climatic factors exert a combined influence at the verge of population regaining process of the mite in the field. This may probably hinder the harmony of life cycle, multiplication of generation and hence its population size. The mite attained a high population early in January, 2016 because of high temperature, very low RH and practically no rainfall. This tendency was also reported from Guerrero, Mexico (Mariau 1969), Brazil (Lawson-Balagbo et al., 2008; Reis et al., 2008) and Sri Lanka (Aratchige et al., 2012). The positive and negative influence of temperature and rainfall, respectively on this mite's population were already recorded for South Indian conditions (Pushpa and Nandihalli, 2009). The adverse effect of rainfall leading to a reduction in the population density of *Mononychellus tanajoa* (Bondar) and its predators in Africa was reported by Yaninek *et al.* (1989). However, contradictory reports also exist from Benin and the Ivory Coast supporting a negative relationship between the coconut mite population and temperature, with 5 times the population density of the mite in wet season oppose to the dry season (Julia and Mariau, 1979). *Aceria guerreronis* peaked during January, 2017 in the present study but decline again with a decrease in temperature in succeeding months of June, in the presence of higher RH and rainfall. The rainfall further increased during the monsoon period of June – July, resulting in lower temperatures, culminating in a further decline of the mite population. Afterwards, the temperature got up steadily, reaching higher gradients with a striking decrease in both RH and rainfall. The decline of mite population owing to rainfall and increase in RH observed during the present study contradicts the earlier findings (Otterbein, 1988) in Costa Rica that the

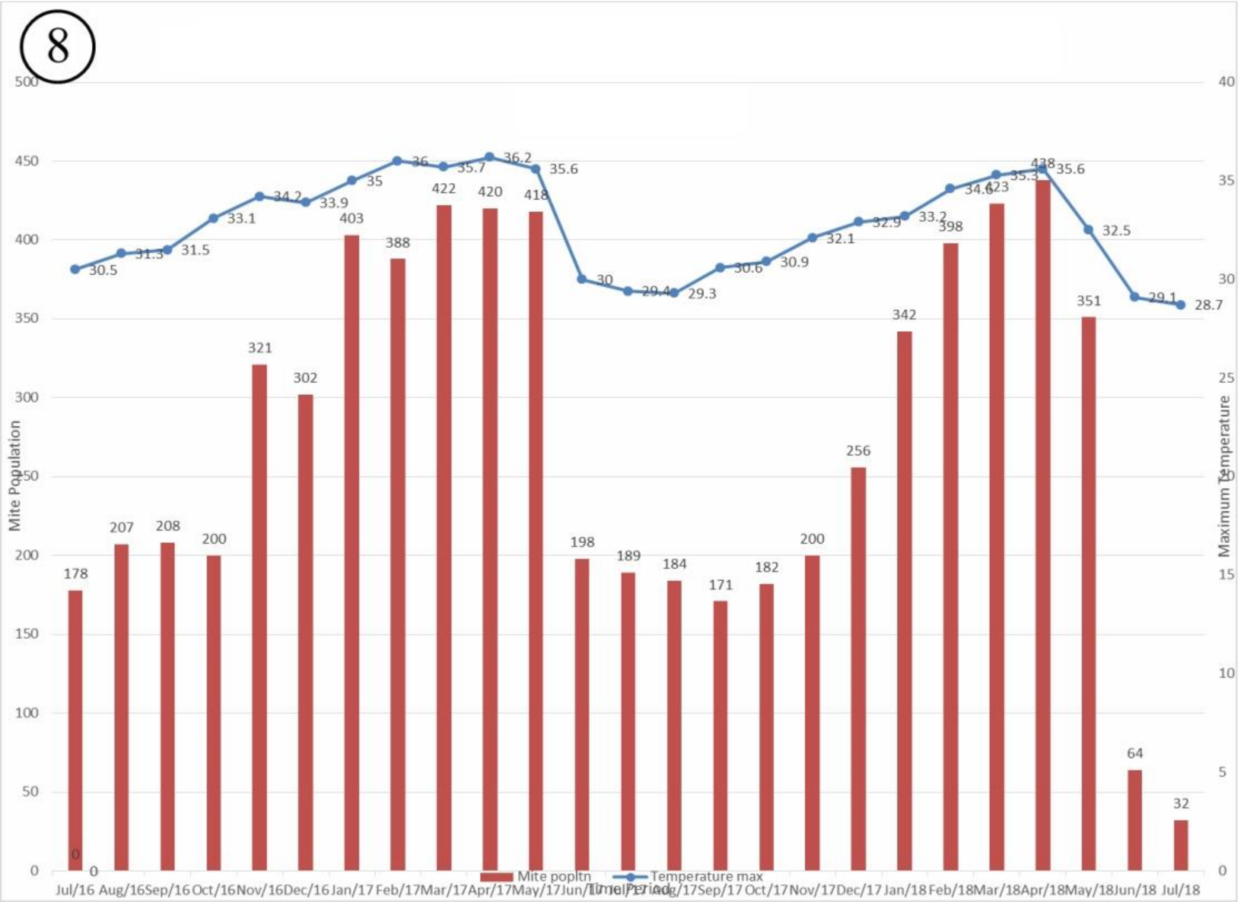

Figure 8. Influence of temperature on mite population during 2016-2018.

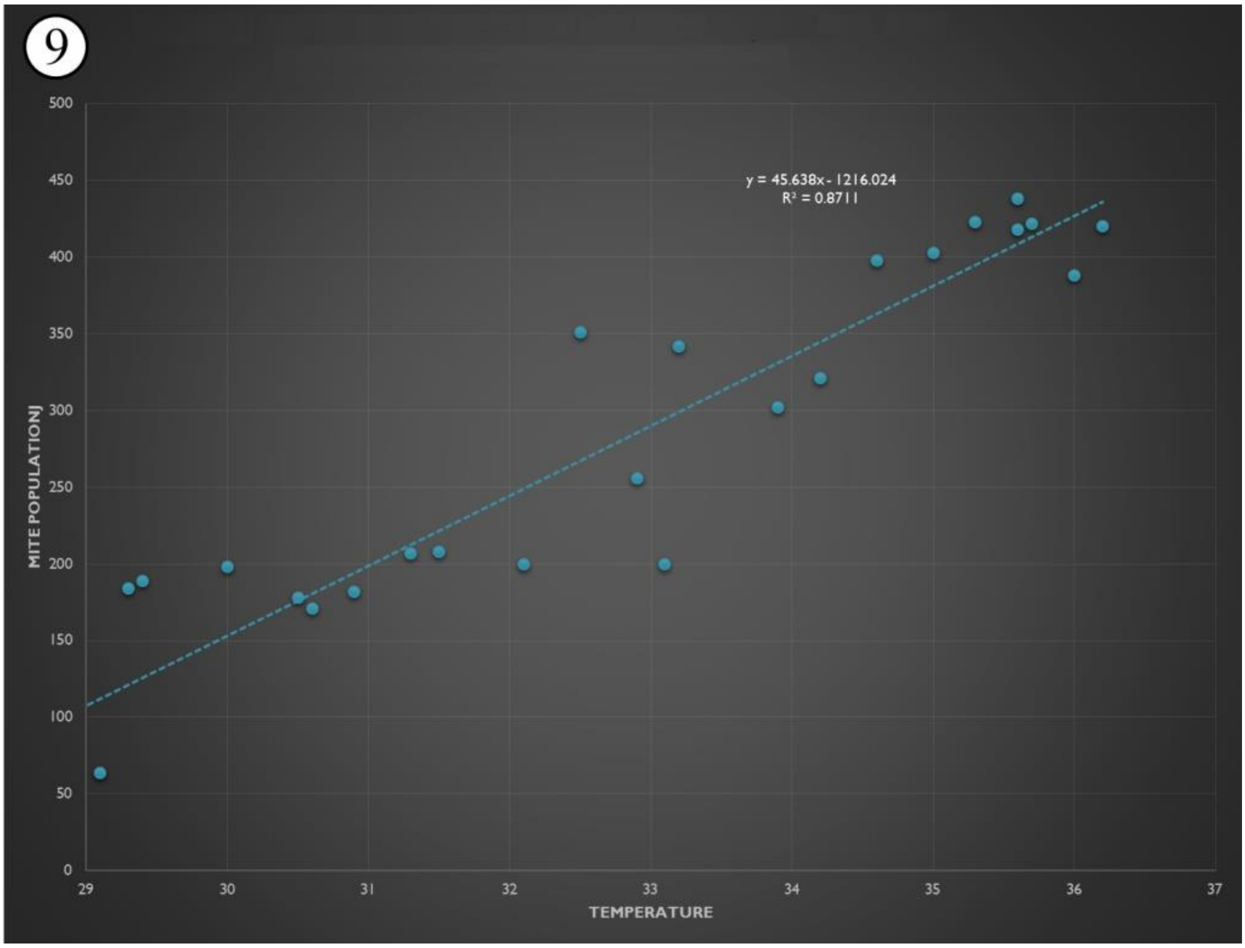

Figure 9. Multiple regression model for the mite population for the period of July 2016-2018.

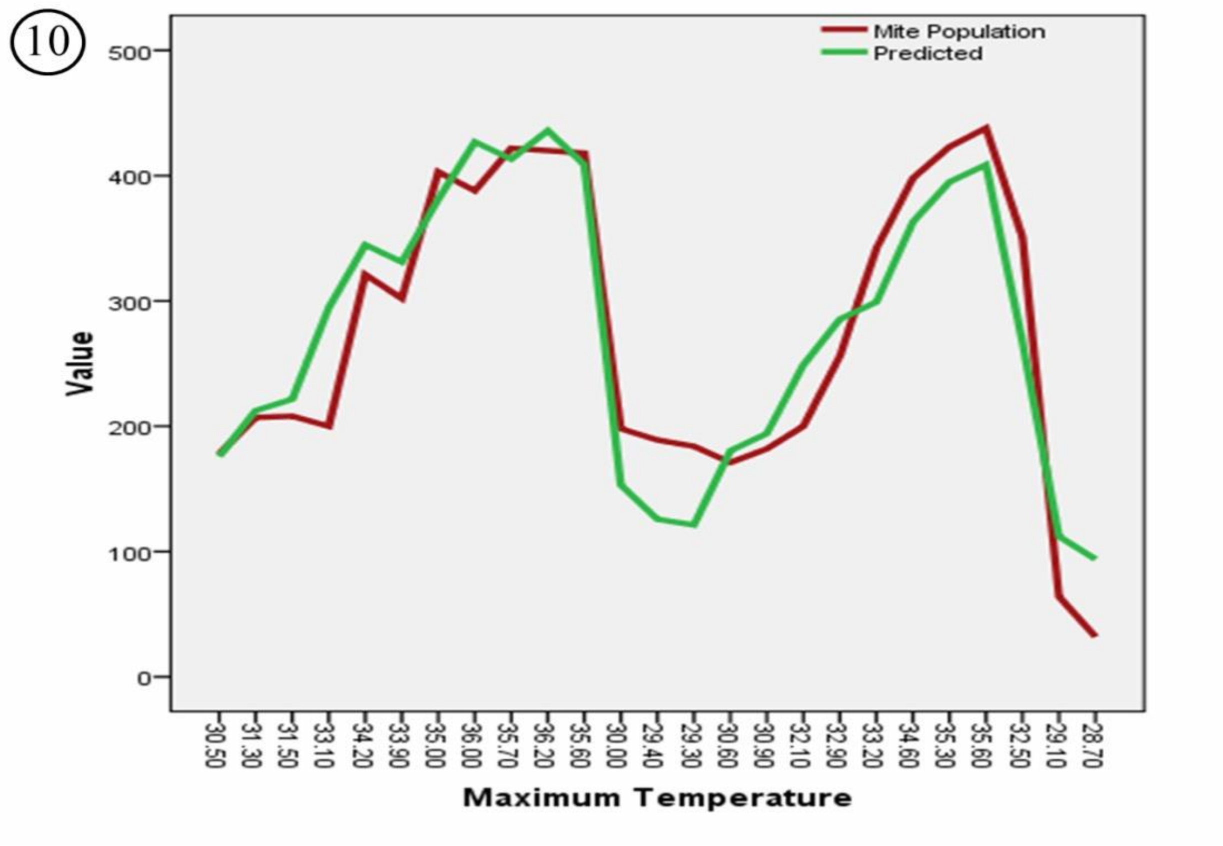

Figure 10. Comparison of mite population observed and predicted values with temperature.

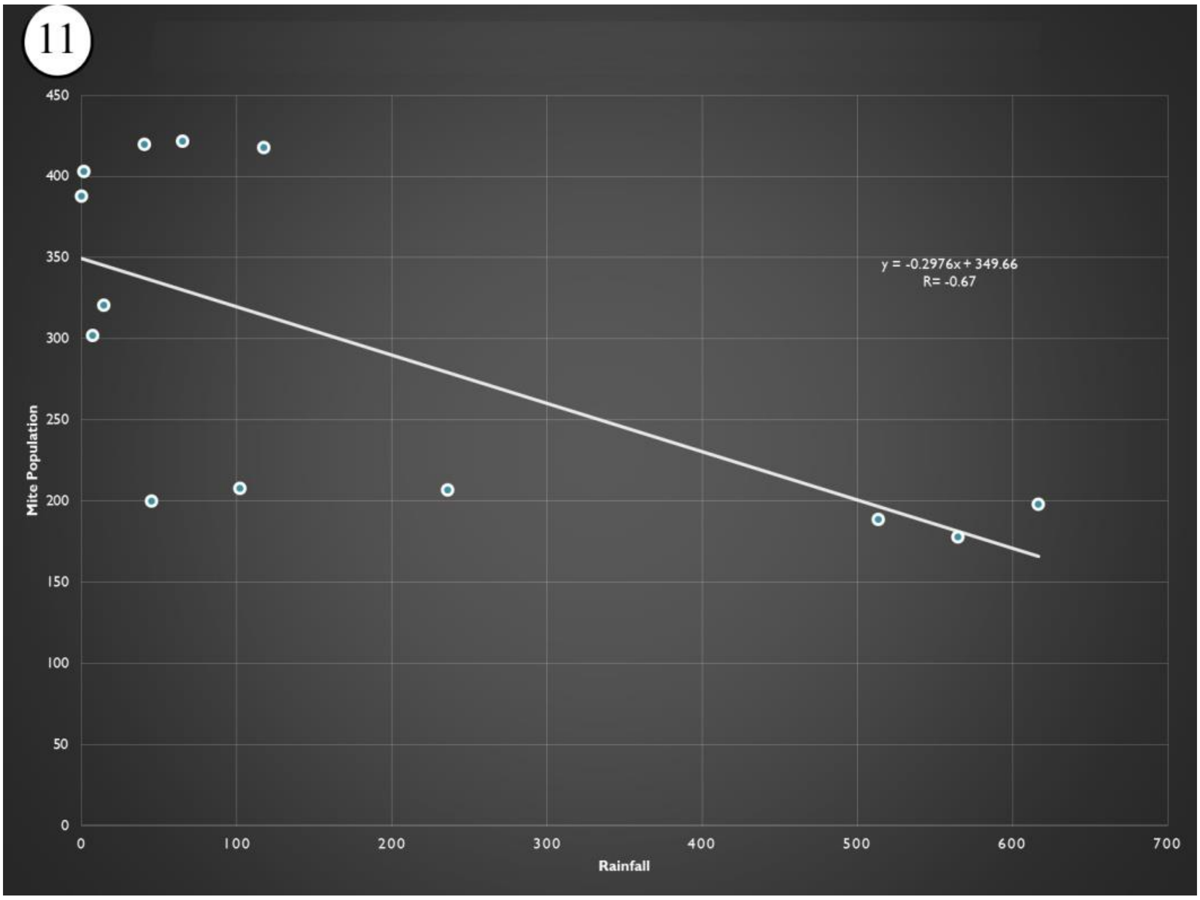

Figure 11. Influence of rainfall on mite population for the period of July 2016-July 2017.

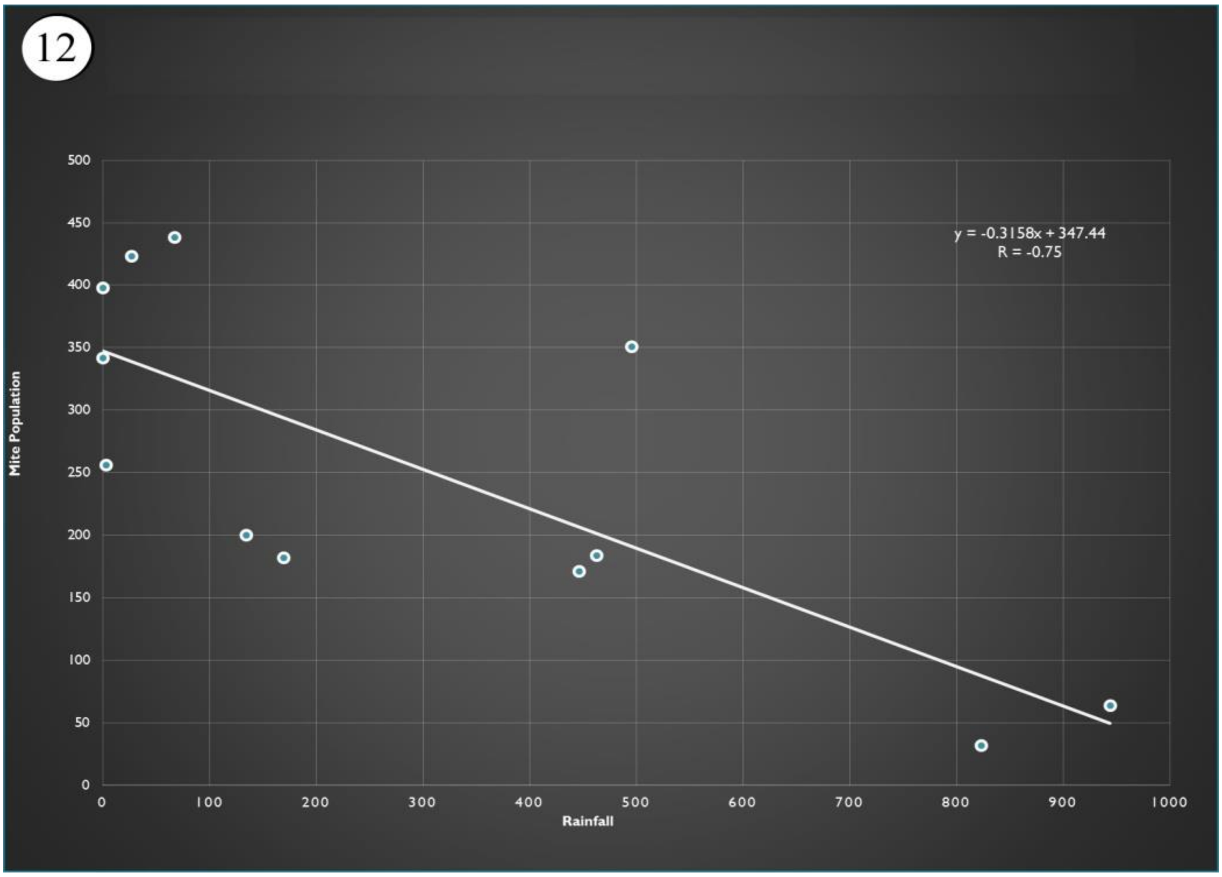

Figure 12. Influence of rainfall on mite population for the period of August 2017-July 2018.

greatest nut damage is caused by the mite in periods of frequent heavy rainfall and high humidity.

However, the mite population could not rise up to the original trend and level in population build up, attributing the influence of all the climatic factors as depicted in 2016. It is interesting to note that the population has attained the maximum level in January to May during 2017 and 2018 and decline again during the successive months, reaching to the minimum during the months of June to October of all the above said years. The climatic influence, particularly after March though proved favourable to population replenishment of the mite, the population could not be regained. This led to the suppression of population leading to its decline. Several such co-incidents intermittently in the fields might have operated to bring down the population of the mite. Therefore, individual and collective influence of all the above climatic factors in the population build-up of mite is well evidenced. The influence of "global warming" if any, experienced during the study period need to be assessed to get a clear picture on the influence of climatic factors. Prolonged temperature above 35 °C attributed to a supportive factor to our laboratory observation on the number of generations this mite could complete per year. (Haq, 2001; Sobha and Haq, 2011). Temperature above 35 °C was not found favourable for the completion of life cycle as usual. The duration of the developmental period of the mite extended double the time than normally required. The nymphal stages were not found feeding and ultimately were found dying. Very often, the newly emerged females were not found ovipositioning. This prompted to think that prevalence of temperature above 35 °C in the field has been instrumental to the population decline of the mite throughout Kerala.

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