Investigation note

Population fluctuation of *Aceria annonae* (Keifer, 1973) (Prostigmata: Eriophyidae), in three municipalities of Nayarit, Mexico

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Abstract

Nayarit is the main producer of soursop (*Annona muricata* L.) worldwide. Among the main limitations for production are mites, so, in order to know the population fluctuation of the eriophyid *Acerio annonae* (Keifer) between February and December 2016, periodic sampling was done every 30 days in three municipalities and four localities: Compostela (Altavista and El Divisadero), Xalisco (San Antonio) and Tepic (El Trapichillo). For the samplings, 10 trees were considered by location, randomly selected; each tree was divided into five sampling areas, one per cardinal point, with one leaf (sample) per area, also randomly selected, for a total of 50 samples per location. The samples were taken to the agricultural parasitology laboratory of the Agricultural Academic Unit at the Autonomous University of Nayarit, where the total number of adults and adults per sheet was periodically quantified from each locality. The variables number of erineos by leaf, number of adults by erineos and the climatic factors, were correlated by means of the correlation coefficient of Pearson (SAS Institute, 2004). Of the four localities only positive correlation was obtained in the locality of San Antonio, where the temperature seems to have an effect on the variables of erineos per leaf (CC= 0.89885 and Prob> |R|= 0.0002) and adults by erineo (CC= 0.62875 and Prob> |R|= 0.0385), for the locality of El Trapichillo, only the variable erineos per leaf was correlated with the temperature with the number of erineos per leaf, (CC= 0.85937 and Prob> |R|= 0.0007).

Keywords: Annonaceae, climatic factors, correlation coefficient, sampling.

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Worldwide, Mexico is the main producer of soursop (*Annona muricata* L.) with a cultivated area of 5 915 ha (Vidal and Nieto, 1997), followed by other countries such as Venezuela with 2 174 ha (Manzano, 2006), Brazil with 2000 ha (Nieto *et al*., 1998) and Costa Rica with 500 ha (Elizondo, 1998), being our country, the main supplier of soursop products and by-products to the United States of America. However, within the main limiting problems for their production are the phytosanitary products and within them the insects that are considered plague, since they affect both the yield and the quality of the fruit, as well as its commercialization (Hernández *et al*., 2006).

Bautista *et al*. (2003), report six pests in the cultivation of the soursop in Nayarit and four insects of low economic importance. On the other hand, Hernandez *et al*. (2006) reported 18 species of plague organisms, with affectations to plantations in different states of Mexico. Much importance has been given to insect pests such as the fruit borer (*Optatus palmaris* Pascoe) (Coleoptera: Curculionidae), striped worm (*Gonodonta pyrgo* Cramer) (Lepidoptera: Noctuidae), seed borer (*Bephratelloides cubensis* Ashmead) (Hymenoptera: Eurytomidae) and recently the pink hibiscus cochineal (*Maconellicoccus hirsutus* Green).

However, other organisms may be causing affectations to the crop and of which many aspects of their relation with the soursop are unknown; such is the case of the mite erineo of the soursop, *Aceria annonae* (Keifer) (Prostigmata: Eriophyidae), which was recently reported in the production area of the state of Nayarit, without the importance being given by the lack of knowledge of its biology and habits, so their management has not been adequate, since the information on their effects on the crop is zero in the country, although it is already reported for the states of Jalisco, Oaxaca and Veracruz (Hoffman and López-Campos, 2000; Acuña-Soto and Estrada-Venegas, 2009).

The leaves infested by this mite are observed in the bundle, with protuberances that as the leaves develop they increase in size and in early stages they can shrink or bend and on the underside there is an excessive formation of trichomes, damage that is known as erineo (Figures 1a and 1b) (Ochoa and Vargas, 1994). Worldwide there are no works related to *A. annonae* and it is only mentioned that it is causing damage to soursop crops in areas of the Atlantic, Pacific and in Costa Rica and that this eriophyid can be controlled with sulfur-based compounds (Ochoa and Vargas, 1994). For this reason, the objective of this research was to determine the population fluctuation erineo mite of the soursop in three municipalities of the state of Nayarit, over a period of 11 months, and thereby obtain population data with which to design a strategy for the future of management for this species.

The present investigation was developed in three Municipalities of the state of Nayarit, in the common Divisadero of the Municipality of Compostela and located at coordinates 21° 08’ 21° 08’ 46.7’’ North latitude and 105° 13’ 09.4’’ West longitude, the Altavista common 21° 05’ 57.1’’ North latitude and 105° 10’ 16.2’’ West longitude, both at an altitude of 21 m, the San Antonio common 21° 22’ 37.9.1’’ North latitude and 105° 03’ 49.8’’ West longitude of the Municipality of Xalisco at an altitude of 400 m and in the Trapichillo common 21° 33’ 25.6’’ North latitude and 104° 49’ 15.9’’ West longitude, at an altitude of 657 m from the Municipality of Tepic.

Soursop leaves collection

Ten soursop trees were chosen per experimental site and each sampling was randomized in each locality, with a periodicity of thirty days. From each tree, five sampling areas were randomly selected one leaf per area, giving a total of 50 samples per locality (Landeros *et al*., 2003). The population samples of *A. annonae* were made during a period of 11 months from February to December 2016, the leaves of each sample were deposited in duly labeled brown paper bags and placed in a cooler for their conservation during the transfer to the laboratory of Agricultural Parasitology of the Academic Unit of Agriculture of the Autonomous University of Nayarit.

From the material collected, the total count of erineos by leaf and by location was first performed. The eriophids were extracted and assembled according to the methods proposed by Amrine and Manson (1996), of the mites obtained the total number of adults was counted. The corroboration of A. annonae was carried out with the comparison of adult females obtained in this work with the original description proposed by Keifer (1973).

Temperature and relative humidity

The data of temperature and relative humidity were obtained from the climatological stations in the area of influence. National Water Commission (CONAGUA). Meteorological Observatory of Tepic Nayarit, located at 21º 31' 21'' North latitude and 104º 53' 35'' West longitude and National Water Commission. Station of the Marcos Municipality of Bay of Banderas located at 20º 57' 18'' North latitude and 105º 21' 10'' West longitude.

Statistical analysis

An analysis of the Pearson correlation coefficient (SAS Institute, 2004) was performed for the variables number of erineos per leaf and number of adults by erineos, this with the purpose of knowing how they are affected by climatic factors (Hernández-Zaragoza *et al*., 2017).

Population fluctuation

When estimating the total number of erineos per leaves, we can observe that in the four sampling zones the behavior of *A. annonae* presents a general pattern, where the number of erineos increases from the months of April to July and decreases in July to February (Figures 1-4). This behavior has been reported, for other eriophids in temperate zones that produce malformations such as *Phytoptus phloeocoptes* (Nalepa) in peach and *Aceria cinerea* (Nalepa) in walnut, where it has been observed that the greatest abundance of malformations and number of individuals occurs in the months where summer begins and decreases as winter begins (Boczek, 1974; Keifer *et al*., 1982). In case of eriophids from tropical climates, where there are no marked seasons, it has been observed that the damage fluctuates; through time, and are associated rather with the peaks populations where the greatest abundance of individuals occurs, such is the case of *Phyllocoptruta oleivora* (Ashmead), *Aceria guerreronis* Keifer and *A. granati* (Canestrini and Massalongo) (Moore and Howard, 1996; Landeros *et al*., 2003; Acuña-Soto *et al*., 2015).

In the case of the number of adults by erineos, we can observe that in general, two population peaks occur throughout the year of sampling one in the months of April-May and the second in August-September (Figures 1-4). These data are consistent with the observations made for other eriophids present in tropical climates such as *Phyllocoptruta oleivora* (Ashmead) and *Aceria litchii* (Keifer) (Landeros *et al*., 2003; De Zevedo *et al*., 2014). A possible explanation that arises for *A. annoae* to occur in two population peaks, at two very different times in the year, may be due to the absence or low populations of predators in those times, an issue that must be corroborated with studies population of natural enemies.

It is also possible to propose the hypothesis that *A. annoae* has the capacity to develop in both seasons, a situation that has also been proposed for *A. litchii* (De Zevedo *et al*., 2014). Because it is possible that the physiological conditions of the leaves from which it feeds are adequate for the development in those two seasons of the year and this is related in some way to the physiology of the tree (flowering and fruiting periods) in the area study; in the face of this assertion, similar situations have also been reported for *A. litchii*, which is an eriophid that produces erineos in the litchi leaf (Alam and Wadud, 1963; Martins *et al*., 2001).

In three of the four collection zones an unusual decrease in the number of individuals was observed in the month of September, for the locality El Divisadero, this decrease is also observed in the month of May (Figures 1, 3 and 4) for the latter, this situation can be attributed more than anything to the collection method since being totally random it is very possible that the collected leaves, both the erineos and the leaves were already expiring and therefore there were few individuals within the erineos. In the case of the reduction of organisms in the month of September, it is very likely that it is more related to garden management issues, since in the case of the Altavista locality this pattern is not observed.

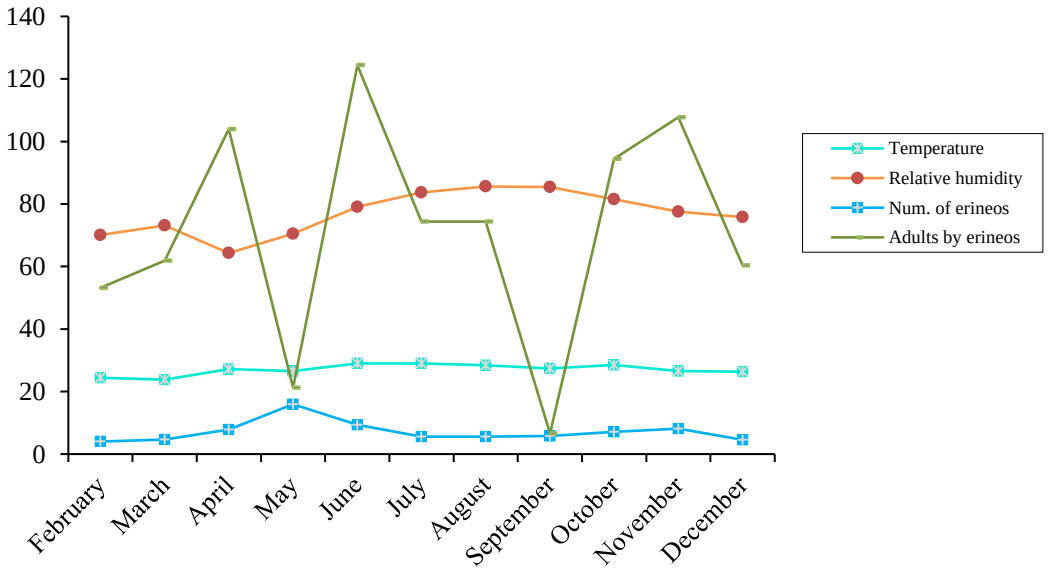

Figure 1. Population fluctuation of *A. annonae* in the El Divisadero common, Municipality of Compostela.

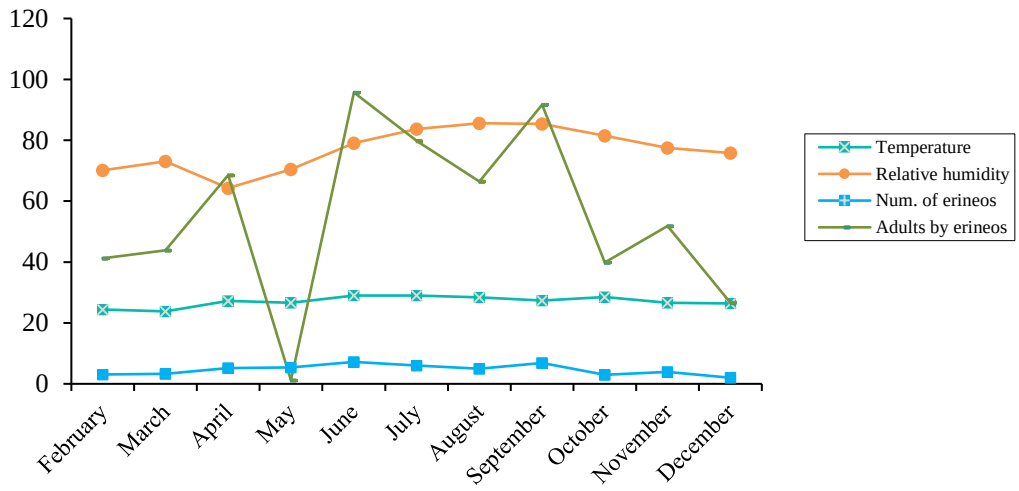

Figure 2. Population fluctuation of *A. annonae* in the Altavista common, Municipality of Compostela.

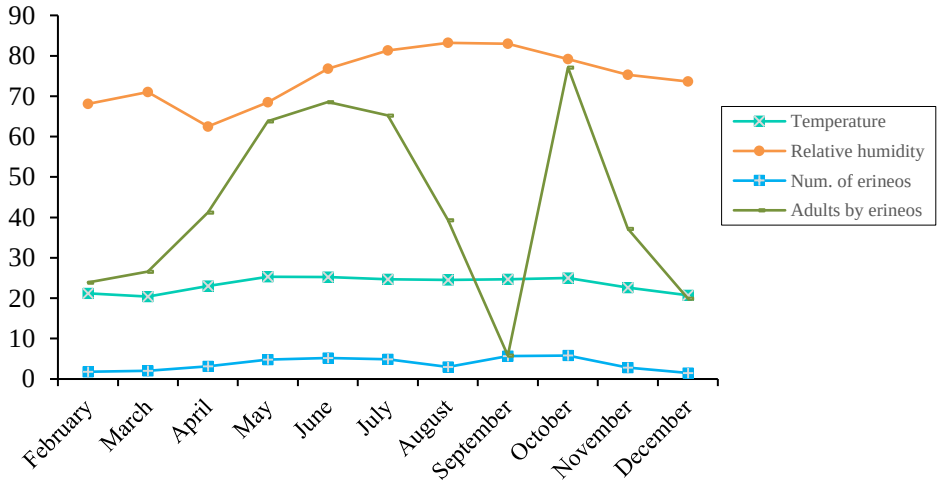

Figure 3. Population fluctuation of *A. annonae* in the San Antonio common, Municipality of Xalisco.

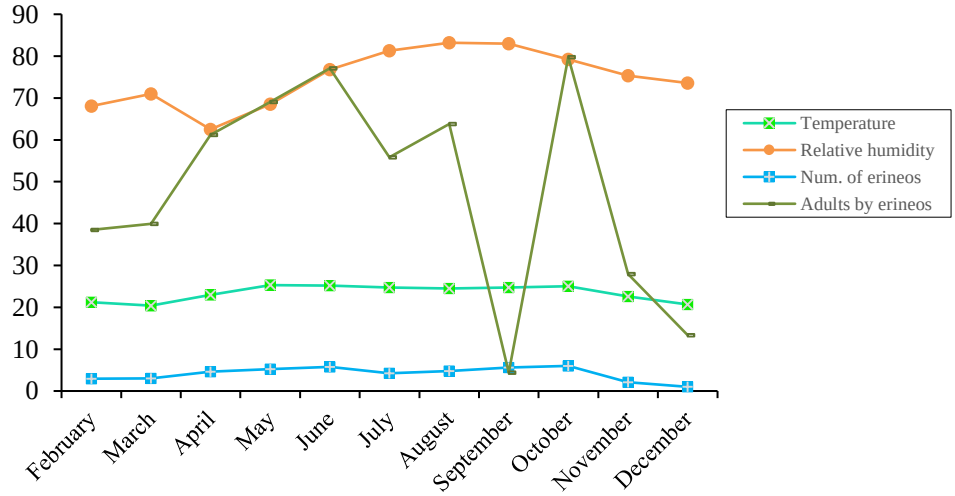

Figure 4. Population fluctuation of *A. annonae* in the El Trapichillo common, Municipality of Tepic.

Correlation of environmental parameters

Only positive correlation was obtained in the locality of San Antonio, where the temperature seems to have an effect on the variables of erineos/leaf (CC= 0.89885 and Prob> |R|= 0.0002) and adults/erineo (CC= 0.62875 and Prob> |R|= 0.0385), for the locality of Trapichillo, only the variable erineos/leaf was correlated with the temperature with the number of erineos/leaf, (CC= 0.85937 and Prob> |R|= 0.0007) (Table 1). In the rest of the comparisons, no statistical differences were found, which affirm that the climatic factors have an influence on the population fluctuation of *A. annonae* (Table 1).

Table 1. Correlation coefficients for number of erineos and adults of *A. annonae* in soursop leaves compared to abiotic factors in Nayarit.

Number of erineos per leaf and medium temperature	Number of erineos per leaf and relative humidity	Number of adults by erineos and medium temperature	Number of adults by erineos and relative humidity
Divisadero, Compostela, Nayarit			
0.21409[1]	-0.26675[1]	0.155[1]	-0.3907[1]
0.5273[2]	0.4278[2]	0.6491[2]	0.2348[2]
Altavista, Compostela, Nayarit			
0.57005[1]	0.31017[1]	0.50985[1]	0.47256[1]
0.0671[2]	0.3533[2]	0.1091[2]	0.1422[2]
San Antonio, Xalisco, Nayarit			
0.89885[1]	0.47535[1]	0.62875[1]	0.07405[1]
0.0002[2*]	0.1395[2]	0.0385[2*]	0.8297[2]
Trapichillo, Tepic, Nayarit			
0.85937[1]	0.29385[1]	0.54812[1]	-0.08469[1]
0.0007[2*]	0.3822[2]	0.0809[2]	0.8045[2]

[1]= Correlation coefficient (CC); [2]= Prob>R. [*]= the variables are correlated (α= 0.05).

In the two localities where there was a positive correlation with climatic factors, it may be due to the fact that, in these localities, there are very particular climatic characteristics (microclimates) that may be affecting the population fluctuation of *A. annonae* and the damage produced, or it is possible that is due to the sensitivity of the model, and therefore the data obtained in this locality, are influenced by the positive values in the correlation model.

These data are interesting since in this study *A. annonae* presents an atypical pattern in its population fluctuation with respect to other eriophids that live in tropical climates and that produce malformations such as *A. litchii*, *Aceria pongamiae* Keifer and *Aceria doctersi* (Nalepa) in which have been shown to have their largest populations and damages in the months of April-May and decrease towards the end months of the year (October-December) (Picoli *et al*., 2010, Nasareen and Ramani, 2014, Nasareen and Ramani, 2015) similarly known for these eriophids, the increase in the number of individuals and associated damage, is not positively related to factors such as climate, precipitation and relative humidity (Picoli *et al*., 2010; Nasareen and Ramani, 2014; Nasareen and Ramani, 2015) and this is mainly due to the fact that they are

protected within the erineo or the gall (Figure 5a and 5b) and it would be expected that external environmental factors do not have an impact negative in the populations as it has been referred by Westphal and Manson (1996).

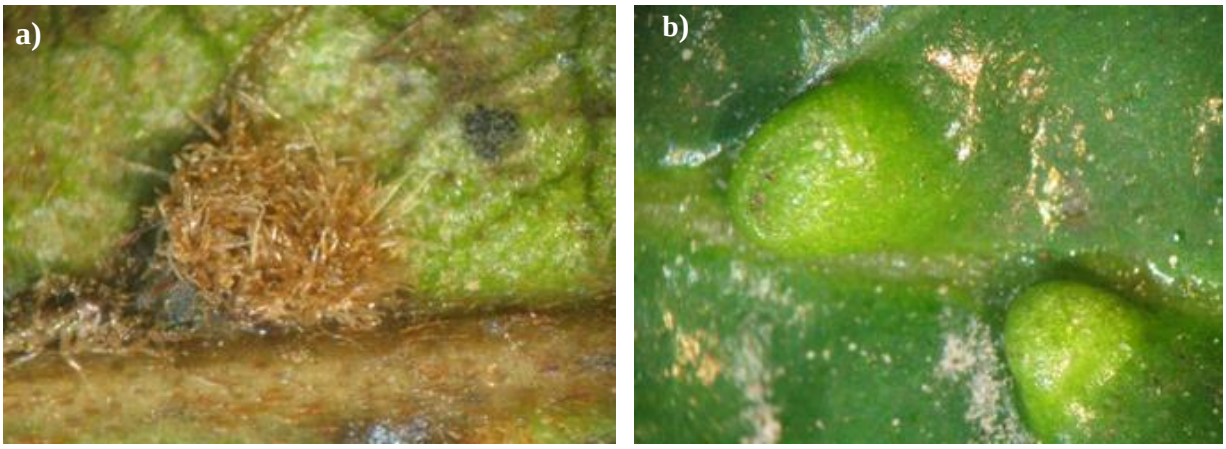

Figure 5. a) erineos in the soursop tree leaf bundle; and b) erineos on the underside of a soursop tree leaf.

In this study, *A. annonae* seems to behave more like a free-living eriophid with the ability to present at least two population peaks marked during the year (Figures 1-4) as has also been reported for *P. oleivora* (Landeros *et al*., 2003; Al-Azzazy, 2016) and for *Aceria mangiferae* (Sayed) (Abou-Awad, 1981), it is possible that being short-cycle organisms can reproduce very quickly so their population density changes, situation that it has been observed by Taylor (1984) for some insect populations.

The population peaks observed could also be explained by changing (dynamic) factors in the study area with which *A. annonae* has adapted to exploit the present resources and it is possible that it is also related to physiological factors of the plant, since, in this study the leaves were collected at random, it is possible that some of them younger than others will have greater infestation in relation to each other.

This condition that eriophids prefer more tender leaves has been studied for herbaceous species such as *Aceria tosichella* Keifer and *Abacarus hystrix* (Nalepa) in wheat (Nault and Styer 1969, Gibson, 1974), and in gall-forming eriophids, such as *Aculus tetanothrix* Nalepa, in Salix spp. (Kuczynski and Skoracka, 2005). However, there are also cases where this behavior does not occur, for example, in *Eriophyes laevis* Nalepa on leaves of *Alnus glutinosa* (Vuorisalo *et al*., 1989).

Conclusions

It is quite possible that the fluctuation of *A. annonae* found in this study is also related to other factors; for example, the age of the branch and the tissue from which it feeds, the quadrant of the tree where it inhabits and the morphology of the microhabitat, as has been suggested by Davies *et al*. (2001) as well as the concentrations of secondary products that the leaves produce, the same leaf texture, humidity and temperature that differ between the different strata and quadrants of the plant, factors that affect the population behavior of eriophyids and have been discussed for these mites associated with tea plants in India.

This study is a first approximation on the knowledge of the fluctuation of *A. annonae* associated with the cultivation of the soursop in the state of Nayarit, it is expected that the data obtained will serve as a basis, to make other more specific and with this to be able to implement in the future, integrated management programs for the control of this eriophid, of which in the country many of the basic aspects are unknown, mainly due to the fact that it is not considered of economic importance and without affectation for the production of the soursop.

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