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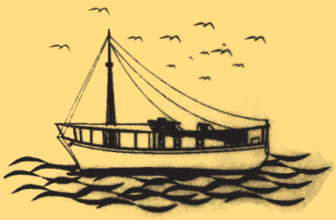

BOLETÍN DEL CENTRO DE INVESTIGACIONES BIOLÓGICAS

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UNA REVISTA INTERNACIONAL DE BIOLOGÍA PUBLICADA POR LA
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Daño estacional por ardillas rojas (*Notosciurus granatensis* Humboldt 1811) a mazorcas de cacao (*Theobroma cacao* L.) en Mérida, Venezuela.

RESUMEN

En toda su área de distribución el cacao es dañado por hongos, insectos, ácaros y ardillas. En este estudio se evalúa la estacionalidad climática del daño por ardillas rojas en diez unidades de producción de la Cordillera de Mérida, Venezuela. Aunque no se encontraron diferencias estadísticamente significativas ($p>0.05$) entre las épocas seca y lluviosa, los resultados muestran un mayor nivel de daño durante el periodo de lluvias cuando las ardillas se reproducen aprovechando una mayor oferta de alimentos.

Palabras clave: Andes, cultivo, clima, neotrópico, pérdidas, plagas, roedores.

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INTRODUCTION

Cocoa (*Theobroma cacao* L.) is affected by different diseases throughout its distribution area. However, two pathologies cause the most significant losses: black pod rot derived by various species of *Phytophthora*, and witches' broom caused by *Moniliophthora* spp. (Marelli *et al*. 2019). Insects and mites also figure among the pests that affect the crop. The most influential insects are the Coleoptera (*Xyleborus ferrugineus, Xilosandrus morigerus, Steirastoma depressum, S. breve*, and *Brachyomus octotuberculatus*), Thysanoptera (*Selenothrips rubrocinctus*), Hymenoptera (*Atta* sp.), as well as some Hemiptera. The most relevant mites are *Floracarus theobromae* and *Eriophyes reyesi* (ICCO 2022).

Cocoa is also damaged worldwide by squirrels (Lee 1982, Warren and Emamdie 1993, Chadee and Chadee 1994, Reyes and Capriles 2000, Abdul 2005, Monge and Hilje 2006, Mollineau *et al*. 2008, Alvarado *et al*. 2014, López *et al*. 2014, Wood and Singleton 2014, Sánchez-Mora *et al*. 2015). In the neotropical region, the red squirrel (*Notosciurus granatensis*) causes significant damage to cocoa pods, and its geographic distribution matches that of the crop (Warren and Emmandie 1993).

The squirrels gnaw the pods, extract the seeds and feed on the mucilage; when they do not devour the pod entirely, the bacteria and fungi finally decompose the exposed seeds (Parra and Camejo 2015). This damage reduces the crops' productivity and the producers' income (Mollineau *et al*. 2008, López *et al*. 2014); consequently, the producers loss millions of dollars annually throughout the region.

A management plan is required to reduce rodent damage effectively, and one of the basic requirements to generate it is to know the damage seasonality and its relationship with population dynamics (Lloyd and Baldwin 2021). That is because rodents can adjust their activity patterns to optimize energy incomes and thus guarantee their reproductive success and reduce the risk of predation throughout the year (Guidobono 2013, Revollo-Cadima 2021, Wróbel and Bogdziewickz 2015).

In Venezuela, damage by red squirrels has only been studied by Molina and Briceño (2018, 2021) with no published works related to the climate. This contribution aims to evaluate the damage caused by red squirrels in cocoa plantations in the Cordillera de Mérida, Venezuela, during the two climatic seasons: dry and rainy.

MATERIAL AND METHODS

The study area

The work was carried out in 10 farms distributed in the state of Mérida as indicated in Table 1.

Table 1. Geographical location of the farms.

Code	Name	Coordinates	Parish	Municipality
F2	Santa Lucía	71°37'80"	Mesa Bolívar	Antonio Pinto Salinas
F3	San Rafael	71°37'84"	Mesa Bolívar	Antonio Pinto Salinas
F4	Mi Refugio	71°38'12"	Mesa Bolívar	Antonio Pinto Salinas
F6	La Vega	071°38'74"	Mesa Bolívar	Antonio Pinto Salinas
F7	La Escondida	71°38'76"	Mesa Bolívar	Antonio Pinto Salinas
F9	Los Manzanos	71°38'75"	Mesa Bolívar	Antonio Pinto Salinas
F32	La Esperanza	71°18'37"	Río Frío	Caracciolo Parra y Olmedo
F33	El Rosal	71°18'35"	Río Frío	Caracciolo Parra y Olmedo
F34	La Montaña	71°18'03"	Río Frío	Caracciolo Parra y Olmedo
F35	Los Taguanes	8°56'07"	Río Frío	Caracciolo Parra y Olmedo

Most crops have an area of 2 ha or fewer; criollo cocoas predominate, although it is common to find hybrids and, less frequently, foreign cocoas. Plant spacing is 3 x 3 m. Weed control is mainly mechanical. There is a marked tendency towards scarcity of shade vegetation, which, when present, is usually not very diverse, generally with two tree strata: the upper one made up of native trees, mainly cedar (*Cedrela odora-*

ta), pardillo (*Cordia alliodora*), and bucare (*Erythrina poeppigiana*), nevertheless, occasionally caraño (*Protium* sp.), jobo (*Spondias mombin*) and higuerón (*Ficus* spp.) trees are found; and an intermediate stratum made up mainly of *E. poeppigiana*, and guamo (*Inga* spp.), sporadically finding surure (*Myrcia fallax*) and yagrumo (*Cecropia* spp.) plants, and even exotic species such as bamboo (*Bambusa vulgaris*).

In some cases, we found more than two vertical layers in the shade vegetation. The plants that make up the lower stratum were fruit trees: avocado (*Persea americana*), soursop (*Annona muricata*), orange (*Citrus cinensis*), mandarin (*Citrus reticulata*), lemon (*Citrus auratiifolia*), banana (*Musa AAA*) and plantain banana (*Musa AAB*).

The study area has three sub-landscapes: hills, cones, and valleys. The hills modeled by Quaternary erosion in Tertiary and Lower Pleistocene are small, with slopes between 10° and 30°; the cones are alluvial plains with slopes between 3 and 8°; and the valleys are the product of the river cuts through the cones or hills and have slopes that vary between 3 and 5° (Vivas 1992).

The relief and altitude are the principal determinants of climate due to its mountainous condition; these parameters regulate the temperature and rainfall. As a rule, altitude causes a decrease in temperature between 0.60 to 0.65^{o}C for every 100 m of elevation. The hottest months are May-June. There is a bimodal pattern typical of the Lake Maracaibo depression with two precipitation maxima: the first between April and May and the second between June and August, and two minima: one between January or February and the other in March, July, August, or September (Vivas 1992).

Identification of the biological agent causing the damage

Woodpeckers principally the red-crowned woodpecker *Melanerpes rubricapillus*,

and red squirrels damage the cocoa pods in the study area. Although rats and monkeys can also attack these fruits worldwide, we did not find evidence of bites by smaller rodents in this work; likewise, we did not detect the attack by primates, whose presence hardly goes unnoticed because they are very conspicuous and noisy.

Damage by red squirrels begins when they break the pod to feed on the mucilage that covers the seeds (Fig. 1A). The damage is easily distinguished from that caused by woodpeckers because these birds pierce the pods, leaving circular holes whose diameter is usually not more than 2 cm (Fig. 1D), while red squirrels leave much bigger and irregularly shaped holes (Fig. 1C) that can cover almost the entire fruit (Fig. 1B); in addition, in the pods bitten by squirrels, the grooves left by the incisor teeth can be easily seen.

Damage assessment

We randomly selected 12 plants in each farm and counted twice, during the rainy season of 2018 and the dry season of 2021, the number of pods bitten by the squirrels and the total number of pods occurring in the plant to calculate the percentage of damage. We consider each farm as a replica.

Data analysis

We defined the two groups of data corresponding to the climatic periods following the criteria of López *et al*. (2010). We used the Wilcoxon signed-rank test (Siegel and Castellan 2007) to check the existence of statistically significant differences in the level of damage between the dry season (November- March) and the rainy season (May- September). We processed data using the SPSS20 (IBM 2011).

Figure 1. Cocoa pods without damage (A, note the mucilage that coats the seeds), squirrel-damaged (B and C), and woodpecker-damaged (D, note hole size and shape). Source: M. Molina.

RESULTS AND DISCUSSION

The average damage level was 3.6% for the dry season and 8.8% for the rainy period. Nevertheless, the differences between the two seasons were not statistically significant ($p>0.05$).

Figure 2 reveals more damage to most of crops during the rainy season; however, the statistical analysis did not reflect significant differences. Except for farms 3 and 33, the damage was higher in the rainy season.

Our results contrast with those of López *et al*. (2014), who found losses between 26 and 34% for Nicaragua, and those of Mollineau *et al*. (2008), who reported losses above 30% for Trinidad and Tobago. Although the average level of damage found is lower than those reported by these authors, it is very important for Mérida producers since they face a crisis that is reflected mainly through scarcity and high costs of agro-inputs at the field level.

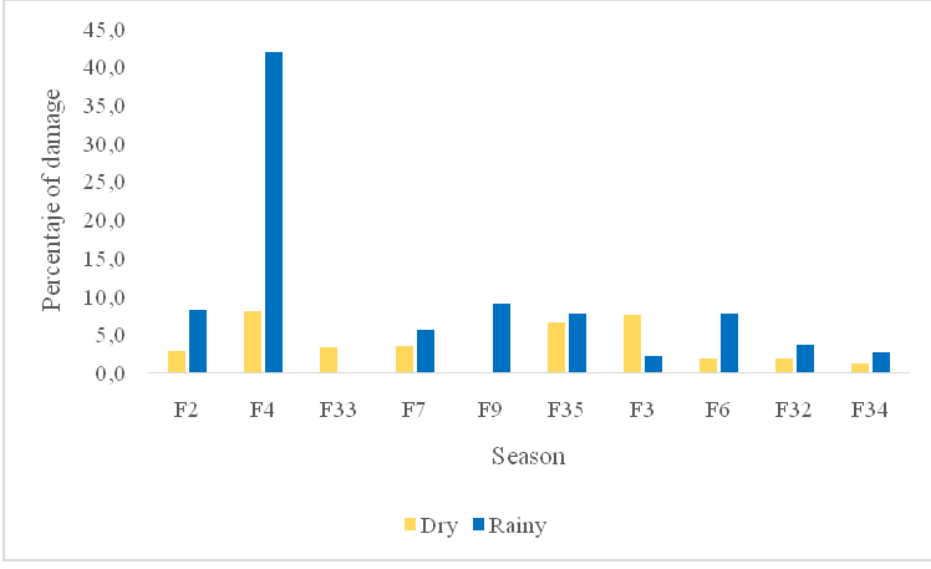

Figure 2. Relationship between the magnitude of damage and the climatic seasonality. F: farm.

However, the losses caused by red squirrels are related to those generated by fungi which in some neotropical regions is approximately 40% (Correa *et al*. 2014). In fact, after red squirrels attack the cocoa pods, fungi and bacteria enter, deteriorating them completely (Molina and Briceño 2018).

In Venezuela, red squirrels reproduce at the end of the rainy season (Linares 1998); thus, it is reasonable to expect more significant damage at that time since the energy expenditure for lactation and rearing, generally, is higher. Rodents can adjust their daily and seasonal activity patterns to optimize energy gains and reduce predation risk according to climate variations (Wróbel and Bogdziewickz 2015).

The squirrels are likely taking advantage of the greater availability of cocoa fruits during the rainy season (Wilcoxon Signed Ranks Test, $p<0.05$) and a higher supply of complementary foods (Molina, M., unpublished data). According to Witmer and Proulx (2010), when rodents have access to food in high quantity or quality, the percentage of the population in reproductive condition can increase, adult animals can mate earlier than usual, the proportion of females giving birth can grow, even the size of the litter can be increased, which would consequently generate an increment in the level of damage.

Producers can use the present results to enhance their knowledge of the cocoa plantation and to take better decisions regarding the pest management. Therefore, they would control the damage and reduce losses.

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CONTENTS