Chapter

Beetles and Meteorological Conditions: A Case Study

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Abstract

The meteorological factors study in the beetle population dynamics, as well as its association with vegetation, is of fundamental importance for understanding the variation that occurs in its population. Thus, it was reported the influence of temperature, humidity, insolation and precipitation on the beetles in general and it was presented a case study that examined the relationship between time and population fluctuation of curculionids in Mata de Cocal and an area used for crop rotation and animal grazing, in the city of Teresina, Brazil, from August 2011 to July 2012. It was verified that beetles populations certain are governed and conditioned by meteorological variables to a greater or lesser extent depending on the characteristics of the community itself and the biotic and abiotic environmental factors of the area where they live: the temperature that changes the its metabolic rate, the insolation and humidity that can affect its fertility and longevity can be cited as examples. From the case presented, It was found that the Curculionidae community has a positive association with precipitation and humidity and a negative association with insolation and temperature, being that in native forests curculionids are not as dependent on meteorological variables as in agricultural fields.

Keywords: ecology, biometeorology, entomology, Coleoptera, Curculionidae

1. Introduction

Coleopteran insects, which they are popularly known as beetles, are important indicators of the environment quality, as they are susceptible to climatic variations and occupy a habitats diversity [1–3]. Among the beetles, the family Curculionidae Latreille, 1802, is a very important group present in forest ecosystems due to the role of wood deterioration they make.[1]

Insects like all living beings are subject to the nature forces, so there may be an influence that can inhibit or favor the species certain development. For example, the hottest and driest events on El Niño are having an alarming effect on biodiversity in the Amazon Rainforest, contributing to the reduction of insects in the Amazon and across the globe[2] [4]. Intense droughts and forest fires during the last El Niño climatic phenomenon, combined with human disturbances - deforestation and

[1] Curculionids are known as *Rüsselkäfer* or *Rüssler* in German, *charançon* in French and weevil in English. In Brazil, they are known as *gorgulhos*, *carneirinhos* or *bicudos* depending on the region.

[2] El Niño is an atmospheric-oceanic event is the abnormal warming of surface waters of the tropical Pacific Ocean. It affects regional and global meteorological conditions, changing wind dynamics around the world, changing rainfall patterns in tropical and mid-latitudes.

burning to clear areas for agricultural production and the sale of illegal wood - led to the reduction of beetles in the Amazon, the numbers dropped in half - with effects that can last at least two years, according to the researchers: about 8000 beetles were counted in 2010; 3700 in 2016, after El Niño; and 2600 beetles in 2017 [4].

Thus, in view of the climate changes that are already occurring and that are predicted for the coming years, the meteorological factors study in the beetle population dynamics, as well as its association with vegetation, is of fundamental importance for understanding the variation that occurs in its population.

In this way will be discussed the influence of temperature, humidity, insolation and precipitation on the beetles in general, firstly, in this chapter. And a second moment, as it is a relevant subject and to complement the scientific literature about the family Curculionidae when associated with the native forest and the areas agriculture and meteorological variables, a case study will be reported that aimed to analyze the curculionids relationship to temporal factors (precipitation, insolation, temperature and humidity) in Mata de Cocal (native forest) and in an area used for crop rotation and animal grazing (agricultural field).

2. Beetles and meteorological conditions

Around the world, extreme climatic events increase and expose the vulnerability of insect populations, altering the biological functioning and the community structure of these invertebrates. Depending on a given meteorological situation, in addition to affecting the forests biodiversity and the ecosystem functioning, the community of a given species can become a pest for an agricultural crop.[3]

Thus, beetles are subject to natural forces that can inhibit or favor the species certain development, because they are associated with the relative humidity, precipitation, insolation and temperature mainly [1]. The following will be seen how each of these factors can influence the insects.

The ambient temperature regulates the insects' internal temperature, as they are pecilothermal animals - they do not have a thermoregulation system. Temperature gives insects a change in their metabolic rate interfering with their development – egg, larva and pupa phase – and their behavior [2, 3]. Thus, when the ambient temperature is favorable, the smaller insects benefit from the easy heat exchange with the environment, also having more efficient respiratory and circulatory activity, more intense metabolic activity and greater capacity to use food resources [2]. In general, for insects, the optimum temperature for the fastest development and the offspring largest number is close to 25° C and the optimum range for the insects most is between 15 and 38° C [7].

Unfavorable temperatures decrease the insect's metabolic activity. Very low temperatures can lead to an almost absolute killing of certain species of beetles [3]. For example, −16° C is the critical value for the North American tree bark beetle species *Dendroctonus frontalis* Zimm, 1868, which belongs to the Curculionidae family [3, 8]. There is also a negative influence of the average temperature increase in the forest environment in relation to the European beetle *Ips typographus* (L.), 1758, which also belongs to the same family [3, 9–10].

[3] In South America, weather conditions (temperature, precipitation and wind dynamics) are related to the displacement route - which involves Paraguay, Argentina, Brazil and Uruguay - of the locust cloud that can destroy a plantation in just one day [5]. Too, the increase in temperature relates positively to the generations number of the fruit fly, *Anastrepha grandis* [6]. Consequently, high temperatures, in addition to increasing the population of the fruit fly, favor the spread of this insect in areas that do not yet inhabit and may thus accentuate losses for agricultural production [6].

Some insects, like plants, need a certain number of sunshine hours to complete their development. These hours interfere with fertility and longevity [2]. In addition to humidity, precipitation, temperature, insolation is decisive for the distribution the insects fauna richness [1, 11, 12]. Some beetles families, in northeastern Brazil, have associated this meteorological variable positively [1, 11, 13].

The amount of water contained in the insects body varies between 70 to 90%, which depends on the food type they consume and the environment in which they live [2]. The relative humidity is directly related to the insects exposure or their protection, the low moisture content can affect the physiology, longevity, development and insects oviposition [14]. For most insects, the favorable range for greater longevity, fertility and development speed ranging from 40 to 80% [7].

The rainfall may indirectly interfere with the insects. In study, in the Ponta Grossa city- Brazil, in areas with different anthropization degrees and plant succession, it was found that the insects seasonality is related to the rainy season, as there is a greater availability of food resources, which provides a high population peak [15]. However, the excess water can be harmful to plants, it can cause water stress and soil get soggy [1].

There are brazilian studies in which there was the highest record of specimens sampled in the rainy season. For example, in a fragment of Atlantic Forest, in the Gurjaú Ecological Reserve, Santos obtained 71.5% of the total sampled specimens in the rainy season (May to July 2003) and 28.5% of the total sampled beetles in the dry season (October and November 2003) [16].

Few species of coprophagous beetles survive in areas with an average annual rainfall of less than 250 mm, the individuals number increases only at the beginning of the first rains and with the rise in air temperature [17]. Corroborating this understanding, studies have shown that, in pastures, the scarab community population fluctuation is predominantly governed by the region's macro-climatic variables and that the beetles presence is seasonal and conditioned by temporal parameters, correlating to the compensated average air temperature negatively and to the compensated average relative humidity and the pluviometric precipitation positively [18, 19]. In Mata de Cocal, it was confirmed canonical correlation between sets of variables monthly record of beetles occurrence and monthly weather data [1].

To attest to the meteorological factors influence of on the curculionid community population fluctuation, in an area of forest native (Mata de Cocal) and agriculture (crop rotation with grazing animals), a case study will be presented in the next section.

3. Case study

3.1 Methodology

This study was carried out at the Agricultural Sciences Center localized at the Federal University of Piauí (UFPI), in the Teresina city, from August 2011 to July 2012.

Teresina's climate, based on the classification made by Thornthwaite and Mather, is C1sA'a', it is characterized as dry subhumid, megathermic, with moderate hydrous surplus in summer and a potential evapotranspiration of 32.2% in the trimester – September, October and November [20].

A native vegetation area was used for sampling, its respective latitude and longitude is 5° 2′52 "S and 42 ° 47'11" W, which it presents formation denominated Mata de Cocal. The other area used is characterized by being an agricultural field with respective latitude and longitude is 52° 2 '57' 'S and 42° 46′ 57 "W, where during the present study there was a concomitant and rotational cultivation of pigeon pea (*Cajanus cajan* (L.) Millsp.), cowpea (*Vigna unguiculata* (L.) Walp), corn (*Zea mays L.)* and watermelon *(Citrullus lanatus* (Thunb.) Matsum & Nakai), in addition to the occasional presence of sheep *(Ovis aries* L., 1758*)* and goats *(Capra aegagrus hircus* L., 1758).

Geographically, this native vegetation is concentrated in the Piauí and Maranhão states, most western portion of the Northeast region, widely occupied by dicots and palm trees formations [21]. In vegetation terms, an extensive mosaic is formed with so different physiognomies that the region's specialty in having disseminated features with different species and structures is observed in little space, accompanied by alterion in soil and climate [22]. The Piauí and Maranhão are an extensive ecotonal zone located between the Amazon sub-humid and the Northeastern semi-arid, transition region [23].

For the samples, unattractive pitfall traps were used to capture the insects. (These traps were also used, for example, see [19, 24])Three independent sample units are used, called "stations" located at ground level. Each station consisted of four plastic containers with a capacity of 500 mL, a diameter of 10 cm and a height of 11 cm, covered by a plastic plate 20 cm in diameter, suspended by pieces of wood approximately 15 cm, to prevent or reduce water entry in the rainy season. The containers were buried with the edge at ground level, with the addition of 200 ml of 4% formaldehyde solution as fixative liquid. The flasks were connected by metal bulkheads, 100 cm long by 20 cm high, to direct the insects to the station's containers. The stations were arranged in the shape of a Y. **Figure 1** (adapted) shows the schematic drawing of the station.

Three identical stations were randomly arranged in each area. Each station kept a distance of 5 m between them. They were obtained weekly samples, totaling 52 samples from August 2011 to July 2012. At the UFPI's entomology laboratory, screening and identification of Coleoptera specimens was carried out, besides the deposit of the material sampled for its preservation, for possible future studies.

The monthly meteorological data of the compensated average air temperature, compensated relative humidity, precipitation and insolation were obtained through the network of the National Institute of Meteorology – INMET. The weather station from which the weather data originated has a respective latitude and longitude of 5 ° 220.16 "S and 42 ° 48'14.77"W and an altitude of 75 m. The areas of native forest and agricultural field in which the samples were obtained are within a radius of 3 km from the aforementioned weather station.

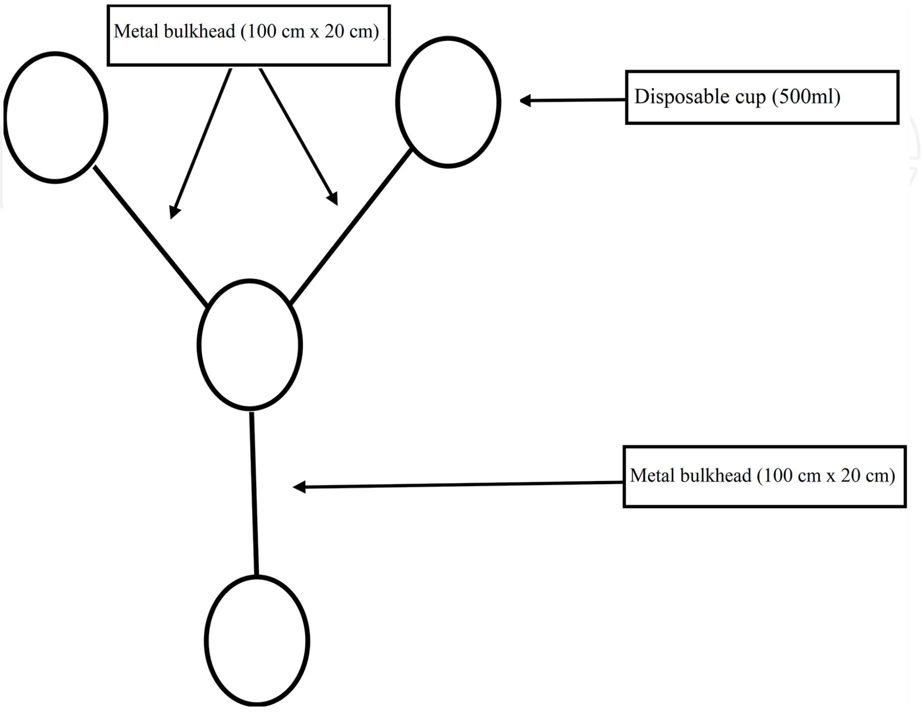

Figure 1.
Station design (adapted).

Faunistic indices were calculated: dominance, abundance, frequency and constancy, as well as diversity indices, H variance and confidence interval with the ANAFAU software [25]. Correlations were performed using the Pearson method between the records of monthly occurrence of the population fluctuation of the subfamilies and the monthly data of the meteorological variables using the software BIOESTAT version 5.3 [26]. Later, the canonical correlation was performed between the sets of the monthly occurrence of the population fluctuation of the subfamilies and the set of monthly meteorological data by the same software.

3.2 Results and discussion

3.2.1 Population fluctuation and fauna measures

Table 1 shows that in the period analyzed in the Mata de Cocal 591 insects of the Curculionidae family were sampled and distributed in 2 subfamilies: Molytinae Schönherr, 1823, and Scolytinae Latreille, 1804, with 22 and 569 specimens respectively. Already in the agricultural field 63 insects of this family were collected and distributed in Molytinae and Scolytinae too, with 41 and 22 specimens respectively. In total, 654 Curculionidae beetles were collected, 90.37% in the Mata de Cocal area and 9.63% in the agriculture area.

The subfamily Molytinae was more numerous in the agricultural field than the same subfamily in Mata de Cocal, while Scolytinae presented more specimens in this area than in that one.

The population fluctuation of beetles ranged from a minimum of 0 specimens in Mata de Cocal, in the months of August, October and November 2011, and March and July 2012, to a maximum of 513 in April 2012, which represented 86.80% of the insects collected in that area. In the agricultural field, in the months of September, October and November 2011, no specimen was collected from the family studied, while 32 were collected in the month of April 2012, which represented 50.79% of the specimens collected in that area. For all subfamilies, the population peak occurred in April.

The population peak of a given insect community occurs when the set of homeostatic mechanisms in nature, in relation to one's own family or species, as intrinsics – internal – and extrinsics– external–, is favorable to its development in a given habitat, over a given period of time [1]. Intrinsic mechanisms depend on the members of the population themselves, as is the case with intraspecific competition, while extrinsic mechanisms depend on the participation of something outside the population itself, such as interspecific competition, food and space restrictions, weathering, parasitism, predatism and meteorological variations [1]. Thus, the April month had the most favorable environmental homeostatic conditions for the studied communities of curculionids.

Table 2 shows that all subfamilies were dominant, constant and accessory. As for abundance, subfamilies were very abundant in Mata de Cocal, while they were common in the agricultural field. Also, the fauna indexes – Shannon-Weaner diversity, Margalef wealth and equitability – were different among the curculionid communities of the studied areas. The highest values of these indexes were obtained in the agriculture area.

Normally the difference between insect community is the relationship of insects to biotic factors – vegetables diversity; intra and interspecific competitions; mammal diversity– and abiotic factors – such as seasonality with its characteristics of temperature, air humidity, rainfall and photoperiod; soil edaphic conditions; among other factors [1]. In this way, the association of the Curculionidae community to the biotic and abiotic factors of which they are inserted may explain the difference in terms of abundance and fauna indexes presented in the studied areas.

Area	Subfamily	2011					2012							Total
		Aug.	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	
Mata de Cocal	Scolytinae	0	0	0	0	0	0	0	0	506	45	18	0	569
	Molytinae	0	1	0	0	1	8	4	0	7	0	1	0	22
Agricultural field	Scolytinae	0	0	0	0	0	0	0	0	20	1	1	0	22
	Molytinae	1	0	0	0	3	8	7	8	12	0	0	2	41
Total		1	1	0	0	4	16	11	8	545	46	20	2	654

Table 1.
Monthly records of population fluctuation of curculionids data collected in the Mata de Cocal and in the agricultural field.

Area	Subfamily	Dominance	Abundance	Frequency	Constancy
Mata de cocal	Scolytinae	D*	va	F	Y
	Molytinae	D	va	F	Y
Agricultural field	Scolytinae	D	**c**	F	Y
	Molytinae	D	**c**	F	Y

**D = dominant; F = frequent; Y = accessory; c = common; va = very abundant; a =abundant.*
***Mata de cocal:** Diversity Index (Shannon-Weaner) => H = 0.1590 H Confidence Interval (P = 0.05) => [0.156938; 0.161106] Wealth Index (Margalef) => ALFA = 0.1567 Uniformity or Equitability Index => E = 0.2294.*
***Agricultural field:** Diversity Index (Shannon-Weaner) => H = 0.6470 H Confidence Interval (P = 0.05) => [0.637532; 0.656375] Wealth Index (Margalef) => ALFA = 0.2414 Uniformity or Equitability Index => E = 0.9334.*

Table 2.
Faunistic analysis of the curculionid subfamilies sampled in Mata de Cocal and in the agricultural field.

3.2.2 Curculionids and meteorological variables

3.2.2.1 Weather data

Throughout the study, there was an average insolation of 8.4 h.d-1, an average relative humidity of 72.4%, an average daily compensated air temperature of 27.4°C and 1218.9 mm of rainfall. When these values are compared to the climatological normal from 1980 to 2009 calculated by Bastos and Andrade Júnior – who it had an average insolation of 7.8 h.d-1, relative humidity of 69.8%, average air temperature of 28.2°C and 1351.9 mm annual rainfall–, it was verified that the insolation and humidity were higher while precipitation and temperature were below [27]. The record of monthly meteorological data for the period is shown in **Table 3**.

Year	Month	Insolation (h.d^{-1})	Relative humidity (%)	Precipitation (mm)	Average temperature (° C)
2011	Aug.	10.1	65.4	10.8	27.2
	Sep.	10.3	58.1	0.6	28.5
	Oct.	8.8	66.1	167.6	28.6
	Nov.	7.8	74.8	124.6	27.4
	Dec.	8.6	68.2	23.4	28.3
2012	Jan.	6.4	75.7	133.1	27.1
	Feb.	5.6	83.4	317.1	26.2
	Mar.	7.4	85	264	26.3
	Apr.	7.7	82.5	121	26.7
	May	9.3	77.3	31.3	27.2
	Jun.	8.8	72.7	25.4	27.2
	Jul.	10	60.8	0	27.5

Source: INMET Network data.

Table 3.
Meteorological data (insolation, compensated average relative humidity, precipitation and average compensated air temperature) from August 1, 2011 to July 31, 2012 in Teresina.

3.2.2.2 Relationship between curculionids and meteorological variables

Beetles like all living things are subject to the nature forces, so there is a relevant influence in a way that can inhibit or favor a particular group of insects. Studying the relationship between meteorological factors and the population fluctuation of beetles is important for understanding the variation that occurs in their population.

For investigation and understanding of this association in the Mata de Cocal and in the agricultural field, the monthly records of the subfamilies fluctuation and the monthly meteorological data were correlated.

Significantly, in Mata de Cocal, the subfamily Molytinae was negatively associated with heat stroke (−0.61; $p < 0.05$), while the same subfamily, in an agricultural area, was negatively associated with insolation (−0.70; $p < 0.05$) and temperature (−0.61; $p < 0.05$), and positively with humidity (0.68; $p < 0.05$) and precipitation (0.56; $p < 0.10$). In both areas, the Scolytinae subfamily had no significant association with a p-value equal to>0.10. **Figures 2–5** show that only the subfamily Molytinae, in the agriculture area, was significantly associated with all meteorological variables (**Table 4**).

Canonical correlation was performed between the monthly records of the subfamilies and the data set related to insolation, humidity, precipitation and temperature.

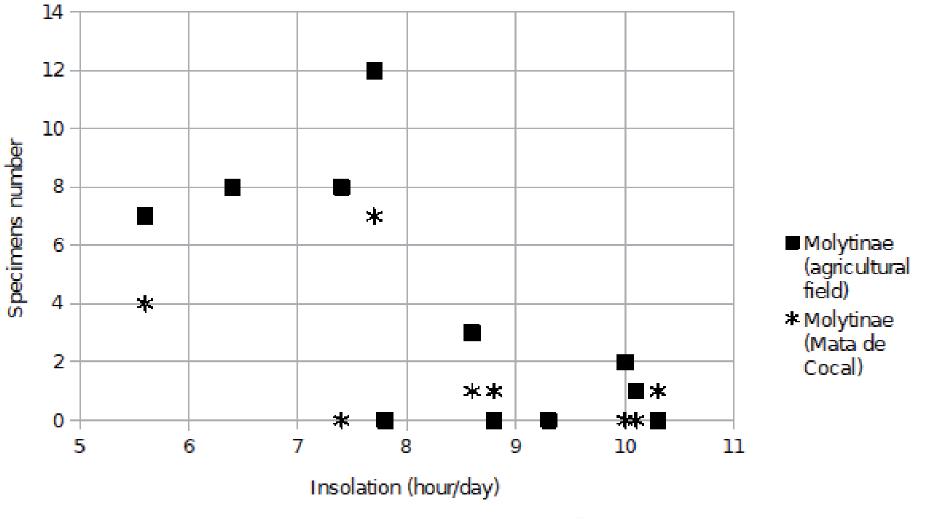

Figure 2.
Dispersion diagram: the daily insolation versus the monthly population fluctuation of Molytinae.

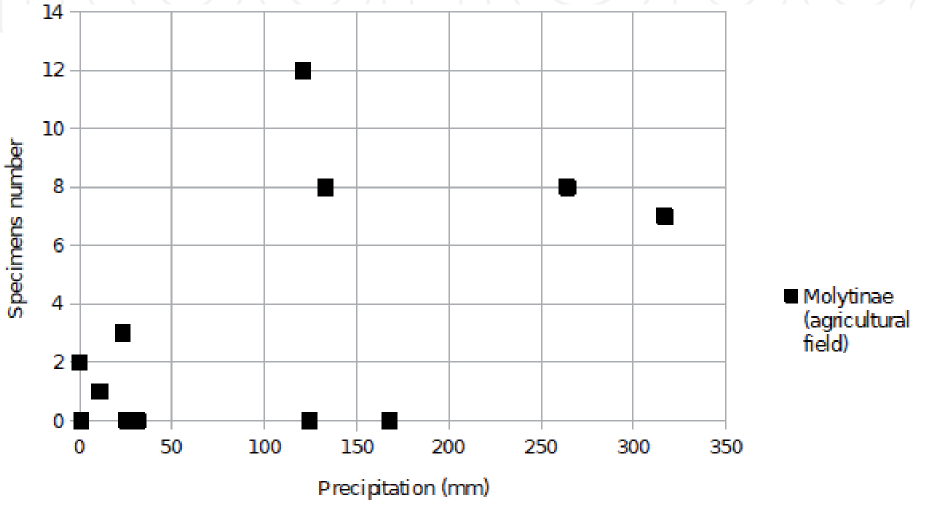

Figure 3.
Dispersion diagram: the precipitation data versus the monthly population fluctuation of Molytinae.

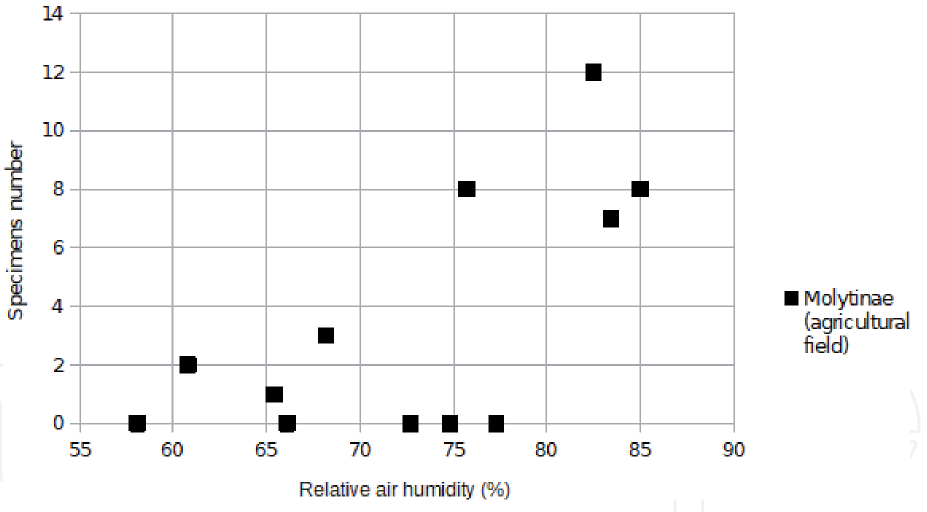

Figure 4.
Dispersion diagram: the monthly relative air humidity data versus the monthly population fluctuation of Molytinae.

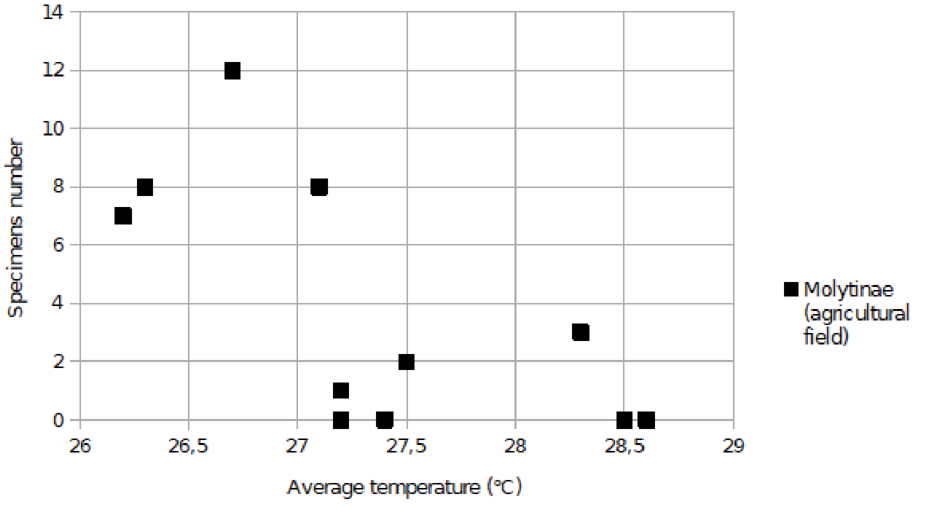

Figure 5.
Dispersion diagram: the monthly average temperature data versus the monthly population fluctuation of Molytinae.

Subfamily Molytinae	Insolation (h.d^{-1})		Humidity (%)		Precipitation (mm)		Temperature (°C)	
	(r)	p- value	(r)	p- value	(r)	p- value	(r)	p- value
Mata de cocal	−0.61	< 0.05	0.42	ns*	0.29	ns	−0.38	ns
Agricultural field	−0.63	< 0.05	0.68	< 0.05	0.56	< 0.10	−0.70	< 0.05

N (pairs) = 12; degrees of freedom = 10;
** ns = not significant.*

Table 4.
Correlation between monthly records of population curculionids fluctuation and monthly meteorological data in Mata de Cocal and in agriculture area.

Canonical correlations and eigenvalues were observed in **Tables 5** and **6**. The correlation between the pair of canonical variables, also called canonical R, was approximately 0.79 in both areas, which represents the best possible correlation between any linear combination of the monthly meteorological data with the records monthly of the subfamilies Curculionidae. The Canonical R statistic expresses the relationship magnitude between the variables sets.

	Mata de cocal		Agricultural field	
	Molytinae	Scolytinae	Molytinae	Scolytinae
V	0.93	0.21	0.97	0.40

***Mata de cocal:** canonical R= 0.79; canonical R^2= 0.63; χ2 = 11.5400, 15; Degrees of freedom= 8; p-value < 0.1729.*
***Agricultural field:** canonical R= 0.79; canonical R^2 = 0,62; χ2 = 10.6400, 15; Degrees of freedom= 8; p-value <0.2229.*

Table 5.
Canonical correlation between the beetle population fluctuation records and the meteorological data set (V).

	Insolation ($h.d^{-1}$)	Relative air humidity (%)	Precipitation (mm)	Average temperature (° C)
U (mata de cocal)	−0.80	0.42	0.42	−0.33
U (Agricultural field)	−0.87	0.86	0.82	−0.87

***Mata de cocal**: canonical R= 0.79; canonical R^2= 0.63; χ2 = 11.5400, 15; Degrees of freedom= 8; p-value < 0.1729.*
***Agricultural field:** canonical R = 0,79; canonical R^2= 0.62; χ2 = 10.6400, 15; Degrees of freedom= 8; p-value < 0.2229.*

Table 6.
Canonical correlation between data on meteorological variables and beetle population fluctuation record sets (U).

The Chi-Square (χ2) equal to 11.5400, with 8 degrees of freedom, was recorded in the Mata de Cocal, and the Chi-Square (χ2) equal to 10.6400, with 8 degrees of freedom, in the agricultural area, for the association between the variables sets: monthly records of the subfamilies population fluctuation and the monthly meteorological data. The Molytinae subfamily had a greater association with the monthly data set on meteorological variables in both areas.

The Curculionidae community in the agricultural area obtained the greatest associations with the monthly meteorological data as shown in **Table 6**. In both areas, there was association with the relative air humidity and precipitation positively and insolation and the average temperature in a negative way. In Mata de Cocal, there was a greater association with insolation (−0.80) and a lower association with temperature (−0.33), while there was a greater association with insolation and temperature (−0.87) and less association with precipitation (0.82) in the agricultural area.

Probably, the presence of trees in Mata de Cocal provided microtemporal conditions that favored the subfamilies not to become so dependent on meteorological variables.

3.3 Ecological niche of the family Curculionidae

The identified subfamilies specimens occupy a functional or biological position within the ecosystem in which they are inserted. This includes what they represent in the overall ecosystem, by what they do and how they do.

The curculionids, along with Cerambycidae family beetles, are the ones that occur most associated with native and exotic forest species, performing an important role in the wood degradation [28]. They stand out for the great number of species and high degree of polyphagia: there are species that can be xylophages, mycophages or spermatophytes [28–31]. They occur in forest species native to the Mata de Cocal, such as the babassu coconut palm [32]. These insects are common in tropical regions and only attack live trees that show changes in their physiological conditions [28, 31].

The curculionids diet basis is deficient in essential vitamins of group B and sterols, whose absence is compensated by a diet rich in nitrogen supplied by symbiotic fungi that synthesize them from nutrients absorbed from the galleries that they make inside the wood [30]. These specimens have a fundamental ecological role in the forests formation, as they recycle vegetable biomass. When they consume their hosts tissues, they facilitate the saprophytic organisms entry that accelerate the vegetable material deterioration [31].

Given that each species can be associated with several factors such as the climate, the soil, the vegetation type, among others, the deforestation processes of the native forest areas, can lead to the species loss, causing changes in their community [1].

All physical and biological entities in a given ecosystem form a unified and complex integral system [1]. As seen, there is a deep, direct and essential link between curculionids and the ecological processes of the ecosystem in which they are inserted.

Given this importance, it is necessary for them to remain in the environment in which they are, for that reason, there must be the maintenance of meteorological conditions related to insolation, precipitation, temperature and humidity, as well as the conservation – rational use – of the Mata de Cocal when its preservation is not possible – full and permanent protection.

4. Conclusion

Given the above, it is inferred that beetles populations certain (such as the subfamily Molytinae in the present study) are governed and conditioned by meteorological variables to a greater or lesser extent depending on the characteristics of the community itself and the biotic and abiotic environmental factors of the area where they live. From the case presented, it verifies that the Curculionidae community has a positive association with precipitation and humidity and a negative association with insolation and temperature, being that in native forests curculionids are not as dependent on meteorological variables as in agricultural fields.

Finally, as this chapter shows the association of curculionids with meteorological parameters in two habitats: Mata de Cocal and agricultural field; it becomes important as a parameter for a first description for further ecological studies of taxonomic refinements and deeper inflections.

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