Edaphic macrofauna associated with the cultivation of maize (Zea mays)
Macrofauna edáfica asociada al cultivo de maíz (Zea mays)

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Data of the Article

Abstract

Macrofauna is a biological indicator of soils, in this sense, the objective of this research was to determine the edaphic macrofauna community and its physicochemical properties of the soil, by means of its abundance and richness of groups during the growing season and post-harvest of corn. Three monoliths 25 x 25 cm wide by 30 cm deep were established. Soil samples were taken in each plot, then the organic matter (OM) content, hydrogen potential (pH), electrical conductivity (EC) and nitrogen (N) content were determined. The results show differences between atmospheric temperatures during the development period (25 °C) and the post-harvest period (41.4 °C). Physicochemical parameters such as pH ranged between 8.5 and 8.3. The maximum Shannon index was 0.48 (growing season) and 0.13 (post-harvest season). The greatest number of individuals was ants (111) and was identified during the post-harvest period. In this sense, the biological diversity was lower in the growing season of corn, and during the post-harvest period a greater number of ant organisms was determined, which was associated with the resistance to high temperatures.

Keywords:
Corn, altitude, abundance, development, post-harvest.


Resumen

La macrofauna es un indicador biológico de suelos, en este sentido el objetivo de esta investigación fue determinar la comunidad de macrofauna edáfica y sus propiedades fisicoquímicas del suelo, por medio de su abundancia y riqueza de grupos durante la época de crecimiento y post cosecha del maíz. Se establecieron tres monolitos 25 x 25 cm de ancho por 30 cm de profundidad. Se tomaron muestras de suelo en cada parcela, luego se determinó el contenido de materia orgánica (MO), potencial de hidrógeno (pH), conductividad eléctrica (CE) y contenido de nitrógeno (N). Los resultados muestran diferencias entre las temperaturas atmosféricas, durante la época de desarrollo (25 °C) y la época de post cosecha (41.4 °C). Los parámetros fisicoquímicos como el pH oscilaron en 8.5 y 8.3. El índice de Shannon máximo fue de 0.48 (época de post cosecha) y de 0.13 (época de desarrollo). La mayor cantidad de individuos fue de hormigas (111) y se identificó durante la época de post cosecha. En tal sentido la diversidad biológica fue menor en
Introduction

Soil fauna can be considered a very effective means of helping microorganisms to dominate and expand into soil horizons, improving their fertility, equilibrium, and vegetation development. Edaphic macrofauna (EM) is one of the indicators of soil quality, and is widely distributed in all soil types, but is very sensitive to different human interventions. EM is used as a bioindicator, due to its simplicity, low cost, contributes to the control of soil structure, altering its aggregation and porosity, improving infiltration, changing water retention patterns, contributing to the mineralization of organic matter (OM), with the decomposition of leaf litter.

Macroinvertebrates in the soil alter microbial activity in the processes of OM mineralization and humification, thus influencing the availability of assimilable nutrients for plants, in addition, these organisms contribute to the vertical mobility of assimilable nutrients, which is of great benefit to plant root systems.

The abundance and diversity of EM are important factors for the sustainability of primary production in ecosystems with different land covers, and their richness reflects the state of soil degradation. EM can be affected by climatic periods, likewise, the population of organisms can be observed in greater quantity during the rainy season, some crops have detrimental effects on EM, especially earthworms.

Very little is known about the distribution of EM under conditions of elevated temperatures and low OM content. Studies relate the probability of physical degradation and soil compaction to the population of EM. Other studies have reported that soil invertebrates are highly correlated with the surrounding vegetation, and highlight the importance of soil biota in the recovery of degraded areas.

The factors that can cause the reduced density of edaphic biota in corn crops may possibly be the loss of OM. In these crops during the growing season, populations of species that are mostly pests, such as Melolonthidae ("blind hen") are usually observed. There is scarce information on EM in corn crops. Based on the above, the objective of this research was to determine the edaphic macrofauna and physicochemical properties of the soil dedicated to corn cultivation.

Materials and methods

Location. Sampling was carried out in January and October 2020, in the hamlet of San Isidro, district of
Cajaruro, province of Utcubamba, Amazonas Region-Peru, Figure 1. San Isidro is located at an altitude of 990 meters above sea level. With coordinates 149950 east and 9350074 west. The coordinates were measured with the GPS model GPSMAP 66i-GARMIN. The plot is located on the right bank of the Utcubamba River and is characterized by being an agricultural sector, its main crop is hard yellow corn. The average production per hectare is 4000 kg (80 qq/ha)

The predominant soils are vertisols. The climate is warm, varying according to the altitudinal levels of the zone, from 10 to 40 ºC. Rainfall varies from 200 to 1000 mm per year, with more intense rainfall from January to March, and from June to September is the dry season.

**Methodology.** Two periods were taken into account: a) corn development period when it was one month into its growth b) post-harvest period (two months after harvest), a corn plot of one ha (10000 m²) was selected, the plot was 15 years old. For the sampling, three monoliths of 25 x 25 cm wide by 30 cm deep were extracted, according to the methodology "Tropical Soil Biology and Fertility" or TSBI. The selection of the EM was carried out in situ, and manually with the help of a white blanket. It consisted of removing foreign bodies such as stones and plant debris. The extracted organisms were stored in flasks with 70% ethyl alcohol for subsequent identification and visual counting in the agro-industrial engineering laboratory of the Universidad Nacional Toribio Rodríguez de Mendoza (UNTRM). The richness of the samples and diversity were then calculated using Shannon's (H') and Simpson's (DSi) index. Soil samples were taken to analyze pH, EC, with the EPA 9045/Soil-Water Ratio 1:1 method. The organic carbon (C) and nitrogen (N) content of the soil was determined from the soil OM, using the method proposed by Walkley & Black. The analyses were carried out at the Soil and Water Research Laboratory of the Research Institute for Sustainable Development of Ceja de Selva (INDES-CES) of the UNTRM. Atmospheric temperature and relative humidity were taken with a Thermohygrometer Model: VA-EDT-1-55 and soil temperature was taken with a 13 cm needle digital thermometer, code 111TMP14.

For data processing, Minitab 17 was used to determine averages and their standard deviation in the temperatures (development and post-harvest period of corn).

**Results**

Table 1 shows the results of soil temperature and atmospheric temperature in the San Isidro farmhouse, in the post-harvest stage, the atmospheric temperature was higher, compared to the soil temperature, with a variation of only 0.9 ºC.
Table 1 Temperature during the two sampling periods

<table>
<thead>
<tr>
<th>Period</th>
<th>ST</th>
<th>AT</th>
<th>RH %</th>
<th>ST</th>
<th>AT</th>
<th>RH %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development phase (February)</td>
<td>23.3±1.4</td>
<td>25.5±1.4</td>
<td>71.5±6.5</td>
<td>24.2±1.3</td>
<td>31.4±1.6</td>
<td>49.9±2.2</td>
</tr>
<tr>
<td>Post-harvest phase (October)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*ST= Soil temperature, AT= Atmospheric temperature, RH= Relative humidity

Physicochemical parameters. Figure 2 shows the behavior of the physicochemical parameters for the February period (development phase), October period (post-harvest period). The MO for the post-harvest period decreased from 5.67 to 3.37 %. Soil nitrogen was also reduced for the post-harvest period (0.28-0.17 %).

Edaphic macrofauna in the developmental stage of maize. Thirteen ME families were identified at the crop development stage and the individuals that stood out were caterpillars (Table 2).

Figure 2 Behavior of the physicochemical parameters of soil

Table 2 Edaphic macrofauna for the maize development period in an area of 0.625 m²

<table>
<thead>
<tr>
<th>Época</th>
<th>orders</th>
<th>families</th>
<th>Common name</th>
<th>N° Individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lepidoptera</td>
<td>Scarabaeidae</td>
<td>Cucaracha</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Hymenoptera</td>
<td>Formicidae</td>
<td>Hormiga</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Hemipteros</td>
<td>Cynidae</td>
<td>Chinché</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Araneae</td>
<td>Lycosidae</td>
<td>Araña</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Haplotaxida</td>
<td>Lumbricidae</td>
<td>Lombriz</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Dermaptera</td>
<td>Forficulidae</td>
<td>Tijeras</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Isoptera</td>
<td>Termitidae</td>
<td>comejen</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Diptera</td>
<td>Muscidae</td>
<td>Mosca</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Coleoptera Linnaeus</td>
<td>Bostrichidae</td>
<td>Escarabújo</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Lepidoptera</td>
<td>Noctuidae</td>
<td>Oruga</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Coleópteros</td>
<td>Elateridae</td>
<td>Gusano</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Diptera</td>
<td>Culicidae</td>
<td>Zancudo</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Blattodea</td>
<td>Termítidae</td>
<td>Cochinilla</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>40</td>
</tr>
</tbody>
</table>

During the post-harvest period, 12 families were identified, distributed in 12 orders. The maximum number is 86 individuals of Formicidae and occurred in the post-harvest stage (Table 3).

Table 3. Edaphic macrofauna for the post-harvest period of maize in an area of 0.625 m².

| Shannon and Simpson index. In the development stage, the Shannon index yielded a value of 0.13, while in the post-harvest stage the Shannon index was 0.48. The Simpsons index confirms the faunal richness, showing the same behavior with values of 2.09 during the corn development stage and 7.69 for the post-harvest stage (Figure 3).

Discussion

ME individuals could be influenced by atmospheric and soil temperature, it was observed that the increase in temperature during the post-harvest period is directly related to the number of individuals and
their abundance. Just as the elimination of vegetation can reduce the protection of the soil against climatic variations, causing high insolation, high temperatures, and low humidity, it makes the soil environment of some individuals less favorable for their survival. Humidity can be a limiting factor for plants; however, some species of soil fauna have developed mechanisms to tolerate extreme drought conditions.

Table 3. Edaphic macrofauna for the post-harvest period of maize in an area of 0.625 m²

<table>
<thead>
<tr>
<th>Orders</th>
<th>Families</th>
<th>Common name</th>
<th>N° Individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lepidoptera</td>
<td>Scarabaeidae</td>
<td>Cucaracha</td>
<td>6</td>
</tr>
<tr>
<td>Scolopendrida</td>
<td>Scolopendridae</td>
<td>Ciempies</td>
<td>4</td>
</tr>
<tr>
<td>Hymenoptera</td>
<td>Formicidae</td>
<td>Hormiga</td>
<td>86</td>
</tr>
<tr>
<td>Hemiptera</td>
<td>Cydnidae</td>
<td>Chinché</td>
<td>4</td>
</tr>
<tr>
<td>Araneae</td>
<td>Lycosidae</td>
<td>Araña</td>
<td>5</td>
</tr>
<tr>
<td>Haplotauxida</td>
<td>Lumbricidae</td>
<td>Lombriz</td>
<td>1</td>
</tr>
<tr>
<td>Isoptera</td>
<td>Termitidae</td>
<td>comejen</td>
<td>3</td>
</tr>
<tr>
<td>Lepidoptera</td>
<td>Noctuidae</td>
<td>Oruga</td>
<td>8</td>
</tr>
<tr>
<td>Coleópteros</td>
<td>Elateridae</td>
<td>Gusano</td>
<td>4</td>
</tr>
<tr>
<td>Diptera</td>
<td>Culicidae</td>
<td>Zancudo</td>
<td>1</td>
</tr>
<tr>
<td>Blattodea</td>
<td>Termitidae</td>
<td>Cochinilla</td>
<td>3</td>
</tr>
<tr>
<td>Ortópteros</td>
<td>Grylloidea</td>
<td>Grillo</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>126</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

During the corn development period, a greater abundance of caterpillars could be observed; their presence is intuited because they feed on corn leaves, the presence of earthworms in small quantities in both periods is attributed to the fact that they tend to prevail in humid, non-compacted edaphic environments with high MO content. However, the greatest quantity of earthworms was during the development of corn, the results are related to the development of these plants since earthworms tend to leave deep soils in search of favorable environments.

In the post-harvest stage, the greatest number of individuals, ants, characteristics of the summer season, and the remains of the corn stover, the tillage systems can influence the abundance of predatory groups. Ants are important bioindicators, since they adapt to different disturbance regimes, such as an increase in the number of invasive plants, inhibition of decomposition, and contamination levels, generally due to agrochemicals. The number of families of soil macrofauna in corn crops is similar to that of native vegetation, leaving open the possibility of studying it in neighboring native plots. Ants and termites are classified as "ecosystem engineers," present in low altitude soils. Ants were observed to be prevalent in abundance and resistance in systems that had some level of anthropic intervention. The richness and abundance of the macrofauna were those that coincided in the post-harvest, summer season. The dominant family in most of the land-use systems was Formicidae (ants), land-use change may be one of the greatest threats to soil biodiversity.
When results of lower macrofauna density during the dry season are observed, this does not agree with the results of Jiménez et al.\textsuperscript{47}, however, the existence of a greater presence of the order Araneae (Arachnida) is valid.

Variables such as MO, affect the distribution of the edaphic groups of fauna\textsuperscript{48}, pH values close to 7, the number of individuals may decrease, however, this is in accordance with the type of soil use\textsuperscript{49}. In this study, the pH was between 8.5 and 8.3 for the post-harvest period. Temperature and humidity are factors that regulate the OM\textsuperscript{50-51}, earthworms were associated with OM and pH, and it was found that when OM and pH showed high values, there were more earthworms.

Shannon's index, as well as Simpson's index, indicate a similar behavior indicating the abundance of the EM, with greater abundance being observed in the post-harvest period. In agreement with the study conducted by Reis-Ferreira et al.\textsuperscript{52}, the abundance and total richness in maize soils were generally higher in the dry season. The specific richness of the ME of this site is low, possibly reflecting the state of soil degradation\textsuperscript{53}. The Shannon index usually has higher values in times of maximum rainfall\textsuperscript{54}. MO is important for diversifying soil OM communities\textsuperscript{55}.

The highest abundance was observed during the post-harvest period, when the greatest number of individuals represented by ants, characteristic of dry soils at low altitudes, and was associated with physicochemical parameters. The temperature and the remains of corn stover during the post-harvest period may have influenced the number of individuals (ants). OM and N are characteristic of humid soils where it is affirmed by obtaining high values in the corn development period, unlike the post-harvest period, which yielded low values.

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**Conflicts of interest**

The authors declare that this research does not generate conflicts of interest.

**Acknowledgments**

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**Ethical considerations**

Approval of the research by the Ethics Committee of the Research Institute for Sustainable Development of Ceja de Selva (INDES-CES), National University Toribio Rodriguez de Mendoza of Amazonas (UNTRM).

**Authors' contributions**

_Eli Morales Rojas_, the main author of the project, design, and execution. As well as the accompaniment in the interpretation of the data related to the edaphic
macrofauna, elaboration, and preparation of the research report. **Segundo Chavez Quintana**, the establishment of tests and systematization of the information and revision of the manuscript. **Roxana Hurtado Burga**, has participated in the design of the research, systematization of the information obtained, and preparation of the scientific manuscript. **Manuel Milla Pino**, participated in the research design, systematization of the information obtained, and preparation of the scientific manuscript. **Tito Sanchez Santillan**, participated in the research design, systematization of the information obtained, and preparation of the scientific manuscript. **Erik Martos Collazos Silva**, participated in the research design, systematization of the information obtained, and preparation of the scientific manuscript.

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