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Diversity of Coleoptera in Maize Crops (*Zea mays* L.) and a Secondary Succession Area in Paraíba, Brazil

Angélica da Silva Salustino[1], Maria Ítala Alves de Souza[1], Ana Jéssica Soares Barbosa[1], Josefa Jussara Rêgo Silva[1], Valdemir Ribeiro Cavalcante Silva[1], Fabio Mielezrski[1], Gleidyane Novais Lopes[1] & Carlos Henrrique de Brito[1]

[1] Departamento de Fitotecnia e Ciências Ambientais, Universidade Federal da Paraíba, Campus II, Areia, Paraíba, Brazil

Correspondence: Angélica da Silva Salustino, Departamento de Fitotecnia e Ciências Ambientais, Universidade Federal da Paraíba, Campus II, Areia, Paraíba, Brazil. Tel: 55-83-9815-3945. E-mail: angelicasalustino@gmail.com

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Abstract

This work compares the diversity of beetles (Coleoptera) in areas of maize cultivation with fertilization (NPK) and without fertilization, and a field in secondary succession (capoeira) aiming to understand the relation of these organisms in the different systems. The study was carried out in a farm belonging to EMEPA-PB, in the city of Alagoinha, Paraíba state, Brazil, from July to August 2018. Insects were captured in Provid traps and collected every seven days during the vegetative period of the crop. The screenings were carried out at the Zoology Laboratory of the Universidade Federal da Paraiba and the specimens identified at the family level. Data were analyzed using the ANAFAU program. Ten families of beetles were found: Alleculidae, Cecindelidae, Coccinellidae, Carabidae, Scarabaeidae, Cleridae, Staphylinidae, Erotylidae, Chrysomelidae, and Tenebrionidae. Five families were common in all studied areas except for Staphylinidae that was absent in the fertilized area. Beetle families classified as predatory insects were more abundant in the non-fertilized maize system and secondary succession area, except the Coccinellidae family. The families considered as maize crop pests (Scarabaeidae, Chrysomelidae, and Tenebrionidae) had higher abundance in the fertilized maize system. The Erotylidae family also showed predominance in the non-fertilized area. We conclude that there is a greater diversity of beetle in the non-fertilized maize crop when compared to the other studied areas.

Keywords: faunal survey, biodiversity, arthropods, fertilization

1. Introduction

Maize [*Zea mays* L. (Poaceae)] is one of the most cultivated and consumed cereals worldwide due to its extensive use as human and animal food and for industrial purposes. Brazil is the world second largest exporter of maize, with most production occurring in the southern and center-western regions (CONAB, 2017; Fancelli et al., 2015). In northeastern Brazil, maize also has significant socioeconomic importance, since several small producers depend on this crop and do not have technical management inputs (Cruz & Pereira, 2002).

Maize cultivation requires some nutrients, for example, nitrogen (Nakao et al., 2014), so the management of soil and fertilization are essential for the good development of the crop. There is a great variety of organisms present in the soil which have varied functions and many sizes and metabolic forms (Oliveira et al., 2009). The presence of organisms promotes proper functioning of life cycles in soil, becoming primordial in the development and maintenance of the cultures (Mendes et al., 2009). These organisms protect the organic matter from mineralization caused by the mechanical action in soil, besides favoring the mobility of nutrients (Silva & Salvadori, 2004; Sánchez & Reinés, 2001).

However, the fragmentation of forests to establish productive activities, such as agriculture, mining, and livestock, comprises one a leading factor causing loss of biodiversity (Newbold et al., 2015). Thus, some groups of insects tend to disappear or even to be replaced by opportunistic organisms, causing disturbances in the agricultural systems (Gullan & Cranston, 2008).

The Coleoptera order comprises the largest group of Insecta class, whose representatives are strictly related to the soil (Begha et al., 2018; Triplehorn & Johnson, 2011). The beetles stand out as a vital group from the economic and ecological point of view because some species act as pests, other as natural enemies, pollinators and even decomposers of organic matter (Nichols et al., 2011; Lima et al., 2013; Costa et al., 2014). Some species of beetles are herbivorous, feeding on several crops, thus causing economic damages to the farmers. On the other hand, they may benefit crops by recycling nutrients and contributing to the biological control of weeds and pest insects (Begha et al., 2018; Casari et al., 2012).

Therefore, the investigation of the benefits provided by invertebrates is a fundamental tool for understanding the dynamics of agricultural production. Because insects have many functions in the environment, it is essential to characterize them. Therefore, the knowledge about Coleoptera species affecting local crops is a way of understanding their impact on agriculture and indicating correct management practices for cropping. In this perspective, this survey aimed to characterize the diversity of beetles in areas of fertilized maize crops (NPK) and areas without fertilization, as well as to understand the relation of these organisms in the different systems.

2. Method

The survey was carried out at the State Agricultural Research Company of Paraíba (Empresa Estadual de Pesquisa Agropecuária da Paraíba; EMEPA-PB), in Alagoinha city (06º57′00″ S, 35º32′42″ W; 133 m), in the meso-region of Agreste, Paraiba, Brazil, from July to August 2018. According to Köppen classification, the local climate is As' (Brazil, 1972), characterized as humid with autumn-winter rains (EMBRAPA, 1999). The captures of insects occurred at the end of the rainy season between July and August, with rainfall averaging 26.05 mm and temperatures ranging from 22 to 26 ºC (AESA, 2018).

The experiment was carried out in three areas, being two maize cultivation areas with and without fertilization (NPK addition) and one of secondary succession called capoeira. The maize areas were prepared with mechanical traction (one plowing and two harrowings). The maize cultivar was 'Ipanema'. In both crops, we used a four-row sowing machine with a spacing of 0.80 m × 0.20 m, with a population of 62,500 plants/ha. The fertilization was carried out based on the soil analysis, with the application of 80 kg of nitrogen in the urea form, 60 kg of simple superphosphate, and 40 kg of potassium in the form of potassium chloride. The non-fertilized area received no crop protection after sowing.

Five Provid-type traps were set up in each area. The traps were made with pet bottles (2 L), with dimensions of 4 × 4 cm and height of 15 cm from the base to the holes. In the field, the traps were installed in the central lines of each area spaced at 2.5 meters and buried in the ground so that the edges were at the level of surface facilitating the entrance of insects. Inside each trap, we added a solution composed of 20 ml of 70% alcohol, 30 ml of neutral detergent, 25 ml of water, and five drops of formaldehyde to preserve the captured specimens. The traps were inspected weekly.

The collected material was sent to the laboratory of Invertebrate Zoology in the Biological Sciences Department of the Federal University of Paraíba (UFPB-Campus II), where the triages were carried out, and specimens counted and identified at the family level. Identification was carried out using a stereoscopic microscope and identification keys.

The data were analyzed with the ANAFAU program (Moraes et al., 2003). We calculated the indexes of dominance, abundance, frequency, and constancy.

3. Results and Discussion

The traps collected a total of 263 Coleoptera specimens, with representatives of 10 families from two cropping systems in the maize crop (maize fertilized with NPK and maize without fertilizer sources) and a secondary succession area.

In the fertilized maize crop, 100 individuals were captured, comprising nine families: Alleculidae, Cecindelidae, Coccinellidae, Carabidae, Scarabaeidae, Cleridae, Erotylidae, Chrysomelidae, Tenebrionidae. The predominant families (*) were Scarabaeidae and Tenebrionidae, which had the highest faunal indexes as dominant, very abundant, very frequent, and constant, making up a total of 61% of the identified arthropods (Table 1).

Table 1. Faunal analysis of Coleoptera collected in maize crop fertilized with NPK

Family	Individuals	%	D	A	F	C
Alleculidae	11	11	d	c	f	w
Cecindelidae	7	7	d	c	f	w
Coccinellidae	3	3	nd	d	if	y
Carabidae	3	3	nd	d	if	w
*Scarabaeidae	34	34	d	va	vf	w
Cleridae	1	1	nd	d	if	y
Erotylidae	12	12	d	c	f	w
Chrysomelidae	2	2	nd	d	if	y
*Tenebrionidae	27	27	d	va	vf	w
Total	100	100				

Note. D = Dominance: d = dominant; nd = non-dominant. A = Abundance: va = very abundant; c = common and d = dispersed. F = Frequency: vf = very frequent; f = frequent and if = infrequent. C = Constancy: w = constant; y = accessory. * Predominant Family.

In the area of maize cultivation without fertilization, 120 beetles were collected, comprising ten families: Alleculidae, Cecindelidae, Coccinellidae, Carabidae, Scarabaeidae, Cleridae, Staphylinidae, Erotylidae, Chrysomelidae, Tenebrionidae. Among these, the Scarabaeidae and Erotylidae families were predominant, accounting for 60.9% of the collected insects (Table 2).

Table 2. Faunal analysis of Coleoptera collected in non-fertilized maize crop

Family	Individuals	%	D	A	F	C
Alleculidae	5	4.2	nd	c	f	w
Cecindelidae	16	13.3	d	c	f	w
Coccinellidae	3	2.5	nd	c	f	y
Carabidae	5	4.2	nd	c	f	w
*Scarabaeidae	26	21.7	d	va	vf	w
Cleridae	3	2.5	nd	c	F	y
Staphylinidae	2	1.6	nd	d	if	y
*Erotylidae	47	39.2	d	va	vf	w
Chrysomelidae	2	1.6	nd	d	if	w
Tenebrionidae	11	9.2	d	c	f	w
Total	120	100				

Note. D = Dominance: d = dominant; nd = non-dominant. A = Abundance: va = very abundant; c = common and d = dispersed. F = Frequency: vf = very frequent; f = frequent and if = infrequent. C = Constancy: w = constant; y = accessory. * Predominant Family.

In the second succession area, 43 beetles were collected, consisting of five families: Coccinellidae, Carabidae, Scarabaeidae, Staphylinidae, Tenebrionidae. The Scarabaeidae family was predominant, which accounted for 46.5% of the specimens (Table 3).

Table 3. Analise faunística de coleópteros coletados em área de capoeira

Family	Individuals	%	D	A	F	C
Coccinellidae	2	4.6	nd	d	if	y
Carabidae	4	9.3	nd	c	f	w
*Scarabaeidae	20	46.5	d	va	vf	w
Staphylinidae	7	16.3	d	c	f	w
Tenebrionidae	10	23.3	d	c	f	w
Total	43	100				

Note. D = Dominance: d = dominant; nd = non-dominant. A = Abundance: va = very abundant; c = common and d = dispersed. F = Frequency: vf = very frequent; f = frequent and if = infrequent. C = Constancy: w = constant; y = accessory. * Predominant Family.

The families found in our survey are commonly found in entomological studies on Coleoptera in different environments including agricultural areas.

The Scarabaeidae family (scarabs) was predominant in this study. Some species have tight association with maize crop, among them *Cyclocephala flavipennis*, *Diloboderus abderus*, *Dyscinetus dubius*, *Euetheola humilis*, *Liogenys* sp., *Phyllophaga triticophaga*, and *Stenocrates* sp., whose larvae are pests of great importance since they feed on the root system, causing severe damages to the crop (Rodrigues et al., 2011; Cunha et al., 2007).

The species *Diloboderus abderus* Sturm (Coleoptera: Scarabaeidae) damages wheat crops because its larvae consume the seeds and the root system in a depth that varies between 10 and 30 cm from the ground, weakening or even kill the plants (Valle et al., 2017). Some species of *Liogenys* Guerin-Meneville, 1831 cause damage to soybean and maize crops, occurring in many Brazilian states (Cherman et al., 2011).

However, scarabs are also vital for ecosystems, contributing to nutrient cycling and soil quality. Dung beetles, for example, feed on feces and dead animals. In this way, these insects perform an ecological service by removing excrement and incorporating them in the soil through the excavation of tunnels (Nichols et al., 2008; Almeida & Louzada, 2009; Salomão et al., 2017).

The second most abundant family, Tenebrionidae, comprises common inhabitants of different arid and semi-arid environments around the world (Santos et al., 2002; Bartholomew & Moghrabi, 2018). Larvae and adults are mainly associated with two types of habitat, the soil and trees. In arid regions, they show an important ecological role as detritivores and as a source of food for several vertebrates (Crawford, 1981; Ruiz & Caballero, 2014). Tenebrionids feed on decomposing plant or animal matter, while some larvae inhabit the soil feeding on roots and seeds (Gonçalves, 2017). The *Lagria villosa* species, a Tenebrionidae, is widely distributed in Brazil, mainly in areas of crops, such as maize, beans, and soybean (Macari, 2013).

The second most abundant family in non-fertilized maize was Erotylity, which is a medium-sized family with approximately 3200 species distributed worldwide (Grzynowicz, 2002). Due to its mycophagous habit, larvae and adults feed on fungal bodies and adults are often found in places where these microorganisms are present (Gallo et al., 2002).

In the Chrysomelidae family, most species are herbivorous, feeding on various parts of the plant such as roots, stems, leaves, and fruits. Some species of this family are pests of agricultural importance, while others stand out as potential agents in the biological control of weeds (Jolivet et al., 2002).

Diabrotica speciosa (Germar) (Chrysomelidae), the Cucurbit Beetle, is an economically important pest in several cultures of the Neotropical region, representing quarantine risks in Nearctic and Palearctic areas (Nardi et al., 2012). In Brazil, the number of resources spent to control *D. speciosa* and its economic impact on agriculture are still unknown. However, there is a significant amount of active ingredients applied annually to control this pest, both in adult and larval stages, especially in crops such as maize, beans, and potatoes in the southeastern and southern regions of the country (Ávila et al., 2011).

Many species of Carabidae, Coccinellidae, Cecindelidae, Claridae, and Staphylinidae have great economic importance and deserve studies on pest management. They may be kept in agricultural systems to contribute as biological controls, acting as natural enemies of other arthropods including pests and insect populations (Cividanes et al., 2009; Triplehorn & Johnson, 2011; Rifkind, 2012; Vidotto et al., 2018).

Carabidae and Staphylinidae are predator insects inhabiting soils. Among the prey of Carabidae are ants, aphids, caterpillars, insect eggs, springtails, and mites, while small Staphylinidae species feed on nematodes, mites, and springtails (Ekschmitt et al., 1997). According to Cividanes et al. (2014), some species of Carabidae and Staphylinidae beetles have a high predatory potential on the fourth instar of the velvetbean caterpillar, *Anticarsia gemmatalis* (Hübner), in the laboratory, causing mortality rate greater than or equal to 80%. Some species of Carabidae are notable for their predominance in maize and soybean cultivars such as *Scarites* sp.1, *Abaris basistriata*, *Odontocheila nodicornis*, *Calosoma granulatum*, and *Loxandrus* sp.1, being dominant in agroecosystems (Martins et al., 2013).

There is no information about damages or benefits of the Alleculidae family on maize culture, but they are essential arthropods to maintain the balance of ecosystems.

Comparing the occurrence of Coleoptera in maize cultivations with and without fertilization and the secondary succession area, we verified that the families classified as predatory insects were more abundance in non-fertilized maize and the secondary succession, except the family Coccinellidae that had higher abundance in the areas of fertilized maize and secondary succession. The maize crop pests (Scarabaeidae, Chrysomelidae, Tenebrionidae) showed higher abundance in the maize system with fertilization of NPK and in the capoeira area, except for the Chrysomelidae family, which was absent in the secondary succession area. The Erotylidae family also showed predominance in the non-fertilized area (Figure 1).

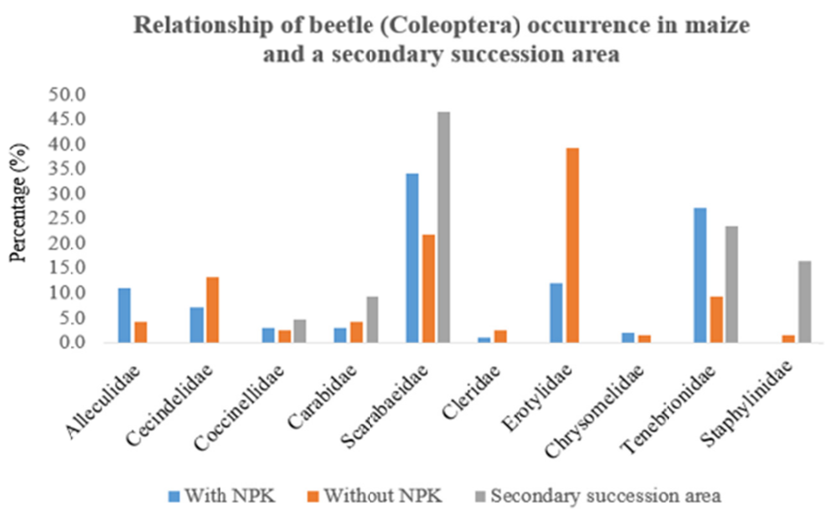

Figure 1. Relationship of beetle (Coleoptera) occurrence in maize crop systems with and without fertilization using NPK and a secondary succession area

According to Martins et al. (2013), no-till cultivation areas with large forest fragments show a greater diversity of Carabidae and Staphylinidae species when compared to areas with conventional preparation of soil. This fact corroborates our results because since both families were more abundant in the cultivation of non-fertilized maize and without crop protection after planting as well as in the area of secondary succession.

The diversity of Coleoptera in the soil may be related to the availability of organic matter and the diversification of plants in the area, which are critical pieces for the maintenance of soil temperature and humidity (Boscardin et al., 2017). The high level of organic matter may explain the diversity of beetles in the area of non-fertilized maize (Silva & Carvalho, 2000; Nunes et al., 2009).

The predominance of Erotylidae in the area of non-fertilized maize may be related to the local moisture since the vegetal cover favored the development of fungi, the primary food source of these insects.

The pest predominance found in fertilized maize may reflect a prediction of the "Trofobiose" theory (Chaboussou, 2006), which states that improperly managed soil fertilization can cause a nutritional imbalance in the plant, making it more or less susceptible to attack by insect pests.

Another hypothesis for the emergence of pests would be the possibility of insects fed with fertilized plants being better nourished and consequently more resistant. According to Roel et al. (2017), pupae resulting from caterpillars fed with chemically fertilized maize leaves are heavier than those with organically fertilized leaves, which reflects in the viability of adults.

On the other hand, some insects associated with green manures and different types of natural coverages can harm crops. Since the fauna of the soil relates to the kind of interaction between invertebrates and microorganisms, the digestion of compounds and manure contributes to the structural formation of the soil (Correia, 2005).

The small number of beetles in the secondary succession area may be related to the deforestation process, which causes reduction of habitats and consequently reduction of species, favoring imbalances in the food chains and increasing the incidence of pests (Salati et al., 2006).

Collection work and inventories of Coleoptera are necessary since research on this subject is still incipient. As a result of environmental changes, agricultural systems need monitoring for proper distribution of beetle species.

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