Scientific Paper

Characterization of the edaphic macrofauna in intensive turfgrass production systems

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ABSTRACT: A study was conducted in order to evaluate the performance of the edaphic macrofauna in areas of the intensive turfgrass production farm, of the Pasture and Forage Research Station Indio Hatuey. Three systems were evaluated, with different exploitation years and three replications per system: S1: soils with ten years or more of intensive exploitation; S2: soils with four years of exploitation; and S3: standard condition or reference soils, on which the plots for intensive turfgrass production will be established. In general, the taxonomic composition of the soil macrofauna was similar in the evaluated systems, and there were differences regarding diversity and equitability of the orders. The most disturbed systems (S1 and S2) were the ones with lower taxonomic diversity, with five taxonomic units (tu), due to the continuous monocrop of turfgrasses; the orders of higher representation in S1 were Coleoptera (38,63 %) and Haplotaxida (31,81 %); in S2, Coleoptera (52,63 %) and Haplotaxida (28,94 %) and in S3 the most outstanding were Haplotaxida (34,48 %) and Lepidoptera (12,93 %). These results show the potential of the edaphic macrofauna as indicator of the soil quality, and its sensitivity to the disturbances caused by the intensity in the soil use and management.

Key words: biota, soil management, turfgrasses

INTRODUCTION

Soil degradation is one of the most serious crises faced by the planet, for which it is necessary to study the changes occurred in the soil at global, regional, national and local scales. The cause of the degradation of this resource is related to the direct or indirect action of man, who breaks the natural balance of agroecosystems, by intervening in them. This occurs through various physical, chemical and biological processes, such as: compaction, erosion, acidification, salinization, lixiviation, run-off, reduction of the cation exchange capacity and of the nutrient availability for the plants and biodiversity decrease (Kumar and Kafle, 2009).

The analysis of soil quality allows to detect the changes that occur in it, especially in the biological part; in addition, it provides the basic aspects to evaluate the sustainability of the system management and has a direct relation to sustainable production. For such reasons, soil quality is the primary indicator of their management and is considered a critical component of sustainable agriculture (Karlen *et al*., 1997). In this context soil quality indicators emerged, which allow to evaluate its status and monitor the stability of agroecosystems, from the characterization of the edaphic macrofauna.

The macrofauna includes invertebrates higher than 2 mm of diameter and has an essential role in soil productivity, due to its capacity to alter the surface and edaphic environment in which plants grow (Lavelle *et al*., 2006). In addition, macroinvertebrates intervene in the processes of infiltration, aeration and organic matter incorporation in the soil (Huerta *et al*., 2008).

For those reasons, the macrofauna is considered a biological indicator sensitive to the impacts of soil use on the edaphic quality (Rousseau *et al*., 2013). The composition of the macrofauna communities, as well as their abundance, is indicator of biodiversity and intensity of biological activities (Velásquez *et al*., 2007).

When the turfgrass management and harvest practices are inadequate, the services it provides to society are reduced. In addition, its impact on natural resources and the environment can be damaging and costly (Strandberg *et al*., 2012), for which it is necessary to evaluate the quality of soils destined for turfgrass production, to propose strategies aimed at the sustainable use and management of this resource.

Taking the above-explained facts into consideration, the objective of this research was to characterize the communities of the edaphic macrofauna in intensive turfgrass production systems.

MATERIALS AND METHODS

Geographic location. The study was conducted in areas of the turfgrass production farm of the Pasture and Forage Research Station Indio Hatuey, located between 22º48'7" North latitude and 81º2' West longitude, at 19,01 m.a.s.l., in the Perico municipality, Matanzas province, Cuba (Academia de Ciencias de Cuba, 1989).

Edaphoclimatic conditions

Soil. The soil where the experimental stage was carried out is classified as lixiviated Ferralitic Red (Hernández *et al*., 1999) and shows plain topography.

Climate. In the last five years, the average annual temperature of the zone was 24,38 ºC. The warmest months were July and August, with temperatures of 26,6 ºC and 26,7 ºC, respectively; and January was the coldest one (20,3 ºC). The average annual relative humidity was 80,6 %, with the highest value in October (86,4 %) and the lowest one in April (72,4 %).

Research scenarios

For the selection of the areas the general characterization of each studied system, which have in common their history in the intensive turfgrass production, was taken into consideration. The selection criterion was the time of exploitation of the soils for the intensive turfgrass production.

Description of the studied areas

System 1 (S1): soils with ten years or more of intensive exploitation for turfgrass production (4 ha). Three plots were studied, destined to sod production from the varieties Bermuda 328 and 419.

System 2 (S2): soils with four years of intensive exploitation for turfgrass production (5 ha). Three plots dedicated to sod production, of the species *Stenothaphrum secundatum, Zoysia matrella* and the hybrid of *Cynodon dactylon* x *C. transvaalensis* (Bermuda grass 419), were evaluated.

System 3 (S3): reference soils, where new plots will be established for intensive turfgrass production. This area (9 ha) was divided into three plots (of 3 ha each) to conduct the study, and was considered of reference because it has not been used for such purpose. Before this study it was a silvopastoral system.

Experimental procedure

Sampling. The macrofauna was sampled between 7:00 and 9:00 a.m., in representative sites of each plot, from transepts whose point of origin and direction was randomly selected. For the study ten monoliths of 25 x 25 x 20 cm were excavated in each area, which were divided into two strata: 0-10 and 10-20 cm; each monolith was separated by an interval of 5 m.

The samplings were conducted in October, at the end of the rainy season of 2011, according to the recommendation made by Lavelle *et al*. (2003), and according to the methodology of the National Research Program "Biology and Fertility of the Tropical Soil" (Anderson and Ingram, 1993; Lavelle *et al*., 2003). The earthworms were preserved in formaldehyde at 4 %, and the other invertebrates, in alcohol at 70 % for their later identification in the laboratory.

The macrofauna was manually separated and counted, and identified to the taxonomic level of order using the keys proposed by Ruiz *et al*. (2008). The average values of density (ind/m^2) and biomass (g/m^2) were determined for the edaphic community, for each taxon and per stratum, in each studied plot. The density was determined with relation to the number of individuals and the biomass, from the humid weight in the preserving solution, with the use of an analytical balance.

Statistical design and analysis

The design was completely randomized, for a total of three replications per treatment. The data of macrofauna density and biomass were analyzed through the InfoStat program, free version. Their fulfillment of the assumptions of variance homogeneity (test of Levene, 1960) and of normal distribution (Shapiro Wilks, 1965) was tested; as they did not fulfill such requisites, non-parametric tests were carried out. In order to determine the variations of the density and biomass of the edaphic macrofauna among the systems, the Kruskal-Wallis test was used.

RESULTS AND DISCUSSION

Taxonomic composition and richness of the soil macrofauna

The communities of the soil macrofauna in the studied areas comprise three Phyla, seven classes and nine orders. Table 1 shows the taxonomic composition.

Table 1. Taxonomic composition and presence of the edaphic macrofauna collected in the studied areas.

Phylum	Class	Order	S1	S2	S3
Arthropoda	Insecta	Coleoptera	x	x	x
		Dermaptera			x
		Lepidoptera	x	x	x
	Arachnida	Araneae	x	x	x
	Chilopoda	Geophilomorpha			x
	Diplopoda	Spirobolida			x
	Malacostraca	Isopoda	x	x	x
Mollusca	Gastropoda	Archeogastropoda			x
Annelida	Oligochaeta	Haplotaxida	x	x	x

A total of 198 individuals were collected, in 90 monoliths (table 2). The most represented orders were Haplotaxida (32,8 %) and Coleoptera (26,2 %), and then Lepidoptera (12,1 %); while the other orders did not exceed 10 %.

The analysis of the taxonomic richness, which included the macrofauna groups with the highest appearance frequency in this study, identified the highest number of orders (9) in the reference system (S3), while in S1 and S2 five were identified for each one. This higher number of orders in S3 is related to the permanence of soil cover, motivated by the litter contribution of the trees, which provides shade and allows the values of soil temperature and humidity to remain stable, benefitting the optimum development of the most diverse communities of the edaphic biota (Cabrera *et al*., 2011a). On the contrary, in the systems under exploitation the soil remains uncovered a great part of the time, which has incidence on the increase of its temperature, as well as on the decrease of humidity. These factors impede the development of the macrofauna communities (Zerbino *et al*., 2008).

In S1 and S2, the taxonomic richness (5) present coincided with the number of orders obtained by Sánchez and Milera (2002) in a pastureland with grass monocrop. However, they were lower than the ones reached by Pashanasi (2001) (23 taxa), and by Cabrera *et al*. (2011b), who found 14 orders in pasturelands and 12 in varied crop systems. The difference regarding the number of orders reported by these authors maybe occurred due to the intensity with which these systems were exploited. According to Decaëns (2010), the low richness values are caused by the fact that the number of species decreases when the land use is intensified.

Likewise, Sánchez and Reyes (2003) obtained up to nine orders of the macrofauna with different

Table 2. Number of collected individuals.

Order	S1	S2	S3	Total
Coleoptera	17	20	15	52
Dermaptera	0	0	13	13
Lepidoptera	6	3	15	24
Araneae	4	3	6	13
Geophilomorpha	0	0	6	6
Spirobolida	0	0	8	8
Isopoda	3	1	12	16
Archeogastropoda	0	0	1	1
Haplotaxida	14	11	40	65
Total/area/year	44	38	116	**198**

livestock management, which coincides with the taxonomic richness found in the reference area (S3), which had input of organic matter –like the pastureland– through the animal excreta. For such reason, it is possible that the coincidence in richness is related to the presence of animals in the system.

Table 3 shows the taxonomic diversity and the percentage of total individuals, according to the depth, in each of the systems.

The highest taxonomic diversity corresponded to the reference area, with nine taxonomic units (tu). In general, the values of the three systems are considered low, which shows the degree of anthropogenic disturbance present in the areas (Ramírez, 2013).

The existence of only 5 tu in systems 1 and 2 indicates that the continuous monocrop of turfgrasses affected the taxonomic diversity of the macrofauna. The scarce diversity of orders present in the area is due to the fact that the intensive use of the soil decreased the communities of organisms, as a consequence of the toxic effect of agrochemicals, the physical destruction of habitats and the reduction of the food and the organic matter of the soil (Ruiz *et al*., 2008).

The effect of depth on the macrofauna composition and the distribution of the collected individuals is evident. In the 0-10 depth there is higher taxonomic diversity and the percentages of collected individuals are also higher. These results coincide with the ones obtained by Crespo and Rodríguez (2000), who state that in the surface layer of the soil a significant quantity of individuals is found and a higher activity of the macrofauna occurs.

Density and biomass

According the Kruskal-Wallis non-parametric statistical analysis ($H = 26,57$, $p < 0,001$), there were highly significant differences among the density of S3 and the other systems; while S1 did not differ from S2 (figure 1). These results show the negative effect of the intensive sod harvest on the communities of the edaphic macrofauna.

The density of the edaphic macrofauna is a sensitive variable to the soil use and management (Cabrera, 2012); the density values determined in S1 and S2 are lower than the ones found by Sánchez (2007), who reported a density of 88,87 ind/m^2 in grazing systems. When the sod is harvested, the soil remains bare part of the time, for which the contribution of the aerial biomass is null and that of the underground biomass, scarce. This had incidence on the fact that the nutrient availability is insufficient for the development of the edaphic macrofauna, and causes the temperature increase and the moisture loss in the soil, which constitute inappropriate conditions for the optimum development of invertebrates (Szanser *et al*., 2011).

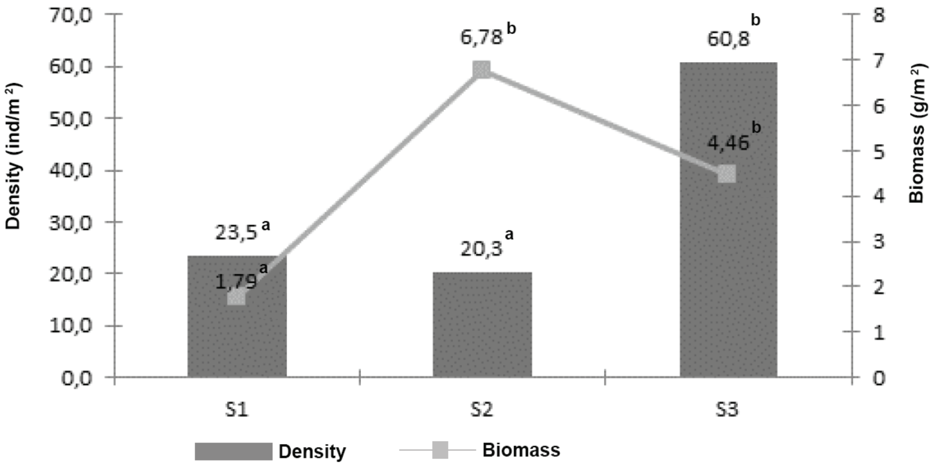
On the other hand, the soil compaction in these systems, due to the entrance of heavy equipment and machinery to the field (for the sod harvest and transportation), can be another factor that affects the macrofauna density and biomass. In this sense, Lok (2005) stated that soil compaction in the pasturelands can reduce the population of edaphic invertebrates.

Nevertheless, S3 had a lower disturbance degree and showed better conditions for the functioning of the edaphic macrofauna communities, because the stratum of a denser population contributes to maintain the soil temperature and moisture values stable and, in turn, contributes litter. These results coincide with those obtained by Zerbino (2008), who reports that density is capable of reflecting the

Table 3. Taxonomic diversity and distribution of total individuals, per depth and per system.

System	Depth (cm)	Taxonomic diversity (tu)		Total individuals		
		Depth	System	Depth	%	System
S1	0-10	5	5	39	88,63	44
	10-20	3		5	11,37	
S2	0-10	5	5	22	57,89	38
	10-20	3		16	42,11	
S3	0-10	8	9	96	82,16	116
	10-20	4		20	17,24	
Total		28	19	198		198

tu: taxonomic units



Different letters indicate significant differences ($p < 0,05$), Kruskal-Wallis)

Figure 1. Average density and biomass of the soil macrofauna, for each of the systems.

differences of vegetation and management of the different soil uses.

Regarding the biomass, according to the Kruskal-Wallis statistical analysis ($H = 11,79$, $p < 0,001$) (figure 1), there were significant differences among the system with more than ten years of exploitation in intensive turfgrass production (S1) and the other systems; while S2 did not differ from S3.

In S2, 6,78 g/m^2 were obtained, similar value to the one reported by Sánchez (2007) in pasturelands: 6,51 g/m^2; and lower than that informed by Cabrera *et al* (2011a): 7,71 g/m^2.

Although the system with four years of intensive turfgrass production (S2) had a density similar to S1, it showed much higher biomass values, because it had a higher time of recovery since the last sod harvest, which had incidence on the fact that the individuals gained more weight. In addition, among the macrofauna orders found, the Coleoptera larvae and the earthworms were the ones with higher biomass weight, and also those of higher number of individuals, for which they had great influence on the total biomass values. These results coincide with the ones obtained by Baretta *et al.* (2010), who found individuals with higher weight in the least disturbed systems.

Figures 2A and 2B show the performance of the density and biomass of the different taxonomic groups of the macrofauna, in the studied areas.

Regarding density (figure 2A), the orders of higher representation were Coleoptera (27,2 ind/m^2) and Haplotaxida (22,4 ind/m^2), in S1; in S2 the performance was similar: Coleoptera (32 ind/m^2) and Haplotaxida (17,6 ind/m^2); while in S3, Haplotaxida (64 ind/m^2) was the most represented order, followed by Lepidoptera (24 ind/m^2).

On the other hand, the orders that made the highest contribution to the total biomass (figure 2B) were Coleoptera (3,22 g/m^2) and Haplotaxida (1,41 g/m^2), in S1; Coleoptera (5,25 g/m^2) and Haplotaxida (0,79 g/m^2), in S2; and Haplotaxida (5,37 g/m^2) and Coleoptera (3,32 g/m^2), in S3. Although the taxonomic classification did not reach the level of family and species, the high biomass values of the order Coleoptera are presumably due to the abundance of *Scarabaeidae larvae*, which coincides with the reports by Cabrera *et al.* (2011a), who state that the larvae of *Scarabaeidae* prevail in sites where a good root system is developed, especially in pasturelands.

In the systems destined to intensive turfgrass production (S1 and S2) the orders present coincided, because of the similarity in the management, for which the colonization was made by individuals of the macrofauna with the capacity to adapt and withstand the alterations to which the edaphic medium is subject.

In general, in the areas destined to intensive turfgrass production, Coleoptera was the most outstanding taxon, with high density and biomass values. These results coincide with the ones obtained by Cabrera *et al.* (2011b), who reported that the individuals of the order Coleoptera stand out for their high values in both indicators.

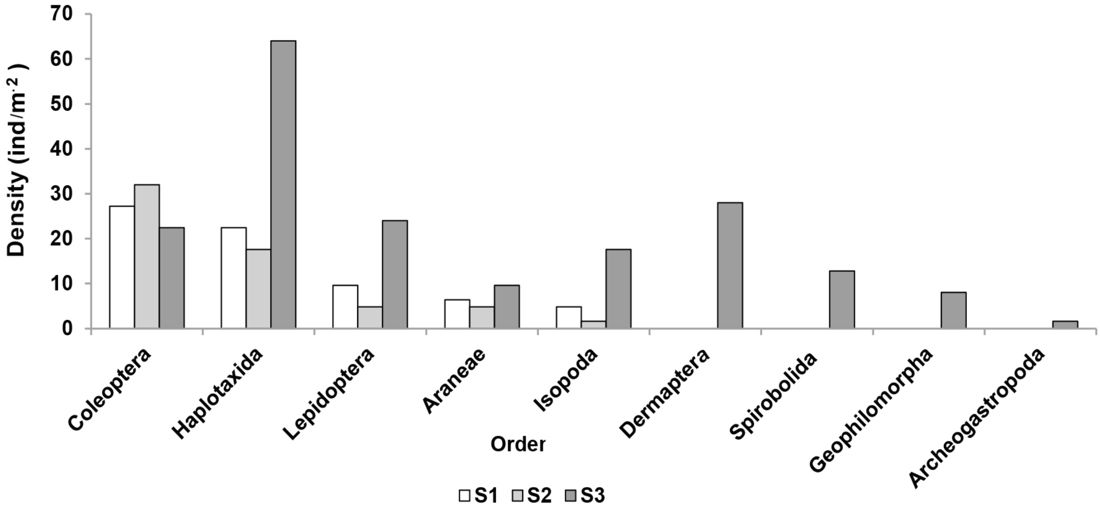


Figure 2A. Average density of the different macrofauna taxa, per system.

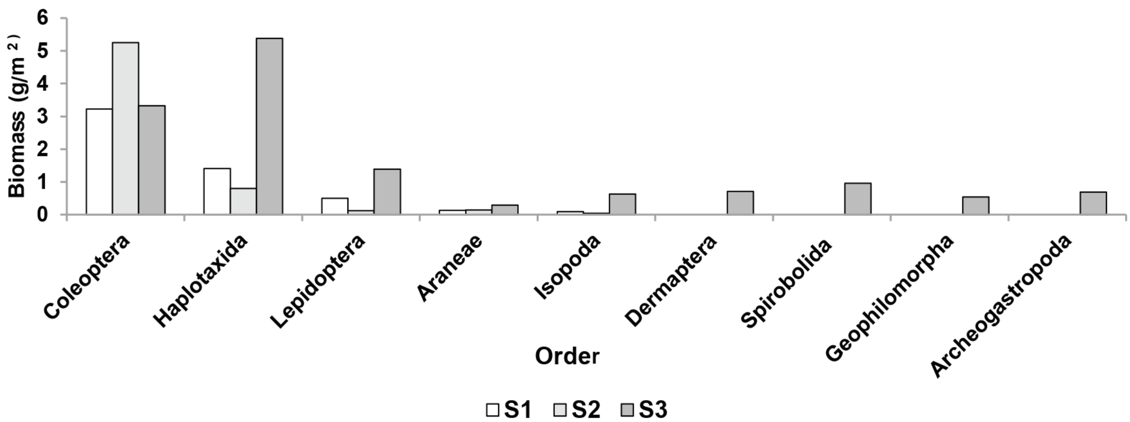


Figure 2B. Average biomass of the different macrofauna taxa, per system

Meanwhile, in the reference area (S3) the order Haplotaxida stood out regarding density and biomass. Feijoo *et al*. (2007) state the importance of the individuals of this order, due to their wide distribution and large size.

The results of density and biomass showed the sensitivity of the edaphic macrofauna communities to soil use and management intensity, in intensive turfgrass production systems.

The density of the edaphic macrofauna did not constitute a sensitive indicator in the systems with a similar floristic composition, although they were managed with different intensity (S1 and S2); however, it was sensitive in the system with a contrast regarding the vegetation diversity (S3).

In general, the study of the edaphic macrofauna reflected the deterioration degree of the soil aimed at the intensive turfgrass production, which is caused, to a large extent, by inadequate management practices and the intensity in soil use and management, for which its potential to be used as an indicator that allows to detect the alterations occurred in the soil, is revealed.

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