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THE ECOLOGICAL ROLE OF SOME FUNCTIONAL GROUPS OF INVERTEBRATES – A REVIEW

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Abstract

It is known that biological diversity is the variability among living organisms from all sources`. It includes diversity within species (genetic diversity), between species (organic diversity) and ecosystems (ecological diversity). Based on scientific literature screening we learned that the link between the functioning of an ecosystem and its biodiversity is a substantial scientific challenge. The present paper highlight that this challenge is more pronounced in soil. Soil is a significant reservoir of biological diversity that supports a wide range of key processes and provides a multitude of ecosystem services. Microorganisms and microfauna (protozoa and nematodes) in the soil are responsible for transforming organic and inorganic compounds into forms that are easily accessible to plants and other organisms through processes such as organic matter decomposition and nutrient cycling. Mesofauna are essential in the food web, increasing the availability of energy and nutrients, especially nitrogen. Soil macrofauna and megafauna are known as ecosystem engineers; they alter soil porosity, water, and gas transport, and bind soil particles, which reduces soil erosion.

Key words*: biodiversity, ecological role of invertebrates, functional groups of invertebrates, soil.*

INTRODUCTION

In recent times, much evidence has accumulated that biodiversity loss has terrible effects on ecosystem services, so important for the entire human society (Wagg et al., 2014). This problem is due to global changes and negatively affects the sustainability of ecosystems and the well-being of people (Bastida et al., 2020). Establishing the link between ecosystem functioning and its biodiversity is a substantial scientific challenge. Nowhere is this challenge greater than in soil. The fundamental processes in the carbon and nitrogen cycles take place in the soil. The precise role of many soil organisms in these cycles is still unknown, although the great diversity and abundance of soil microbial, plant, and animal life appears to influence ecosystem function in various ways (Fitter et al., 2005). Changes in land use (Li et al., 2018), increase in the number and density of invasive plant species (Dawson & Schrama, 2016; Sanderson et al., 2020) influences the diversity and composition of soil invertebrates and nutrient cycling processes so it changes ecosystem functions indirectly (Chen et al., 2007; Zhang et al., 2019), as well as ecosystem services (Spurgeon et al., 2013; Rostás & Hiltpold, 2017).

In addition to changes in land use, climate change is also causing changes in all ecological systems, including the structure and distribution of invertebrate communities. Some studies mention that the soil cannot self-regulate its characteristics when in the food network are links impacted by rising temperatures, loss of moisture, pollution, etc. Due to the changes in the dynamics of the invertebrate community, some functional features of plants also change. Due to the accelerated growth of soil degradation in recent years, it was necessary to identify methods that determine not only the quality of the soil, but in a holistic manner, its health (Lemanceau et al., 2015; Menta & Remelli, 2020). Soil is among the most heterogeneous systems on the planet. It plays a role that cannot be replaced in the biosphere (plant productivity, organic matter degradation and nutrient cycling) (Santorufo et al., 2012). Soil quality is the ability to support agricultural crops and animal productivity, maintain and improve environmental sustainability and human health worldwide (Domínguez et al., 2018; Yang et al., 2020). Inside the soil, plants, invertebrates and microorganisms evolved and developed very complex and intimate interactions that confer high fertility and high soil resilience, changes soil properties and resource availability for other bodies (Wardle et al., 2004; Lavelle et al., 2006).

Soil fertility is its ability to provide nutrients (including water) to plants (Culliney, 2013), taking into account their ecological requirements (Boháč, 1990). A fertile soil can be defined either on the basis of its properties or on the basis of plant production and productivity. Fertility is determined by physical factors (texture, structure, profile depth, water retention capacity, drainage capacity), chemical (pH, the number of essential elements available for plants, the ion exchange capacity, organic and mineral matter content) and biological (soil organisms, dominance-abundance ratio, inter and intraspecific relationships) (Chiriac et al., 2020).

Soil invertebrates can be defined as the totality of ontogenetic stages of organisms that live permanently or temporarily in the soil or on its surface (Manu & Honciuc, 2010c; Manu et al., 2020). Understanding and studying all species of soil biota would require a lot of human, time and financial resources, that is why there is currently a tendency to focus on functional groups of soil organisms that have diverse roles in ecosystems (Walter & Proctor, 1999; Lupardus et al., 2021). These are groups of functionally similar species. The most popular term for such a group is guild. Plant and invertebrates species form functional groups according to their features (Zoeller et al., 2020). The purpose of this literature review was to identify the main ecological roles of functional groups of invertebrates in the soil.

MATERIALS AND METHODS

The method of making this literature review included several stages. First, the stage of establishing keywords according to the topic of interest. Then these keywords were used for querying databases with free access. Depending on the results obtained, the articles that matched the subject were critically analysed and entered into an Excel database. With the help of this database, this analysis of literature was carried out.

RESULTS AND DISCUSSIONS

Soil invertebrates are of great importance in the quality of the soil and given their size, they can be divided into microfauna (e.g. nematode), mesofauna (does not have the size large enough to change the structure of the soil: Mites, Collembola, Enchytraeids, Diplopoda) and macrofauna (change the structure of the soil due to their movements: Isopods, Earthworms, Diptera, Coleoptera). The advantage of the study of these species is that they benefit from great diversity, appear in large numbers, are easily sampled every season (Stork and Eggleton, 1992; Behan-Pelletier, 1999; Manu et al., 2015). Soil invertebrates have several functions in the habitat in which they develop. First of all, they have two roles in the food network: they shred and moisten the ingested plant debris, thus improving the substrate for bacterial activity and for “engineers” of ecosystems (organisms that physically change habitat by modifying the availability of resources for other species) (Culliney, 2013). It directly and indirectly participates in the process of decomposition of organic matter and in the genesis of the soil by modifying its characteristics (porosity, aeration, fertility, infiltration) and are involved in the nutrient cycle (Manu et al., 2019). Directly, the edaphic fauna participates through the consumption of organic matter and through predatorism. Indirectly, the soil fauna participates in the breakdown of plant and animal tissues (Isopods, Myriapods, Termites, Oribatides), preparing the ground for microbial decomposition; passive transport of bacteria, fungi and protozoa in the digestive tract or on their bodies, changing the chemical structure of organic matter, transforming plant residues into humic substances (Manu et al., 2018; Cifuentes-Croquevielle et al., 2020), increase of the available surface for the action of bacteria and fungi; selective consumption of microflora, preventing the aging of microorganism populations, the formation of complex organic matter aggregates, mixing of organic matter, transport to the upper layers of the soil. The roles of soil fauna in the nutrient circuit are multiple: it has a synergistic effect on carbon mineralization, it causes an increase in the rate of release of nutrients, the presence of predators stimulates decomposition activity (Manu et al., 2019). They also play an important role in storing carbon, energy flow, infiltration and storage of water and oxygen in the soil (Kumar et al., 2020). The processes of decomposition and recycling of nutrients are accelerated by the action of invertebrates, either directly (in relation to the structure and activity of populations) or indirectly (by the excretion of nutrients in the soil solution), thus causing an increase in the supply of nutrients available to plants by taking root (Stork & Eggleton, 1992; Chiriac et al., 2020; Stone et al., 2020). Soil fauna plays a key role in changing the physical and chemical composition and accessibility of organic matter (Bray & Wickings, 2019). In addition, they are used as a soil quality indicator (Lavelle et al., 2006; Menta, 2012; Fiera et al., 2020). These are individuals or communities that alter their vital functions and chemical composition in response to certain forms of environmental impact, thus making it possible to draw conclusions on the state of the environment (Onete et al., 2010). Soil invertebrates are excellent candidates for studying the impact of human activity on the environment (Santorufo et al., 2012; Gedoz et al., 2021), especially because they are in direct contact with soil pores and water (Aescht & Foissner, 1996; Dahiya et al., 2022). Most invertebrate groups are sensitive to environmental changes. They respond to soil management and are influenced by environmental characteristics: habitats of refuge, breeding or feeding. For this reason, they function as an environmental quality monitoring tool (Paoletti et al., 2009; Manu et al., 2019; Manu et al., 2020). Some soil invertebrates can be used as indirect indicators (for the entire soil community), as well as direct indicators (for providing services for soil ecosystems) (Domínguez et al., 2018). They provide information on environmental quality that can be included in monitoring programmes (Santorufo et al., 2012; Manu et al., 2022). For example, soil nematodes are sensitive to various changes (management of agricultural areas), so they can be used as ecological indicators (Niu et al., 2023). Also, invertebrates in the soil have the function of regulating the processes that take place in the rhizosphere area and significantly affect the growth of plants (Neagoe et al., 2013).

Depending on the role that invertebrates have, they can be: microbivores (Nematoda, Collembola, Mites), phytophagic (Nematoda, Collembola, Mites, Coleoptera, Aphids, Lepidoptera, Mollusca) and omnivores (Nematoda, Collembola, Mites, Arachnids), predators (Nematoda, Formicidae, Arachnida, Mites, Chilipoda, Coleoptera), decomposers (Coleoptera, Arachnids, Nematodes, Mollusca, Lumbricides, Isopods, Enchytreids, Diptera, Collembola, Diplopods, mites, etc.) (Neher & Barbercheck, 1998).

Collembola play an important role in decomposition processes. Larger species accelerate the mineralization process, while smaller species help humidify the soil (Stork & Eggleton, 1992). Some species have been identified in agroecosystems where they accelerate decomposition, influence microbial activity and nutrient cycling. Phytophagous species influence the distribution of mobile metals (e.g., potassium), and the detritivores species accelerate the rate of mineralization of the less mobile elements (e.g., phosphorus and calcium) (Mulder, 2006; Fiera et al., 2020). Collembola is among the most abundant arthropods in the soil, it plays several roles, the most important of which is in the shredding of litter in forest areas, it accelerates the litter decomposition process, making it more accessible to bacteria and fungi and it prefers humidity (Kaczmarek, 1977). A small number of collembolas stimulate the growth of bacterial activity, but if they multiply excessively, they affect fungal populations and thus can reduce the process of soil humidification (Stork & Eggleton, 1992; Baird et al., 2019).

The role of earthworms in agricultural ecosystems is highly recognized (McTavish & Murphy, 2020). The soils in which they are present have pores with high volume, higher water and nutrient retention capacity (Stork & Eggleton, 1992). Earthworms have been shown to be important "engineers" of the soil (Spurgeon et al., 2013). Basically, this means the ability of organisms to build organomineral structures with certain physical, chemical and microbiological properties through their movements (Jouquet et al., 2006). They may intentionally or accidentally ingest seeds while moving through the soil (McTavish & Murphy, 2020). Thus, they have an important role in the processes taking place in the soil, establishing its quality, influencing the decomposition of organic matter, the cycling of nutrients and soil structure and are key species in trophic networks (Ezeokoli et al., 2021).

Nematodes are the most abundant organisms. Like other invertebrates, they provide numerous ecosystem services and maintain the stability of food networks by ensuring nutrient cycling (Neher, 2001; Zhang et al., 2020). Nematodes are heterotrophs, primary consumers (plant parasites), secondary consumers (predators), and consumers of decomposers (Wasilewska, 1997; Bonkowski et al., 2009). The decomposition process is 90% carried out by microorganisms such as bacteria and fungi. It is facilitated by soil fauna (mites, millipedes, earthworms and termites). The nutrient cycle is closely related to the decomposition of organic matter. Protozoa and nematodes are the ones that establish the rhythm in which soil processes take place. Nutrient cycling is important for water quality (Semprucci & Balsamo, 2012). Nematodes are biological components of several functional groups of the soil trophic network and can be used as an indicator of ecological processes (nutrient cycling and soil protection against invasive pests or species) (Sánchez-Moreno and Talavera, 2013). The main function of bacteria in the food network is to improve the mineralization of nutrients immobilized in organisms by contributing more than 80% to nitrogen mineralization (Ferris et al., 2004). Bacterial nematodes are the first group of invertebrates to react to environmental changes; for example, the introduction of a quantity of nitrogen can change this group structure within 24 hours (Wasilewska, 1997). The increase in the number of fungivores provides information about an increase in soil acidity caused either by excessive use of mineral fertilizers or acid rain. For this reason, nematodes are considered a group of indicators that can highlight changes that occur in soil characteristics. Predatory nematodes represent the highest trophic level in the soil microfauna. The potential to use this group that the bioindicator is reduced due to the small number of individuals, especially in agricultural land. The increase in the abundance of predatory nematodes may be an indicator of an unimpacted environment (Wasilewska, 1997; Scheu, 2002).

Mites are a globally diverse group of arthropods that includes more than 40,000 registered species. They are part of several functional groups (decomposers, herbivores, predators or parasites) (Manu & Honciuc, 2010; Huguier et al., 2014). Species living in soil depend on its structure and composition (Stănescu & Gwiazdowicz, 2004; Sanda et al., 2006; 2006a). They have a great capacity for adaptation and occupy a wide variety of habitats, including rock. In these habitats they have a key role in soil formation processes (Manu, 2011). The trophic adaptability of mite species varies greatly from omnivores (especially those living in soil) to parasitic, highly specialized species, who live and feed on a particular host (Constantinescu et al., 2011). Mites play an important role in the micro and macro-elements circuit known for the development of primary producers. The role of mites is very important in the realization of sol-litter interface relations (Călugăr & Huțu, 1999; Manu, 2008a). They also participate in soil processes (Honciuc & Stănescu, 2000; Stănescu & Honciuc, 2004; Manu et al., 2018a): humidification, mineralization, nutrient circuit, thus influencing soil fertility and productivity (Călugăr, 2009; Manu et al., 2018b). The productivity of ecosystems depends largely on the conjugated action of microbiota and mites, which participate alongside abiotic factors in the organic matter circuit, by accelerating the process of biodegradation and decomposition of organic products (Stănescu & Honciuc, 2004; Călugăr & Huțu, 2008; Manu, 2013). Edaphic fauna in relation to soil microorganisms actively participates in the processes of degradation of vegetable biomass (Călugăr, 2019). Due to their small (microscopic) dimensions, they are often neglected, although they are very important in the decomposition of organic matter (Manu & Honciuc, 2010a; Manu, 2011). It contributes to the improvement of some soil characteristics and plays key roles in many processes that enhance the success of ecological restoration (Manu et al., 2018).

Oribatids are associated with organic matter in most terrestrial ecosystems and are the most numerically dominant of the organic horizons of most soils. Oribatids is actively involved in the decomposition of organic matter, the nutrient cycle and the formation of soil (Liu et al., 2023). All the active stages of these mites feed on a wide variety of materials, including live and dead plants, fungi, mosses, lichens. Oribatids influences the decomposition and structure of the soil through their fecal granules provide a large area for decomposition and are, in turn, an integral component of the soil structure in organic horizons. The oribatids disperse bacteria and fungi, both externally on the surface of their bodies or feeding on spores that survive passing through their digestive tract. Many species trap calcium and other minerals in their thickened cuticle. Thus, their bodies can form reservoirs important for nutrients, especially in limited nutrient environments (Behan-Pelletier, 1999).

CONCLUSIONS

In conclusion, invertebrates in soil influence decomposition processes, mineralization of nutrients and plant growth and interact with microbiota elements (for example: mutualistic relationships with soil mycorrhiza). The underground communities regulate plant growth which in turn regulates the quantity and quality of resources available for soil biota. At the ecosystem level, soil invertebrates perform a wide range of functions that contribute to ecosystem health by maintaining the nutrient cycle, water storage and primary productivity. Plant characteristics are strongly influenced by interactions with aboveground/epigean and belowground organisms. Plant responses can alter trophic interactions between aboveground and soil species.

Soil species interact in different ways with their environment. Foraging interactions are among the most important relationships among organisms, as diet is an essential trait and its quality and distribution shape the structure of soil food webs (Kumar et al., 2020).

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