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Feeding habits of Collembola and their ecological niche

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Resumen. Se realizó este estudio para detectar si cambian los hábitos alimenticios de los colémbolos, dependiendo del nicho ecológico que ocupan en determinados ecosistemas. Así, se presentan los resultados y la comparación de las observaciones realizadas en la dieta de Collembola en tres ecosistemas diferentes: 1) un bosque tropical lluvioso, en Veracruz; 2) dos campos de cultivo en Hidalgo, y 3) organismos asociados a la epífita *Tillandsia violacea* en un bosque templado, también en Hidalgo. Se encontró que existe una estrecha asociación entre varias especies de hongos y los colémbolos en las selvas tropicales. En los ejemplares procedentes de suelos cultivados se encontró presencia de material vegetal y conidias de hongos. Existe una gran diversidad de hábitos alimenticios en las especies asociadas a plantas epífitas. Se encontraron restos de algas, diatomeas y bacterias en los contenidos alimenticios de colémbolos. No obstante, durante la temporada de sequía, en el contenido estomacal de *Ptenothrix marmorata* se encontraron fragmentos de ácaros Prostigmata y Astigmata (Acaridae). En *Seira purpurea* (tanto en la temporada de lluvias como en la de secas), se encontraron fragmentos de exuvias de colémbolos, y también algunos nemátodos parásitos. La presencia de ácaros en el contenido alimenticio de Collembola provenientes de bromeliáceas epífitas puede deberse a que, durante la temporada de sequía, las poblaciones de Astigmata y Prostigmata son enormes (más de 5 000 ind. m^{-2}) y pueden servir de presa a los colémbolos. Es probable que la ingestión de estos organismos por parte de los colémbolos sea accidental, o bien que cuando cambian las condiciones de su nicho ecológico, también se vean forzados a diversificar su dieta.

Palabras clave: Collembola, contenido estomacal, epífitas, basidiocarpos, hongos, suelos agrícolas.

Abstract. This work was conducted to detect changes in feeding habits of spring-

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tails, related to their ecological niche in the ecosystem. We present the results and compare our observations on the diet of Collembola, in three different ecosystems: 1) one tropical rain forest in Veracruz, 2) two cultivated fields in Hidalgo, and 3) the epiphytic plant *Tillandsia violacea* from a temperate forest, also in Hidalgo. There is a close association of some species with several mushrooms in the tropical rain forest. Specimens from cultivated fields have vegetable matter and fungal conidia in their gut contents. There is a distinct type of feeding in the species associated to epiphytic plants. In the latter, the debris of algae, diatoms and bacteria were found. During the dry season, there were fragments of Prostigmata and Astigmata (Acaridae) mites in the gut of *Ptenothrix marmorata*. In *Seira purpurea* (both in the rain and dry seasons), there were fragments of exuvia of springtails, and also some parasitic nematodes. The presence of mites in the digestive tract of Collembola from the epiphytic bromeliads could probably by explained by the fact that during the dry season, the populations of Astigmata and Prostigmata are enormous (more than 5 000 ind. m^{-2}) and probably constitute prey for the springtails. It is also probable that their ingestion is accidental, or even that they are forced to diversify their diet when the conditions of the ecological niche change.

Key words. Collembola, gut contents, epiphytes, basidiocarps, fungi, agricultural soil.

Introduction

Collembola represent one of the most abundant groups in soils, where they play an important ecological role. One of their main contributions to the soils is the regulation of fungal populations (Warnock *et al.* 1982), affecting their dispersion, and also that of bacteria, to colonize new substrata (Visser *et al.* 1981). They also help in establishing relationships with mycorhizae (Gange 2000).

Due to the remarkable affinity of springtails with edaphic habitats, they can be found in a great variety of ecological habitats and can be associated with several organisms such as fungi and epiphytic plants (Palacios-Vargas & Gómez-Anaya 1994, Palacios-Vargas & Castaño-Meneses 2002). In natural environments, Collembola feed on a great variety of resources, such as fungi, bacteria, mosses, pollen grains, spores, decaying plants and debris (McMillan & Healey 1971, Vegter 1983, Sadaka-Laulan *et al.* 1998); nevertheless we have little knowledge about the ecology of most species (Rusek 1998). Some authors have studied the food preferences, finding that they can vary depending on the season and on the vertical distribution of the springtail species (Saur & Ponge 1988).

Another factor which has been considered to have a high influence on the food preference is the microhabitat where they are living; but there are cases where the species share the microhabitat, but differ in the food they take (Ponge 1991). So, it has been observed that in soil and litter there is preference for fungal spores and mycelia, bacteria and fecal pellets (Rosello *et al*. 1986), while the species which climb trees or always live in the canopy, ingest pollen grains and spores more often (Christiansen 1964).

The main purpose of this contribution is to study the gut contents of different species of Collembola, to know their food preferences. Specimens are from three different habitats, fruiting bodies of fungi, epiphytic plants (*Tillandsia violacea*), and cultivated soils. The results are compared to know the differences among them.

Materials and methods

Specimens of Collembola were taken from the alcohol and slide collections in our laboratory. The specimens came from different biotopes: fungal fruiting bodies (collected during different expeditions to the Los Tuxtlas Biological Station, Veracruz, made before 1995); epiphytic bromeliads *Tillandsia viol*acea (collected during the rainy season in September 1998, and in the dry season in April 1999 at “El Chico” National Park, Hidalgo), and cultivated soils (sampled every two months, from December 1998 to October 1999 from San Salvador, Hidalgo). Specimens were mounted in Hoyer’s solution (Krantz 1975) to identify them and observe gut contents under phase contrast light microscopy. Basidiocarps and conidia were identified by specialists.

Results

About 1700 microslides were examined; in most of the cases we found gut contents.

In Los Tuxtlas 43 species of Collembola have been recorded, seven of them associated to basidiocarps of *Amanita* sp., *Boletus* sp. and *Polyporus* sp. (Table 1).

In the epiphytic *Tillandsia violacea* 25 species of Collembola were found in both seasons (Table 1). We were able to identify material in the gut of only four species. Remains of plant material at different degrees of decomposition, and also fungal spores were found in most of the specimens. During drought, fragments of Astigmata mites were observed in the gut of *Ptenothrix marmorata* and *Seira purpurea* (Fig. 1), and in the latter some exuvia of Collembola and parasitic nematodes were also observed (Figs. 2-3).

Thirty one species of Collembola were recorded in agricultural soils; the most abundant were *Proisotoma minuta*, *Cryptophygus thermophilus*, *C. benhami* and *Entomobrya triangularis*; in which we were able to identify gut contents, mainly conidia of *Alternaria* sp., and mitosporic fungi. We detected gut contents in other species, but we could not identify them (Table 1, Fig. 4).

Table 1. Gut content of Collembola from three biotopes

Species	Biotope	Gut content
Hypogastrura essa	AS	Vegetable matter, mitosporic conidians
Ceratophysella gibbosa	BA	Not identified
Xenylla grisea	AS	Vegetable matter, fungal spores
X. christianseni	BA	Not identified
X. welchi	BA	Not identified
Microgastrura minutisima	BP	Not identified
Superodontella cornifer	BB, BP	Not identified
S. cf. Shasta	BA	Not identified
Brachystomella arida	BP	Not identified
Mesaphorura yosii	AS	Vegetable matter, fungal spores
Proisotoma minuta	AS	Vegetable matter, *Alternaria* sp. and mitosporic conidia
Ballistura laticauda	AS	Vegetable matter, mitosporic conidia
Cryptopygus thermophilus	AS	Vegetable matter, *Alternaria* sp. and mitosporic conidia
Cryptopygus benhami	AS	Vegetable matter, *Alternaria* sp. and mitosporic conidia
Isotomurus bimus	AS	Vegetable matter, *Alternaria* sp. and Mitosporic conidia
Entomobrya ligata	AS	Vegetable matter, *Alternaria* sp. and mitosporic conidia
E. triangularis	AS	Vegetable matter, *Alternaria* sp. and mitosporic conidia
Pseudosinella octopunctata	E	Mitosporic conidia
Seira purpurea	E	Nematode and mites exuvia
Sphaeridia sp.	E	Vegetable matter, fungal spores
Ptenothrix marmorata	E	Vegetable matter, astigmatid mite

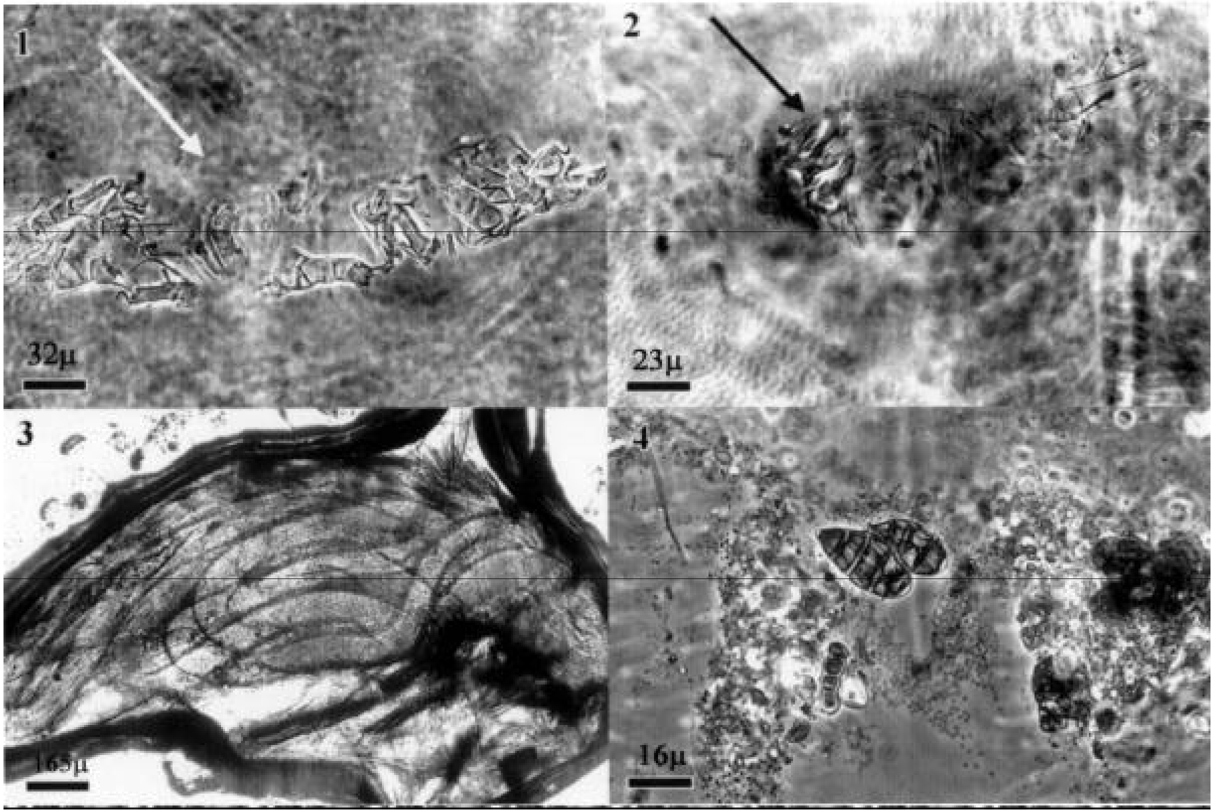
AS= Agricultural soil; BA= Basidiocarps of *Amanita* sp.; BB= Basidiocarps of *Boletus* sp.; BP= Basidiocarps of *Polyporus* sp.; E= Epiphytic plants

Among the studied species, in which we were able to identify the gut contents, in 52% of them there was recognizable plant organic matter; in 39% there were fungal conidia and spores, and only in 9% animal remains were found, mainly mites and springtails (Fig. 5).

Discussion

The highest diversity of feeding habits was found in the agricultural soil species. The most abundant species was *Crytophygus thermophilus*, which seems to be versatile in its feeding habits; it has been collected in litter, decomposing trunks, debris and beach sand; the gut had organic matter and conidia of *Alternaria* sp. and mitosporic fungi.

In species associated with *Tillandsia violacea*, a variety of alimentary habits was also found, and it is remarkable that we found animal remains in their guts and presence of parasitic nematodes. *Seira purpurea* was the species in which animal



Figs. 1-4: 1, remains of Acaridae (Astigmata) mites from the gut of *Seira purpurea* collected in *Tillandsia violacea* at "El Chico" National Park, Hidalgo, Mexico; 2, exuvia of springtail in the gut of *S. purpurea* collected in *T. violacea* at "El Chico" National Park, Hidalgo, Mexico; 3, nematodes in *S. purpurea* collected in *T. violacea* at "El Chico" National Park, Hidalgo, Mexico; 4, conidia of *Alternaria* sp. in the gut of *Proisotoma minuta* from agricultural soils in San Salvador, Hidalgo, Mexico.

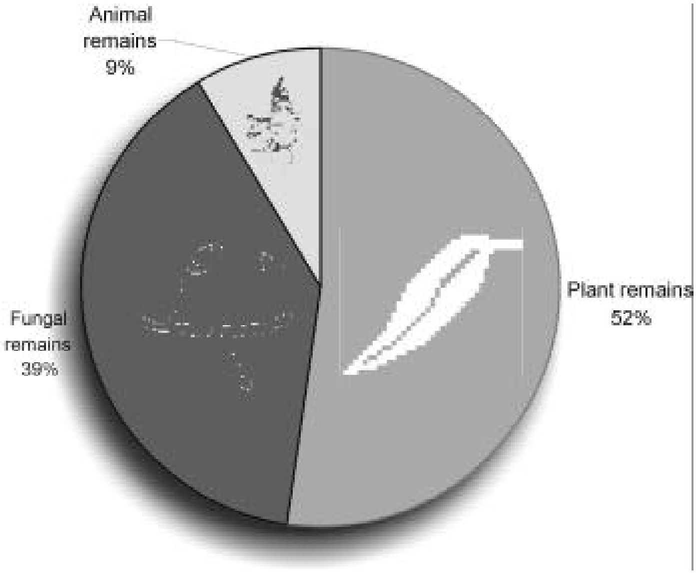


Fig. 5. Relative abundance of different gut contents in Collembola species from three biotopes.

remains were more often found. This is of interest because, even if it is not an abundant species in the epiphytic plants, reaching only 2% of the total abundance in the rainy seasons (Palacios-Vargas & Castaño-Meneses 2003), its abundance increased during the dry season, reaching 8% of the total number of springtails; this species also showed variation in dietary components.

We were not able to identify any material in the gut of the species collected from basidiocarps. This is related to their mouth parts, as in both species, *Superodontella cornifer* and *Microgastrura minutisima*, the mandibles are needle-like (Vázquez & Palacios-Vargas 1996), which indicates that they feed by sucking liquids from fungal tissues (Palacios-Vargas & Gómez-Anaya 1994); Greenslade *et al.* (2002) suggested that Collembola can feed on fungal hyphae only if they have a molar plate, like hypogastrurids, but we could not recognize this material in their guts. Differences in mouthparts in coexisting springtails can reduce competitive pressures, because they can use different resources (Vegter 1983; Chen *et al*. 1997).

More than 57% of the species (4 species) associated with fungal fruiting bodies belong to the Hypogastruridae; remaining are Odentellidae (two species) and Isotomidae (one species). Studies carried out in Australia show that native Brachistomellidae are dominant in fungal fruiting bodies, and the introduced hypogastrurids are second in abundance (Greenslade *et al*. 2002).

Collembola are considered unspecialized feeders of fungal hyphae and spores, bacteria, decaying plant debris, pollen and mineral particles, but depending on their habitat, they can use one or many resources, including change to predation, if conditions are propitious.

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