CAPÍTULO 11

INFLUENCE OF PLANT RESIDUES AND BIOFERTILIZER ON THE POPULATION DYNAMICS OF COLLEMBOLA IN SOIL MICROCOSMS

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ABSTRACT: Biofertilizers are increasingly used as sustainable alternatives to improve soil fertility, yet their effects on soil mesofauna remain poorly understood. This study evaluated the response of collembolan populations to different biofertilizer application rates under controlled laboratory conditions. Soil microcosms were established using clayey soil collected from the 0–10 cm layer of a Rhodic Ferralsol (WRB). Five biofertilizer doses (0, 150, 300, 450, and 600 L ha^{-1}) were tested, and collembolan abundance was assessed in two sampling experiments (different years). The results showed that biofertilizer application significantly influenced collembolan populations. The highest abundance was observed at the intermediate dose of 450 L ha^{-1}, suggesting that moderate inputs of organic matter may stimulate soil biological activity by increasing microbial biomass, an important food resource for these organisms. In contrast, the highest dose (600 L ha^{-1}) resulted in lower abundance compared to the intermediate level, indicating a non-linear response to increasing organic inputs. Overall, the findings demonstrate that collembolan populations are sensitive to biofertilizer application rates and highlight their potential as indicators of changes in soil biological quality. Balanced management of organic inputs may therefore enhance soil biological activity and support key ecological processes in agroecosystems.

KEYWORDS: Biofertilizer; Soil mesofauna; Collembola; Soil biological indicators; Organic inputs; Soil microcosms.

INTRODUCTION

Soil fauna plays a fundamental role in maintaining soil quality and regulating ecological processes associated with organic matter decomposition, nutrient cycling, and soil structuring. Among the organisms that make up this community, collembolans represent one of the most abundant groups of soil mesofauna and are recognized as important bioindicators of environmental quality (Gruss et al., 2024; Potapov et al., 2020). These organisms are widely distributed across terrestrial ecosystems and can reach high population densities, playing a relevant role in the biological dynamics of the soil.

These organisms actively participate in the fragmentation of organic matter and in the control of soil microbiota, mainly acting in the regulation of fungal and bacterial populations. In this way, their activity directly influences processes related to the decomposition of plant residues and the dynamics of soil organic matter (Kold et al., 2018; Potapov et al., 2020). In addition, collembolans show high sensitivity to changes in the physical, chemical, and biological conditions of the soil, which reinforces their use as indicator organisms in studies on soil management and the sustainability of agricultural systems (Zhang et al., 2025).

The addition of organic residues to the soil can significantly modify the structure of edaphic communities. Plant residues from agricultural crops and animal-derived biofertilizers constitute important sources of carbon and nutrients for soil organisms and may stimulate population growth of several groups of soil fauna (Zhang et al., 2025). However, the magnitude of this response depends on the type of residue, the quality of the organic material, and the environmental conditions under which these materials are incorporated.

In this context, experiments conducted in microcosms have been widely used to evaluate the response of soil organisms to different sources of organic matter. These experimental systems allow greater control of environmental conditions and enable a detailed evaluation of the interactions between organic residues, microorganisms, and soil fauna organisms.

Therefore, the objective of this study was to evaluate the effect of the application of biofertilizer doses on the population dynamics of collembolans in soil microcosms.

MATERIALS AND METHODS

The study consisted of the development of two distinct experiments conducted in the Microbiology and Soil Biology Laboratory at the Federal University of Santa Maria (UFSM), Frederico Westphalen campus, RS, Brazil.

The experiment was conducted under laboratory conditions using soil collected from the 0–10 cm layer of a Red Latosol (Rhodic Ferralsol, WRB) with a clayey texture, originating from an area previously cultivated with annual crops under conventional tillage. Soil samples were collected using a corer 10 cm in diameter and 10 cm in depth. After collection, the soil was sieved through a 2-mm mesh, homogenized, and dried in an oven at 60 °C.

The microcosms used for the multiplication of collembolans consisted of cylindrical, transparent polyethylene containers, 16 cm in diameter and 8 cm in height. In each container, 600 g of soil were added, occupying approximately two-thirds of the total volume, ensuring saturation of the macropores. For the experiment involving biofertilizer doses, 3 g of dried, ground black oat straw were added as a source of organic material.

After assembling the microcosms, the soil was brought to a saturation level above field capacity, following the methodology described by Edwards (1995). For this, 300 mL of distilled water were added to each container. The containers were then closed and perforated, with cotton fabric inserted to allow oxygen entry and gas exchange with the environment. The microcosms were maintained in a climate-controlled chamber at 26 ± 1 °C with a 12-hour photoperiod.

Treatments that received biological yeast in combination with biofertilizer doses were supplemented twice a week with 0.2 g of dry baker's yeast (Mauri®).

Experiment with bovine biofertilizer

The experiment with bovine biofertilizer was conducted in a completely randomized design with five biofertilizer doses. The treatments consisted of: control; 0.30 mL (150 L ha^{-1}); 0.60 mL (300 L ha^{-1}); 0.90 mL (450 L ha^{-1}); and 1.12 mL (600 L ha^{-1}), combined with NPK mineral fertilization, applied even without crops, using 300 kg ha^{-1} of the 08–24–18 formula (COMISSÃO..., 2004), with four replications. The amounts of biofertilizer added to each treatment were adjusted based on the surface area of each experimental container.

The bovine biofertilizer was obtained from a local farm in the same municipality and produced by aerobic fermentation containing 15% bovine manure, 5% of the commercial product Microgeo®, and 80% potable water, fermented for 15 days under sunlight exposure.

Physicochemical analysis of the biofertilizer revealed the following characteristics: total solids of 2095 mg L^{-1}; pH 6.75; electrical conductivity of 111.7 µS cm^{-1}; COD of 320 mg L^{-1}; total phosphorus of 15.1 mg L^{-1}; and total nitrogen of 3.36 mg L^{-1}.

For application in the microcosms, the biofertilizer doses were diluted in distilled water so that all treatments received a final volume of 20 mL of solution. During the experimental period, the soil was kept above field capacity, and distilled water was added when necessary to maintain appropriate moisture and ensure the survival of collembolans, following the methodology described by Antoniolli et al. (2013).

Inoculation and incubation of organisms

Collembolans used in the experiment were obtained from decomposing organic compost and maintained and multiplied under laboratory conditions. The individuals were identified as belonging to the family Isotomidae (GALLO, 1988).

After preparing the microcosms, five adult collembolans were introduced into each experimental unit. The containers were then covered and incubated for a period of 45 days.

At the end of the experimental period, based on the counts obtained from the samples, the population density of collembolans per microcosm was estimated.

Extraction and counting of organisms

To quantify collembolans, three 1 cm^3 soil samples were collected from each microcosm, totaling 3 cm^3 per experimental unit.

For organism extraction, the soil samples were placed in 500 mL beakers containing 5 mL of 70% ethanol. The beakers were then filled with water. The solution was homogenized for three minutes and allowed to settle for two minutes.

After settling, the solution was passed through 8- and 48-mesh sieves, a procedure repeated four times. Subsequently, the solution was passed through a 270-mesh sieve to retain the organisms.

The material retained on the sieves was transferred to Petri dishes, and organisms were separated and counted using a stereoscopic microscope with up to 60× magnification.

Statistical analysis

The estimated count data were initially subjected to regression analysis to evaluate the effect of biofertilizer dosage; however, no significant fit was observed. Therefore, the data were analyzed using analysis of variance (ANOVA) with the F-test. For significant effects of qualitative factors, means were compared using Tukey's test at 5% probability. All graphs and statistical analyses were performed using R Studio.

RESULTS

The results show that the estimated abundance of collembolans varied significantly among biofertilizer doses (Figure 1). In general, the highest population densities were observed at 450 L ha^{-1}, particularly in Season 1, reaching values above 1,100 individuals per microcosm. For most other doses (0, 150, 300, and 600 L ha^{-1}), the estimated number of collembolans was considerably lower, ranging from approximately 20 to 500 individuals, depending on the season.

Significant differences between seasons were observed for some doses. For instance, at 0 and 600 L ha^{-1}, Season 2 presented higher abundances than Season 1, whereas at 450 L ha^{-1}, Season 1 exhibited a markedly higher population compared to Season 2.

The letters above the bars indicate statistically significant differences among treatments based on Tukey's test at 5% probability. These results suggest that the effect of biofertilizer on collembolan abundance is dose-dependent and may vary between seasons, with the 450 L ha^{-1} dose promoting the greatest population increase under the tested BOD conditions.

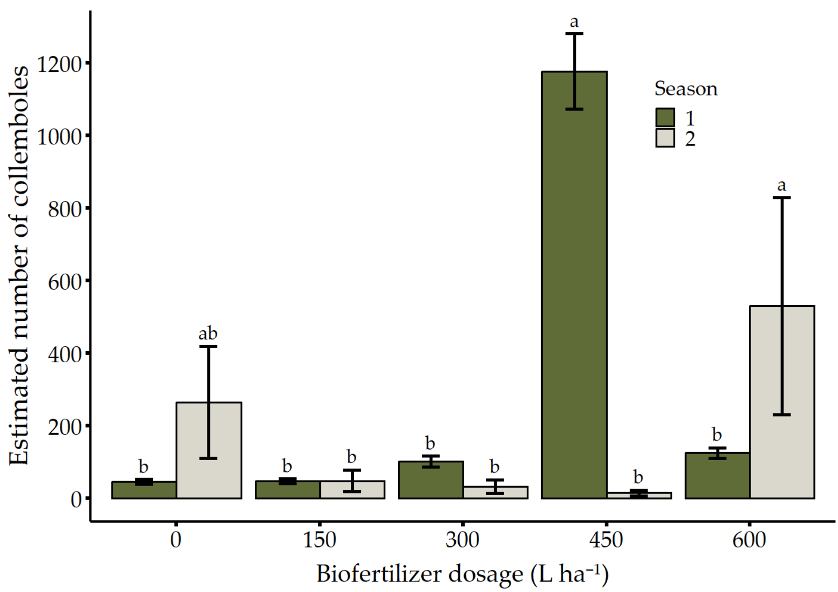

Figure 1 - Effect of biofertilizer dose on estimated collembolan abundance across two seasons under BOD conditions.

The results for the estimated number of collembolans recorded in the BOD chambers showed variation among the evaluated doses (Table 1). In the control treatment (0), values ranged from 44.10 to 247.05 individuals, representing intermediate levels of abundance. In the 150 and 300 doses, a reduction in the number of collembolans was observed compared to the control, with values ranging approximately from 22.05 to 63.70 individuals for the 150 dose and from 43.45 to 107.11 individuals for the 300 dose.

In contrast, the 450 dose presented the highest recorded values, with abundance ranging from 504.55 to 1316.82 individuals, indicating a marked increase in the number of collembolans as well as greater variability among replicates. At the 600 dose, a reduction was observed compared to the 450 dose, with values ranging from 126.01 to 502.86 individuals, although still higher than those observed for the 150 and 300 doses. Overall, the results suggest that higher intermediate doses favored an increase in collembolan abundance under the evaluated conditions.

Replicates	Dose	Est. No. ind.
1	0	78,90172
1	150	63,70229
1	300	43,45373
1	450	605,4042
1	600	502,8554
2	0	229,052
2	150	61,85258
2	300	85,85545
2	450	568,251
2	600	199,3063
3	0	108,3526
3	150	22,05201
3	300	62,90459
3	450	608,5545
3	600	278,5549
4	0	247,052
4	150	43,05201
4	300	67,10401

4	450	623,3059
4	600	197,4566
5	0	116,7023
5	150	53,20229
5	300	74,20516
5	450	504,5459
5	600	459,2052
6	0	44,10401
6	150	37,80344
6	300	107,1097
6	450	1316,82
6	600	126,0115

Table 1 - Estimated collembolan abundance per biofertilizer dose (mean of two seasons).

DISCUSSION

The results demonstrate that biofertilizer application significantly influences the population dynamics of collembolans in soil microcosms. The marked increase in abundance observed at the 450 L ha^{-1} dose suggests that a moderate input of organic matter may stimulate soil biological activity through an increase in microbial biomass, which constitutes one of the main food sources for these organisms. Recent studies indicate that the incorporation of organic inputs tends to intensify interactions between soil microbiota and fauna, favoring detritivorous organisms involved in the processes of decomposition and transformation of organic matter (Bardgett & van der Putten, 2014; Nielsen et al., 2015).

On the other hand, the reduction in abundance observed at the highest applied dose (600 L ha^{-1}) compared to the intermediate dose (450 L ha^{-1}) suggests that excessive levels of organic inputs may temporarily modify soil environmental conditions, affecting the dynamics of mesofauna populations. Changes in oxygen availability, microbial activity, or the concentration of soluble organic compounds may alter the microhabitat and the quality of food resources available to collembolans. This type of non-linear response has already been observed in studies evaluating the effects of different levels of organic matter on soil fauna communities (García-Palacios et al., 2013).

Overall, the results indicate that the response of collembolans to biofertilizer application is strongly dose-dependent, with greater abundance associated with intermediate levels of organic input. This pattern reinforces the role of these organisms as sensitive indicators of changes in soil biological quality and in the availability of energy resources in the edaphic environment. In addition, it highlights the importance of balanced management of organic inputs to promote soil biological activity and to support ecological processes that are fundamental for the sustainability of agroecosystems (Wall et al., 2015).

CONCLUSIONS

Biofertilizer application significantly affected collembolan abundance in soil microcosms. The highest population levels occurred at the intermediate dose (450 L ha^{-1}), indicating that moderate organic inputs stimulate soil biological activity. Higher doses reduced abundance, suggesting a non-linear and dose-dependent response. These results highlight the sensitivity of collembolans as indicators of changes in soil biological quality and emphasize the importance of balanced biofertilizer management.

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