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ECOLOGY

Biological Activity of Ant Nests in the Middle Taiga Zone

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Abstract—Ants are the most widespread social insects. Many species of ants influence a range of soil properties when building their nests in soil. The paper discusses the effects of ants on soil biological activity (nitrogen fixation, denitrification), as well as on biomass and the diversity of microorganisms. In many cases, these processes were more active in anthills. Changes in soil pH caused by nest-building activity of ants were also. There were no patterns in the distribution of pH values. Specific differences between microbial complexes of anthills and corresponding reference soils were revealed.

Keywords: anthills, microbiological activity, micromycetes, bacterial complex

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INTRODUCTION

It is of interest to study the effects of colonial animals on soil properties in terms of their influence on relatively small areas of the soil cover within which it is the most substantial. Considering the high population density of soil colonial animals, local changes in soil properties increase the mosaic soil cover and lead to the appearance of novel econiches, which numerous studies have demonstrated [1, 6].

In the modern-day scientific literature, organisms able to create, maintain, significantly alter, and even destroy habitats are designated *ecosystem engineers* [15, 16]. Among these is the group of *allogeneic ecosystem engineers*, which primarily includes animals able to form novel econiches that transform the environment [17].

Ants are typical allogeneic ecosystem engineers [12] and are one of the most widespread representatives of *Hymenoptera* in Russia. These social insects form large colonies; many species of ants build earthen nests, which not only penetrate into the soil for tens of centimeters but also rise above the surface in characteristic domes (so-called hummocks). These insects possess a broad range of ecological strategies: they belong to geobionts, epigeobionts, herpetobionts, etc. [10]. Ant species that build earthen nests can be considered pedobionts from the viewpoint of their influence on soil properties.

In this study, we assayed the biological activity and composition of bacterial and micromycete populations of ants nests located on different terrain elements.

MATERIALS AND METHODS

The objects of study were soil samples from the aboveground parts of nests (hummocks) inhabited by ants *Lasius niger*, *Formica* sp., and *Myrmica* sp., as well as from reference organogenic soil horizons without insects. The samples were collected during two field seasons in areas located on the floodplain, a terrace, the slope, and the watershed of the high bank of the Veryuga River (Ustyansky district, Arkhangelsk oblast, Russia). The samples were collected on slopes with south-southwest (steepness 5°, slope 1) and southwest (steepness 10°, slope 2) aspects and in two areas of the watershed. Reference soils were soddy-

Table 1. Average parameters of biological activity in samples from ant nests and reference soils

Site	Nitrogen fixation (nmol C_2H_4 g^{-1} h^{-1})	Denitrification (μM N_2O g^{-1} h^{-1})	Biomass (μg C/g of soil)
Watershed			
control	0.44	0.67	531.22
L. niger	8.07	2.63	584.23
Slope			
control	6.56	1.82	592.10
L. niger	11.37	3.65	483.40
Myrmica sp.	3.43	2.49	384.32
Terrace			
control	10.54	0.94	420.80
L. niger	16.06	3.79	501.12
Floodplain			
control	11.04	1.00	423.51
L. niger	0.13	3.63	400.36
Formica sp.	0.04	3.23	500.80

alluvial medium loam on floodplain alluvium, fresh sod–weakly podzolic medium loam (terrace), podzolic moderately cold moderately washed-out medium loam (slope), and fresh soddy–finely podzolic lightly loamy soil on a moraine (watershed) [7]. *L. niger* nests were detected in all areas, whereas *Formica* sp. and *Myrmica* sp. nests were found only on the floodplain and the slope, respectively.

To describe the biological activity in samples from the ant nests and reference soils, the potential nitrogen fixation and denitrification activity were determined by gas chromatography (Crystal 2000, Russia) [5]; the biomass was measured by the substrate-induced respiration method modified by West and Sparling [11, 18]; pH was measured with a potentiometer; species compositions of microbial complexes (bacteria and actinomycetes) were determined by cultivation on agarized peptone yeast glucose (PYG) and Czapek media. The dilution (1 : 100) was selected experimentally. Petri dishes were incubated at 20°C. To determine the number of microorganisms (colony forming units (CFU)/g of substrate), fungi and actinomycetes were counted after 10–14 days of incubation, whereas bacteria were counted after 7–10 days. Fungi and bacteria were identified based on cultural and morphological features, whereas actinomycetes were identified by cultivation on a differentiating medium [2].

RESULTS AND DISCUSSION

Comparison of the diazotrophic activity in the anthills located on different terrain elements and in the reference soils demonstrated that nitrogen fixation activity was higher in ant hills (on average, 11.8 nmol C_2H_4 g^{-1} h^{-1} in the nests of *L. niger* and 5.51 nmol C_2H_4 g^{-1} h^{-1} in the reference soils). The highest activities (16 nmol C_2H_4 g^{-1} h^{-1}) were detected in nests located on the terrace, whereas the lowest activities were determined in nests on the slope (Table 1).

Denitrification activity in the soil samples from ant nests was also significantly higher than that in the reference samples from all the terrain elements. Higher activity was observed in the anthill located on the terrace (3.79 nmol N_2O g^{-1} h^{-1}). On average, the denitrification activity values in the nests of *L. niger* and in the reference samples were 3.4 and 1.2 nmol N_2O g^{-1} h^{-1}, respectively (Table 1).

Earlier, we conducted similar repeat measurements in a survey area in Ryazan oblast (Russia) and revealed a similar pattern [3, 8]. In addition, it was shown that the total nitrogen content in the ant nests insignificantly differed from that in the reference soil, but it did not decrease with the time [4].

Differences in the accumulation and redistribution of nitrogen compounds may be the cause of this phenomenon. Absence of vegetation on the surface of anthills may contribute to the accumulation of nitrate

Table 2. Average pH values in anthills and corresponding reference soils

Sample	pH
Watershed	
control	4.73
L. niger	4.79
Slope	
control	5.47
L. niger	7.25
Myrmica sp.	7.27
Terrace	
control	7.11
L. niger	5.75
Floodplain	
control	7.16
L. niger	7.21
Formica sp.	6.42

Table 3. Number of bacteria and fungi in ant nests determined by cultivation on PYG and Czapek media

Sample (nest of *L. niger*)	Number, CFU × 10^6/g)	
	bacteria	fungi
Watershed		
control	1.89	0.49
anthill	7.01	0.35
Slope 1		
control	1.26	0.26
anthill	10.60	0.19
Slope 2		
control	0.98	0.10
anthill	15.50	0.11
Terrace		
control	1.50	0.02
anthill	5.30	0.15

nitrogen required for denitrification, whereas the nest-building activity of ants may create favorable conditions for nitrification and accelerate the transformation of ammonia nitrogen, inhibiting nitrogen fixation into nitrate form [9]. Thus, ants that mechanically move soil particles and aggregates when building a nest create favorable conditions for increased nitrogen transformation.

Measurement of the biomass by the substrate-induced respiration method did not reveal substantial differences in this parameter between ant nests and reference soils. The data in the Table 1 show that samples collected on different terrain elements differed insignificantly in the amount of biomass.

The pH values in ant nests located on different terrain elements and reference soils differed substantially (Table 2). For example, the pH value in an *L. niger* anthill located on the watershed was about 5, comparable to the value obtained for the corresponding reference sample. At the same time, the pH value in nests of the same species located on the floodplain was slightly alkaline (about 7.16); i.e., it differed insignificantly from those in the reference soil. In a nest of *L. niger* located on the slope, this parameter was 7.25, sufficiently higher than that in the reference soil (5.47).

Changes in acidity caused by ants have been described in the literature. Numerous studies have shown that ants can change the pH to the neutral values, but mechanism of this process is still not understood [13, 14]. A tendency toward alkalization of the medium in the case of the reference soil on the floodplain corresponded to the general views and may be caused by known floodplain processes.

Analysis of the bacterial complexes of the anthills and control podzolic soils demonstrated that the number of bacteria in all nests was several times higher than in the corresponding reference soil samples (Table 3).

The highest number was observed in an anthill located on the slope of the watershed, whereas the lowest number was detected in reference soil samples collected on the steep slope with heavily eroded surface.

The compositions of bacterial complexes of anthills differed fundamentally from the control soils. Predominance of the actinomycetes (their proportions in the complexes often exceeded 50% (Fig. 1)) was a characteristic feature of nest complexes regardless of ant species, soil type, and position in the landscape.

Study of the micromycetes on the ant nests and reference soils demonstrated that the total numbers of fungi in all samples were comparable (Table 3). In most samples, different species of the genus *Penicillium* (from 20 to 95%) were revealed, among which *P. janczewskii*, *P. canescens*, and *P. chermisinum* were predominant. The reference samples also contained the fungus *Fusarium solani*, whereas it was not detected in the samples from the anthills. The species composition of micromycetes in ant nests located on the slope was poor. *Clonostahys rosea*, which can act not only as a saprophyte but can also be a parasite to fungi and insects, was predominant in the population (20–85%). The presence of the zygomycete genus *Cunninghamella* (3–12%) was a common feature of all anthills, which demonstrated the fitness of the population to this natural environment.

Statistical analysis of the species diversity demonstrated that micromycete complexes of anthills were

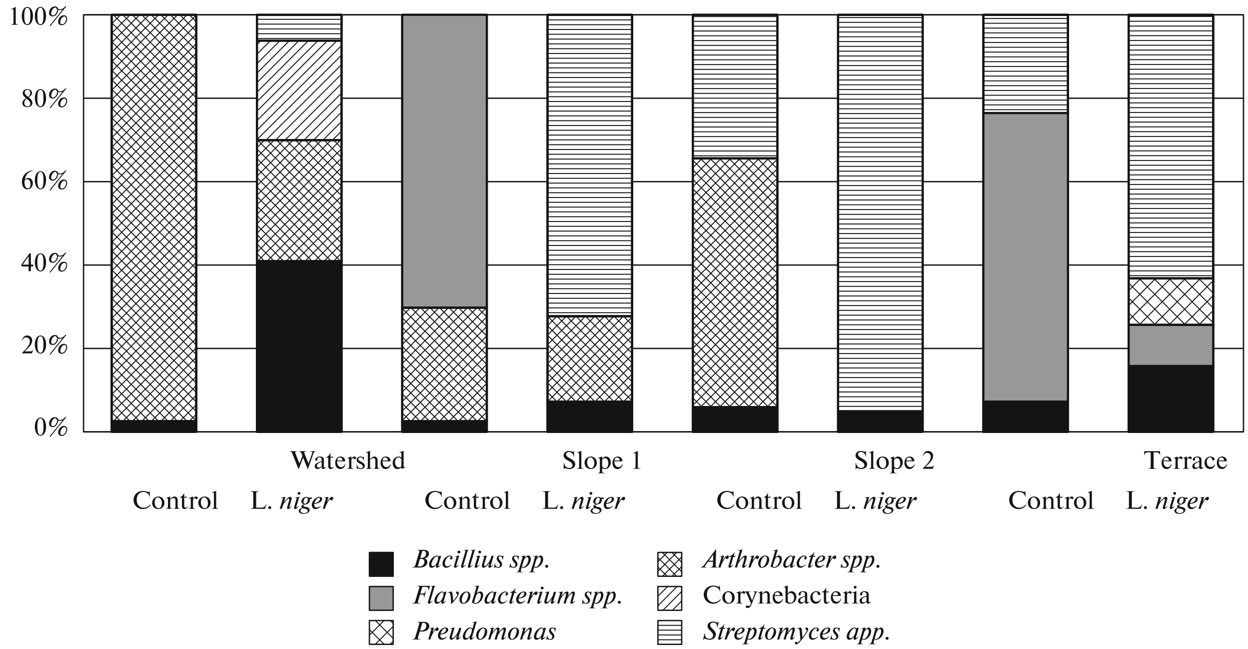

Fig. 1. Bacterial complex of anthills and reference soils.

similar to each other and differed from those of the reference soils.

CONCLUSIONS

Thus, the nest-building activity of ants leads to an increase in microbial activity in the nitrogen cycle. This phenomenon is especially notable in *L. niger* ants, which form large colonies. Ants acting as a soil-forming factor that changes many soil properties are likely not as important as other factors including, terrain. Predominance of actinomycetes of the genus *Streptomyces* in bacterial complexes was a characteristic feature of the microbiocenoses of anthills regardless of the soil type, terrain, and ant species. The hydrolytic fungus *Cunninghamella ehinulata*, as well as other zygomycetes *(Mortierella alpine, Absidia spinosa, Mucor* spp*.*, etc.), were detected in all *L. niger* nests.

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