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Effects of Artificial Acid Rain on Microbial Activity and Biomass

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The emission of air pollutants which form acid components in rain and snow represents a threat to natural ecosystems. Increased leaching of nutrients from soils (ABRAHAMSEN et al. 1976b), decreased pH values in lakes and changes in fish populations (SCHOFIELD 1976) have been suggested as some of the consequences of the increased acidity of rain. Scandinavian coniferous forests are very stable ecosystems, and dramatic short-term effects due to acid rain are hardly to be expected. To simulate long-term effects, artificially acidified rain may be used. We report here decreased microbial activity and biomass in a Norwegian forest soil treated with artificially acidified rain.

SITE DESCRIPTION AND METHODS

A research area of the Norwegian research project "Acid precipitation - effects on forests and fish" was used (Nordmoen, County of Akershus, 11°06'E, 60°16'N, altitude 200m, annual mean precipitation 832 mm, annual mean temperature 4.3°C). The former mixed coniferous forest (Picea abies (L.)Karst., Pinus silvestris L.) was clear-cut in early 1974 and planted with P.silvestris the same year. At the same time watering started with simulated acid rain adjusted with sulphuric acid to pH 3.0 and pH 2.0. The control was watered with ground water (pH 6.1). The area was watered with 50 mm month^{-1} during the vegetation period (5 months) for almost 5 years (ABRAHAMSEN et al. 1976a). The weighted annual mean pH values for the simulated and natural rain (pH 4.3) together were approximately pH 4.5 (control), pH 3.4 (pH 3.0) and pH 2.5 (pH 2.0) (ABRAHAMSEN et al. 1976b). The artificial watering resulted in only minor changes in the overall soil pH of the humus horizon in the control and the pH 3 plot, while watering with pH 2 water decreased the pH by 0.5 units to approximately pH 3.6 (measured autumn 1977, upper 2 cm, S. Hågvar, pers.comm.).

Soil samples from the fermentation and the humus layers (F+H) were taken 19 October 1978. Eight samples were taken in each of 3 treatment areas. (4 randomized plots per treatment with

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2 bulk samples per plot, each bulk sample consisting of 10 subsamples). The samples were transported to the laboratory at 5-10°C and treated within 24 h.

Soil respiration was determined on 5 g samples with thick roots removed, incubated for 18 h in closed vessels at 12°C. Evolved CO_2 was measured gas chromatographically.

Total fungal lengths were determined with a membrane-filter method (SUNDMAN and SIEVELÄ 1978), and total bacterial numbers were determined with acridine-orange stained smears (TROLLDENIER 1972). Active fungal lengths were estimated with the fluorescein diacetate (FDA) staining method (SÖDERSTRÖM 1977), and FDA-active bacterial numbers with a modification of this method (a phosphate-buffer 0.50 M, pH 8.5 was used).

Bacterial cell size (measured in the acridine-orange stained preparations) was calculated after classification into five size classes.

Analysis of variance was used in statistical treatments of the results.

RESULTS AND DISCUSSION

Respiration, FDA-active fungal length and FDA-active bacteria are all parameters related to microbial activity in the soil. These parameters all decreased in the acidified plots (Tab.1). Total fungal length and bacterial numbers did not change significantly in response to artificial acid rain, indicating that the microbial immobilization of mineral elements was little affected in this experiment.

Bacterial cell size (measured in the acridine-orange stained preparations) was smaller in the most acidified plots. Mean cell size in this treatment was 0.10 μm^3, compared to 0.13 μm^3 in the control and the pH 3 treated plot. The reduced cell size could be due to changes in the bacterial population, or it could reflect a lower bacterial growth rate after treatment with pH 2 water.

It seems most likely that the decreased microbial activity, directly or indirectly, is a hydrogen ion effect. However, since pH was adjusted with sulphuric acid, it cannot be excluded that the added sulphate influenced the microorganisms negatively. Through natural rain about 0.8 g SO_4-S m^{-2} is added to the soil annually, while use of pH 3 water added 4 g SO_4-S m^{-2} and $year^{-1}$.

TABLE 1

Fungi, bacteria and soil respiration in the humus horizon of a forest soil treated with artificial acid rain.

	Control	pH3	pH2	S.E.	Sign.diff. (95 %)
Respiration ($g\ CO_2\ g\ dw^{-1} h^{-1} x10^{-5}$)	4.6	4.5	2.4	0.3	Control-pH2 pH3-pH2
Bacteria, FDA-active (number $g\ dw^{-1} x10^{9}$)	7.5	6.6	5.6	0.6	Contol-pH2
Fungi, FDA-active ($m\ g\ dw^{-1}$)	220	180	170	20	
Bacteria, total (number $g\ dw^{-1} x10^{9}$)	24	32	28	11	
Fungi, total ($m\ g\ dw^{-1}$)	1800	1600	1700	300	

Furthermore, reduction in the amount of certain exchangeable cations in soil due to acidification has been found (ABRAHAMSEN et al. 1976b), and this could also exert some influence on the microbial activity.

Changes in forest tree production in Scandinavia due to acidification have not yet been convincingly demonstrated (TAMM 1976). The short-term effect may in fact be an increased growth rate, partly due to increased deposition of nitrogen through the emission of air pollutants (TVEITE and ABRAHAMSEN 1978). TAMM (1976) suggested in a hypothetical model, however, that increased acid deposition in a forest ecosystem may result in decreased site fertility and, subsequently, reduced tree production. The first step in this model is a decreased microbial activity, followed by a decreased microbial immobilization of nitrogen.

Our results imply that the long-term effect of acidified rain could be decreased microbial activity. However, a direct comparison with the natural situation is difficult, since the artificial rain applied in this study had a much lower pH than natural rain. Still, we find these effects on the soil organisms worth serious consideration with Tamm's model in mind. Our results were confirmed in a more extensive investigation, where the effects of artificial acidification on not only microorganisms, but also soil fauna and litter decomposition, were studied in a Swedish coniferous forest (BÅÅTH et al. in press).

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