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INFLUENCE OF THE MICROBIOLOGICAL ACTIVITY ON THE SOIL AGGREGATE STABILITY

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A b s t r a c t. The influence of the microbiological activity on the soil aggregate stability of a silty Chernozem was investigated by promoting the microbial activity through D-glucose solution. After 2 weeks of incubation the microbial activity reached 300 % of the initial value, whereas the soil aggregate stability was triplicated. The effect of aggregate stabilization by fungal biomass was higher than the one due to bacterial biomass.

K e y w o r d s: microbiological activity, soil aggregate stability

INTRODUCTION

The process of aggregation of solid particles occurs in many soils during the pedogenesis. Soil scientists are interested in the study of aggregation phenomena because of their importance in the soil structure formation and all related processes (e.g., water, air, heat and solute flow [2]). There are several and sometimes controversial indications of how soil aggregates can be formed, influenced and stabilized.

Fe oxides and hydroxides, for example, are believed to act as cementing agents between particles. Aggregation is probably less due to crystal growth but more to the attraction between positively charged Fe oxide particles and negatively charged matrix particles, particularly clay silicates. Because the charge of Fe oxide particles is pH-dependent, their aggregation effect is also pH-dependent. Neoformed carbonates seems to act in the same way. Clay minerals, especially those with accentuate swelling/shrinking properties, are also responsible for the formation of small-sized aggregates of prismatic or polyhedrical shape. Moreover, since the aggregate formation is occurring particularly in top soils, even when carbonates, Fe oxides and clay minerals have been leached, the role of organic matter and microorganisms in soil aggregation is evident [3,4].

From an ecological viewpoint, not only the type of aggregates but especially their stability against rainfall or irrigation is of main importance. Therefore, before starting any methodological approach, one should take into consideration that soil aggregates are size-distributed and the water stability of the different aggregate classes may vary. The aim of this study was to observe the effect of the microbiological biomass activity on the aggregate stability of a silty agricultural soil of Lower Austria. In order to do that, two different experimental approaches were carried out, as described below.

MATERIAL AND METHODS

Investigated soil

The investigated soil sample was taken from the A-horizon (0-20 cm depth) of a Chernozem (according to FAO-UNESCO-system, [3]) situated in the Marchfeld (Vienna basin, Lower Austria) and developed on fluviatile sediments

of the River Danube with the following general characteristics: - 7.3 pH ($CaCl_2$); 30.5 % carbonate; 1.6 % organic carbon; 14 % sand, 67 % silt, 19 % clay.

The bulk soil sample was air-dried at 20 °C and than sieved at a mesh-size of 1-2 mm diameter. The aggregates of this size were described by Kemper and Koch [5], Kemper and Rosenau, [6], to be the most frequent in soils and were therefore used in both experiments.

Experimental approach I

This experiment was done in order to demonstrate the effect of the total microbial biomass activity on the soil aggregate stability. Prior to further analyses, the water retention capacity (WRC) and the soil aggregate stability (SAS) of the air-dried sample were determined according to Nehring [8] and Murer *et al.* [7]. Air-dried aggregates (25 g) were than placed in Petri dishes (5 replications) and adjusted to a moisture content of 60 % of the WRC with 3 % glucose solution. After one day of equilibration the initial dimethylsulphoxid-reductase activity was measured (according to Alef and Kleiner [1]). To promote the biological activity the soil sample was incubated at 28 °C in a water-saturated atmosphere for 3 weeks and the microorganisms were fed each third day with 3 % glucose solution. The water content of the samples was kept constantly at 60 % of the WRC. For control 25 g air-dried soil aggregates were placed in a Petri dish, moistened with sterile water and incubated in the same way as the full samples.

During the incubation the following analyses were carried out weekly:

- Measurement of the soil microbial activity by the DMSO-reduction method according to Alef and Kleiner [1];
- Determination of the soil aggregate stability (SAS) by the wet sieving technique of Murer *et al.* [7];
- Measurement of the excess content of D-glucose in the soil shortly before adding glucose (by the UV-method/bioenzymatical analysis - Boehringer Mannheim).

Experimental approach II

The microbial biomass was first obtained by extracting bacterial and fungal progagules from the soil, isolating them by employing selective agar media and augmenting fungi and bacteria in a culture medium. The fresh fungal and bacterial biomass were separated from the culture medium by centrifugation (3000 R/min) and resuspended in a 3 % saccharose solution. The concentration in the bacteria suspension was 30 mg dry biomass/ml solution and that of the fungi suspension was 5 mg dry biomass/ml solution. The air-dried aggregates were first sterilized through gamma-irradiation. Two sets of 5x10 g sterile and air-dried aggregates were transferred into Petri dishes. One set (5 replicates) was amended with 3.3 ml of the bacteria-suspension and 1 set (5 replicates) was amended with 3.3 ml of the suspension containing fungal biomass. Immediately after amendment for both sets the microbial activity was measured by the DMSO-reduction method (according to Alef and Kleiner [1]) and the soil aggregate stability determined by the wet sieving technique (according to Murer *et al.*, [7]). To stimulate the biological activity the two sets were incubated at 28 °C in a water saturated atmosphere for 2 weeks. During incubation the microorganisms were fed each third day with a 3 % saccharose solution for bacteria respectively with a solution containing 3 % saccharose and 0.3 % $NaNO_3$ for fungi. After incubation the DMSO-reductase-activity and the soil aggregate stability of the two sets were measured again. For control 10 g of sterile soil were moistened with sterile water, incubated and analysed in the same way as the full samples.

RESULTS

Experimental approach I

The response of the total microbial activity and the SAS to D-glucose amendment is shown in Fig. 1 and Table 1.

After 2 weeks of incubation the microbial activity reached 300 % of the initial value, thereafter the activity broke down, probably

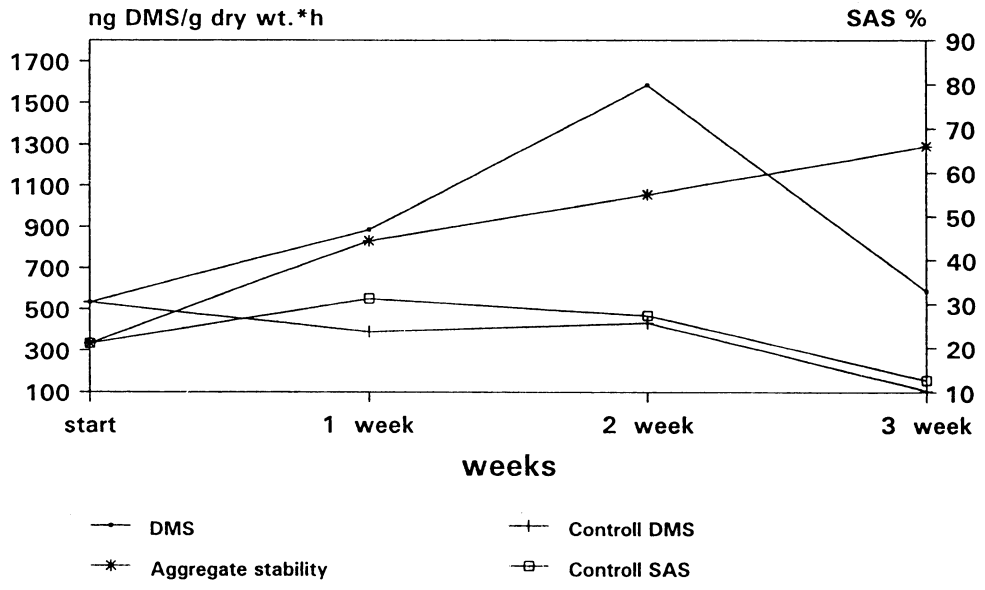

Fig. 1. Alteration of soil microbial activity (dimethylsulphoxid-reductase) and soil aggregate stability (SAS) during the incubation time.

Table 1. Alteration of soil microbial activity and soil aggregate stability during the incubation time

Incubation time	Replicates	mg DMS[1]	SAS%[2]	mg D-glucose[3]
start=control	3	532.88	21	0
1 week	5	885.33	44.42	0
2 weeks	5	1583.99	54.97	0
3 weeks	5	586.03	66.03	0

[1]Amount of DMS evolved by soil biota within 5 h; [2]soil aggregate stability in percentage of the dry weight; [3]D-glucose content in the soil.

due to the lack of nutrients.

At the end of the incubation time the soil aggregate stability was triplicated with respect to the higher microbial activity. The reason for that is because of the higher rate of microbial secretions and decomposition products.

The bioenzymatical determination of D-glucose in the soil solution was negative for each measurement, thus showing that the glucose was entirely used up by the microflora and had no direct influence on aggregate stability.

The dimethylsulphoxid-reductase activity and the soil aggregate stability of the control (soil without glucose amendment) were almost constant during the incubation time, with a slight decrease in the third week.

The analysis of correlation showed a significant positive correlation between the microbial activity and the SAS ($r=0.86$, $\alpha=0.05$).

Experimental approach II

The impact of the two different microorganism groups on the soil aggregate stability is shown in Table 2.

After 2 weeks of incubation and augmentation of the bacteria and fungi, a difference between the aggregate stability of the soil, amended with bacteria and the aggregate stability of the soil, amended with fungal biomass could be recorded.

Table 2. Fungal and bacterial influence on the soil aggregate stability

Sample set	1	2	3	4	5
	Incubation period	mg DMS init.	mg DMS end	SAS % init.	SAS % end
Fungi	2	753.85	956.50	20.9	86
Bacteria	2	846.20	878.10	20.9	74.24
Control	2	313.03	203.51	20.9	20.9

[1]Incubation period in weeks; [2]Initial amount of DMS evolved by soil biota within 5 h; [3]Amount of DMS evolved by soil biota within 5 h at the end of incubation; [4]Soil aggregate stability in percentage of the dry weight at the beginning of incubation; [5]Soil aggregate stability in percentage of the dry weight at the end of incubation.

The result of this experiment shows that the forming and stabilization effects of fungal biomass on soil aggregates are more intensive than those of bacterial biomass. This may be explained by the different morphology of the two organism groups. Fungi form strong hyphes, which tie soil particles together and twist them in their net of hyphes. Bacteria produce slimes and capsules, which stick particles together, but the production of these substrates does not assume the proportions of fungal hyphes.

DISCUSSION AND CONCLUSIONS

It is doubtful that the soil aggregate stability is a sum parameter of different aggregating agents, the main of them are believed to be microbiological secretions, humic substances, Fe oxides, and carbonate. This study demonstrated how microbial growth can rapidly increase the soil aggregate stability by constantly maintaining the other mentioned aggregating agents. Moreover, the microbial population breaks down if it is not simultaneously supported with other nutrients, whereas the aggregating effect seems to act even after the microbial breakdown.

For this soil the effect of fungal biomass on the soil aggregate stability seems to be more intensive than that of bacteria.

Concerning the methods used, it can be stated that the reduction of DMSO to DMS is a commonly occurring metabolic process and it could be observed in microorganisms as well as in higher plants and animals. As reported by Alef and Kleiner [1], among 144 strains of soil microorganisms only 5 strains are not capable to reduce DMSO to DMS. Consequently, the DMSO-reduction-method can be employed to describe the microbial activity in soils. From the methodological viewpoint this method has to be considered as very simple and not time consuming (the evolved dimethylsuphide from dimethylsulphoxide is determined by gas chromatography) but very precise and reproducible. Moreover, it is common opinion that size distribution of soil aggregates can vary widely and in addition, their stability in water can be determined by various methods. In this work the method of Kemper and Koch [5], modified by Murer *et al.* [7], was used as a very quick and applicable method. Nevertheless, it still represents one of several existing method. For the evaluation of the state of soil structure, however, one should determine much more structural soil parameters according to the soil functions and processes to be assessed [2].

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