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RELATIONS BETWEEN SOIL STRUCTURE, NUMBER OF SELECTED GROUPS OF SOIL MICROORGANISMS, ORGANIC MATTER CONTENT AND CULTIVATION SYSTEM

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A b t s r a c t. The aim of this work was to fiut relations between the number of selected groups of soil microorganisms, water stability of soil aggregates, soil porosity and the organic matter content on the basis of field experiment. Two types of soil were used simultaneously for the research: chemozemic rendzina and brown soil. Rotation system was used in plant cultivation. Chemical, physical and microbiological analyses were carried out on the control object and on objects with organic fertilizers and mineral fertilizers N, P, K.

Differences in the sum of fractions of organic C, chiefly in the easily oxidizing fractions in experimental fields on rendzina, in comparison to those on brown soil, can be the result of the predominance of zymogenous bacteria over autochtonous bacteria in the rendzina. Easily oxidizable fractions of C contained in the organic substance of particular fields can be utilized by a high ratio of zymogenous bacteria in the soil samples. It should be noted that characteristic differences in the number of bacteria have been observed in the two types of soils examined. The number of autochtonous microorganisms in brown soil was twice as much as in rendzina. Zymogenous microorganisms constitute more than 90 % of the total number of microorganisms in rendzina. Under the cultivation of red clover an increase of water stability of soil aggregates was stated. From the porosimetric analyses no changes under different cultivation of two soils were observed. The ratio of microorganisms was connected with the type of soil and the system of cultivation.

K e y w o r d s: soil structure, microorganisms, organic matter, cultivation system

INTRODUCTION

Many authors find a relation between soil structure and its fertility. Aggregate structure of soil is generally considered an advantageous feature of soil, especially of its arable layer [6]. The improvement of soil structure by the addition of organic materials in the form of farmyard manure, crop residues, green manures has been known for a long time. But organic matter addition has no effect unless microorganisms are present [2,5,9,12,13]. Badura [2] in his review paper points out the important role of microorganisms in the processes of soil structure formation. Microorganisms are indispensible in decay and transformation of organic substances and humus formation in soil. The role of microorganisms in the formation of water-stable soil aggregates has been studied by many authors among others: Dąbek-Szreniawska [4,5], Harris *et al.* [9], Lynch and Bragg [13]. The importance of soil aggregation in crop production lies in its indirect effect on water and air relationships in the soil.

The main agents of stabilisation are organic materials. These include the products of decomposition of plant residues, animal and microbial remains, and the products of microbial synthesis. In the majority of agricultural soils organic binding agents are of the greatest importance.

The aim of this work is to find relations between the number of selected groups of soil microorganisms, water stability of soil aggregates, soil porosity and organic matter contents on the basis of field experiments.

METHODS

The research was undertaken according to the split blocks model in 4 variants on fields belonging to the University of Agriculture in Lublin in the years 1989-93. The experiment was carried out simultaneously on two types of soil:

1)chernozemic rendzina with deep humic layer (heavy soil),
2)brown soil (light soil).

Some characteristics of these soils are included in Table 1.

The following plants have been cultivated in rotation system as the second in four-year rotation system:

1)fodder beet,
2)cereal mixture (barley + oats) and red clover as a companion crop,
3)red clover,
4)winter wheat.

The following variants of experiments have been carried out:

1)without fertilizers (control object),
2)organic fertilizers - compost+manure - 40 t/ha for fodder beet and 10 t/ha for the remaining plants,
3)mineral fertilizers N, P, K - 160 kg N/ha, 100 kg P_2O_5/ha, 220 kg K_2O/ha.

The chemical, physical and microbiological analyses were carried out on the samples taken from the arable layer of the fields with winter wheat at near maturity stage. Organic carbon content and its fractions in the soil samples were studied using Turin's and Łoginow-Wiśniewski's method [11]. Studies of water-stability of soil aggregates were performed using Bakszejew water-sewing method modified by Walczak and Witkowska [19]. Porosimetric analyses were performed with mercury porosimeter (Carlo Erba 2000) by Konstankiewicz and Stawiński [10]: total porosity, mean of pore radius, maximum pore volume, mean radius of pores.

The number of autochtonous, zymogenous microorganisms was determined according to Winogradsky's research modified by Dąbek-Szreniawska and Hattori [3], Ohta and Hattori [14]. The number of ammonificators and amylolytic microorganisms was defined after Pochon and Tardieux [15].

RESULTS AND DISCUSSION

Soil samples for water stability analyses in our work were taken from the rendzina under presowing stage and growth stage of red clover. As it is shown in Figs 1 and 2 the increase of water stability of aggregates of rendzina soil was observed after the influence of clover growth.

Possibilities of developing aggregate structure in soil depend on the cultivation system applied, fertilization and chiefly on the natural properties of soil. Particular types and kinds of soil may be considerably differentiated as to their ability to form water-resistant aggregates [6].

From the porosimetric analyses total porosity, maximum pore volume, bulk density and mean radius of pores were obtained. On the basis of our experiments no changes were observed of the porosity under different cultivation of the two examined soils (Table 2).

Table 1. Soils characteristics

Soil type	Percent of mechanical fraction (mm)				pH in H_2O	Organic substances (% dry mass)
	1.0-0.1	0.1-0.05	0.05-0.02	<0.02		
Rendzina	27	2	11	60	7.2	6.95
Brown soil	66	9	10	15	6.4	2.09

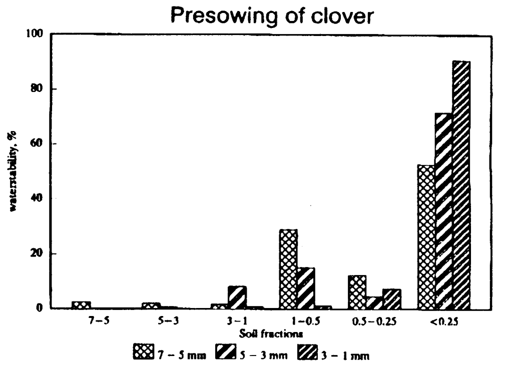

Fig. 1. Water stability of the rendzina aggregates - presowing of clover.

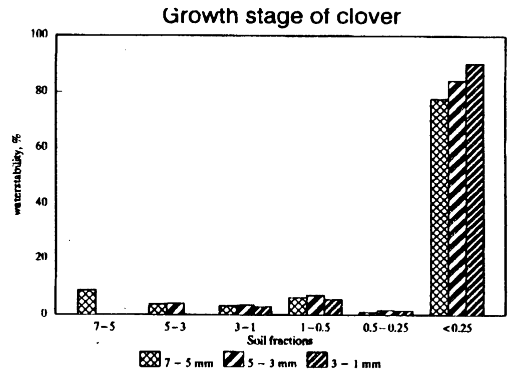

Fig. 2. Water stability of the rendzina aggregates - growth stage of clover.

In our experiments soil samples were taken from differently cultivated and fertilized fields of two types of soils varied in total organic C content and C fractions (See Table 3). In each soil the process of developing of those fractions was probably different. The physicochemical characteristic of these soils are variable and that is why it influences differently the development of particular C fractions.

Differences in the sum of fractions, chiefly in the easily oxidizing fraction of the experimental samples of rendzina, in comparison to those of brown soil, can be the result of the predominance of zymogenous bacteria on autochtonous in the rendzina.

The high ratio of zymogenous bacteria present in the soil samples can utilize easily oxidizable fractions of C contained in the organic substance of particular fields (Tables 2 and 4). In the brown soil the quantity of zymogenous

Table 2. Mercury porosimetric analyses of the soil samples

Soils	Fertilization	Total porosity* (%)	Aver. pore radius* (μm)	Maximum pore volume* (mm^3/g)	Bulk density* (g/cm^3)
Rendzina	Without fertilizers	24.3	0.31	133	1.83
	NPK	23.0	0.20	120	1.90
	Manure	23.1	0.25	125	1.84
Brown soil	Without fertilizers	21.0	1.57	104	2.02
	NPK	18.7	1.54	90	2.09
	Manure	19.3	1.22	92	2.09

*The results of mercury porosimetric analyses do not take into account pores of radius less than 6.5 10^{-10}m and more than 75000 10^{-10}m.

Table 3. Cultivation, fertilization and organic carbon content (%) of soil samples studies (method of Łoginow-Wiśniewski [11])

Soils	Fertilization	Total organic C	Easily oxidizable C	Not oxidizable C
Rendzina	Without fertilizers	2.76	11.96	88.04
	NPK	2.58	15.11	84.88
	Manure	2.40	14.69	85.31
Brown soil	Without fertilizers	0.77	38.08	61.92
	NPK	0.67	32.66	67.34
	Manure	0.76	31.45	68.25

Table 4. The number of microorganisms in soil samples rendzina and brown soil (10^6/g of dry soil)

Soils	Fertilization	Total number of micro-organisms	Zymogenous	Autochtonous	Ammonifi-cators	Amylolytic
Rendzina	Without fertilizers	34.7	33.8	2.6	30.0	17.0
	NPK	31.2	29.6	2.0	30.0	16.0
	Manure	38.5	34.8	2.3	20.0	20.0
Brown soil	Without fertilizers	19.2	15.0	4.2	17.0	11.0
	NPK	22.7	22.0	3.8	22.0	11.0
	Manure	30.5	18.3	4.0	16.0	13.0

microorganisms fell between $15x10^6$/g of dry soiland more than $22x10^6$/g of dry soil depending on fertilization. The quantity of autochtonous microorganisms found in brown soil was almost twice as much as in rendzina. It should be noted that characteristic differences in the number of bacteria were observed in the two types of soil examined. The results presented in our paper indicate that the ratio of zymogenous to autochtonous bacteria is mainly connected with the quantity of labile C as well as with the soil organic matter content.

In the soil samples of fertilized experimental fields - (organic and NPK fertilizers) the ratio of zymogenous to autochtonous microorganisms is more or less similar, although it differs depending on the type of soil. The number of ammonifiers in chernozem rendzina is higher than that in brown soil. Generally a lower number of amylolytic microorganisms (Table 4) was observed in both of the examined soils of our experiments.

Reganold *et al.* [17] stated that the organically-farmed soil had significantly higher organic matter content, thicker top soil depth, higher polysaccharide content, lower modulus of rupture and less soil erosion than the conventionally-farmed soil. This study indicates that, in the long term, the organic farming system was more effective than the conventional farming system in reducing soil erosion and, therefore, maintaining soil productivity [17].

Radke *et al.* [16] refer to experiments carried out in the USA: that in long-term experiments, crops in rotation consistently outyielded those grown continuously. This was true even when sufficient nitrogen was provided for the crop, indicating that the yield increase was due to other factors in addition to nitrogen.

Reid and Goss [18] observed soil aggregate stability (measured by turbidimetric and wet sieving procedures) using five crop species and two soils contained in pots. Aggregate stability of soil contained in pots was improved by the growth in the soil of perennial ryegrass and lucerne for 42 days, whether tested in the fresh or air-dried state. Lynch and Bragg [13] describe in their review paper that under modern intensive agricultural systems, the instability of soil aggregates can be a major limiting factor to the production of arable crops. Lynch and Bragg [13] stated that the organic matter level in soil tends to reach an equilibrium level depending on the farming system, climate, and type of soil, and is affected only slowly by annual additions of plant materials or manures. In a sandy loam soil in England, 100 years of continuous cereals reduced the organic carbon content by 50 % (Johnston, cited from [13]) while annual additions of farmyard manure over 150 years increased the organic carbon content from 1 % to 3 %. In plots established since 1912 on a Dark Brown Chernozemic soil in Canada, Dormaar and Pittman [7] found that cultivated soils contained 47 % less C, 46 % less N, 53 % fewer polysaccharides, 100 % more solvent -extractable C, and 49 % more resinextractable C and had a slightly higher pH than the proximate grassland soil.

Gliński *et al.* [8] attempted a more complete evaluation of structural changes of soil under different tillage methods using the quantitative porosimetric analyses of soil samples.

The manner in which microorganisms acquire available substrates in soil was first considered by Winogradsky (cited from [12]). The zymogenous organisms rapidly increase in biomass in response to the input of fresh substrates, but they die out rapidly unless their energy demands are met. By contrast, the soil also supports a relatively constant biomass, which responds little to the input of fresh substrates; this is the autochtonous population which needs only a small supply of energy for its survival.

Anderson and Domsch [1] stated an increase in the ratio of microbial biomass C to soil organic C during the initial stages of decomposition of farmyard manure when added to the soil, which indicates that the biomass increased in response to the addition of organic amendments.

CONCLUSIONS

1. There exists a relation between the contribution of different microbial groups to the total microbial count and the quality (fractions of different oxidizability) of organic C.

2. From the porosimetric analyses no changes under different cultivation methods of soils were observed.

3. Under the cultivation of red clover an increase of water stability of soil aggregates was observed.

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