

EXAMINATION OF SOME SOIL BIOLOGICAL CHARACTERISTICS OF THREE SOIL TYPES UNDER DIFFERENT PLANT CROPS

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Abstract

*In the Institute of Agrochemistry and Soil Science from Debrecen University of Hungary (UD) some microbiological characteristics of three different soil types, with different plant crops were examined during 2 years (2019-2020), in spring and autumn. Examined soil types were: (1.) Chernozems with corn (*Triticum aestivum* L.); (2) Arenosols, with fruit (*Prunus cerasus* L.) and (3) Solonetz with grassland.*

The highest number of total soil bacteria was found in Chernozem soil under wheat crop ($13.20 \cdot 10^6 \text{ g}^{-1}$), the highest quantity of microbial fungi ($9.93 \cdot 10^3 \text{ g}^{-1}$), and dehydrogenase activity ($240.32 \mu\text{g INTF g}^{-1} \text{ soil } 2 \text{ h}^{-1}$) was found in Solonetz soil, which is an uncultivated soil (pasture). One of the main parameters of the soil biological characteristics is the CO_2 production of the soils, which was the highest on the Chernozem soil and the lower on the Humus of sandy soil.

During the correlation tests, the most close correlation was demonstrated between the parameters of the Solonetz soil (dehydrogenase enzyme – number of microscopic fungi; $r = 0.909$; 0.955 ; total bacterial number - soil respiration; $r = 0.830$; 0.885). Medium and close correlation were found between the soil moisture content and the total number of bacteria in case of Solonetz and Chernozem soils.

Regarding the seasonality, higher abundance of total bacteria was measured in spring and in autumn, moreover the number of fungi, dehydrogenase activity and CO_2 production were higher in the soils.

Based on the measured microbial properties of the soil, this study proved that the biological activity of the soil remained more intense in the Solonetz soil. This is due to the fact that it is located on a natural pasture, undisturbed by agricultural works, which are specific to arable and horticultural crops.

Key words: soil bacteria, fungi, dehydrogenase, CO_2 -production

INTRODUCTION

Nowadays, the environment is under different stress, to which agricultural production also contributes significantly (Marselek, 2006). Industrial agricultural production has resulted in increased environmental damage, and one of the subjects of this process is the soil (Hernandez et al., 2021). In the production area the organic matter content is decreasing, which affects nutrient management, water retention and capacity, soil structure, buffer capacity and many other physical, chemical and biological soil properties, overall, the soil quality (Meng et al., 2019; Ma et al., 2022). In point of view of environmental protection, the continuous monitoring of different soils is very important task.

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However, the long-term preservation of soil productivity is only possible in conjunction with the preservation of soil biodiversity (Wolińska and Stepniewska, 2012; Veres et al., 2015). It is necessary to reduce and limit those activities that play a role in soil pollution in the long term (such as the use of large-scale chemicals and toxic substances) (Ángyán et al., 2003) and may contribute to the deterioration of soil life and the reduction of biodiversity (Biró et al., 2018). We cannot talk about healthy soil without adequate soil life (Wall et al., 2015; Ling et al., 2021).

MATERIAL AND METHOD

In the Agrochemistry and Soil Science Institute, of Debrecen University, some microbiological characteristics of three different soil types - with different crops were examined (the number of bacteria, number of microscopic fungi, soil respiration and dehydrogenase activity). The three soil types were: (1) Calcareous Chernozem (*Chernozems*) with corn (*Triticum aestivum L.*) from Debrecen - Látókép - $\text{pH}_{(\text{H}_2\text{O})} = 6.8$; (2) Humus sandy soil (*Arenosols*) from Debrecen - Pallag - $\text{pH}_{(\text{H}_2\text{O})} = 5.8$, with fruit (*Prunus cerasus L.*) – and (3) Solonetz soil (*Solonetz*) with grassland Hajdúnánás – Tedej, $\text{pH}_{(\text{H}_2\text{O})} = 6.6$.

Soil samples were taken during a period of 2 years (2019 - 2020), in the spring (in May) and in autumn (in September), from the top 20 cm, the most active layer of the soil.

Moisture content was measured gravimetrically, by drying the soil at 105 °C for 24h (Buzás, 1988). The total number (Colony Forming Unit, CFU) of bacteria (bouillon plate) and quantity of microscopic fungi (peptone - glucose - agar) were determined, by plate count method, according to Szegi, 1979. The CO₂ production was measured after a 7 day incubation according to Öhlinger et al., 1996. Dehydrogenase activity characterises mainly the intensity of degradation processes. Its determination is based on the reduction of the used artificial hydrogen acceptor (MSZ-08-1721/3-86).

Variance analyses (*ANOVA*) with *Duncan post hoc test* ($p \leq 0.05$) was used for statistical evaluation and *Pearson's correlation* ($n = 8$) were used to found relationships between soil examined properties (applied programs: IBM SPSS Statistics 23).

RESULTS AND DISCUSSION

The climate change, the decreasing amount of precipitation and its extreme distribution is a particularly important question nowadays (Borelli et al., 2020). The soil moisture determined the microbial soil activity (Borowik and Wyszowska, 2016). The moisture content of the soil samples was average in the soils during the two years (11 - 19 %). The lowest value was

found in Pallag sand (11.10 % on average), while the highest value was measured in the Chernozem soil (19.22 % on average). We also observed that during the two consecutive years the moisture content in the soil decreased in all three areas, to a lesser extent in the Chernozem (19.28 - 19.15 %) and the Solonetz soil (12.64 - 11.02 %), at the same time, the soil moisture in the second year was significantly lower in the area of sand (12.61 - 9.58 %) in the orchard. This is probably, related to the fact that sandy soils are poor in colloids and have a low water holding capacity.

Based on two-year sampling averages, the total number of soil bacteria was highest in soil from Cernoziom ($13.20 \times 10^6 \text{ g}^{-1}$). It was significantly lower in the Solonetz soil ($10.40 \times 10^6 \text{ g}^{-1}$), although it is located on a pasture. The lowest abundance of bacteria was registered in the sandy soil ($6.12 \times 10^6 \text{ g}^{-1}$). Thus, it can be concluded that the number of bacteria in the examined soils was generally higher in spring.

The number of microscopic fungi was higher in the Solonetz soil ($9.93 \times 10^3 \text{ g}^{-1}$) during the two years of the study. This is probably also related to the permanent plant cover - the root mass presence. As a result, the number of microscopic fungi was significantly lower for both Sand and Chernozem soils. The number of microscopic fungi showed higher values in autumn for all three sampling areas, where greater activity was determined in spring (Fig. 1).

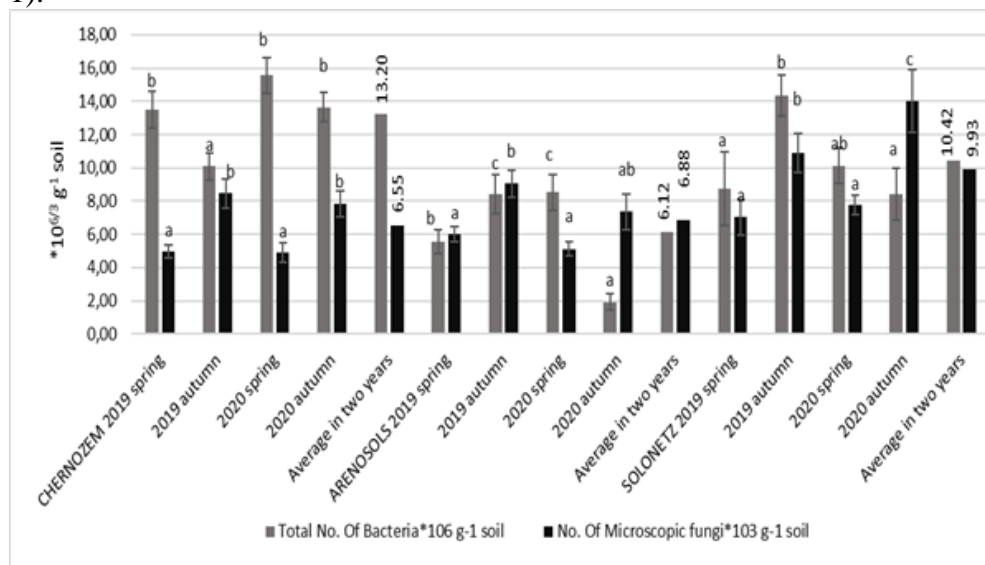


Fig. 1. Seasonal variation of the number of soil bacteria and microscopic fungi during the years 2019-2020, in different cultivation conditions

Total numbers of microscopic bacteria and fungi - play an important role in various soil geochemical and decomposition processes (Bloem et al., 1997; Prasad et al., 2020). The research carried out in this field, shows that

Chernozem has a high biological activity (Veres and Zsuposné, 2003; Nechaeva et al., 2019; Rieznik et al., 2021). Our results are confirmed by others researches, because the highest total number of bacteria was measured on the Chernozem soil ($13.20 \times 10^6 \text{ g}^{-1}$) in the wheat culture, and the lowest in the orchard on the sandy soil ($6.12 \times 10^6 \text{ g}^{-1}$). At the same time, the higher number of microscopic fungi ($9.93 \times 10^3 \text{ g}^{-1}$) was cultured from the Solonetz soil, which was uncultivated, pasture.

The activity of the dehydrogenase enzyme was the highest in the Solonetz soil during both years of the study. The average value was $240.32 \mu\text{g INTF g}^{-1} \text{ soil}$, almost half of which was measured in the Chernozem soil ($133.04 \mu\text{g INTF g}^{-1} \text{ soil}$). No significant differences were found in Chernozem soil between the values registered in spring and autumn. Dehydrogenase activity in the sand soil was the smallest ($71.93 \mu\text{g INTF g}^{-1}$). In the sand soil and in the Solonetz soil, the dehydrogenase was more active in autumn (Table 1).

Table 1

The activity of dehydrogenase enzyme and CO_2 production in different soil cultivation conditions, during the spring and autumn of the years 2019-2020

Soil Types and Samplings	Dehydrogenase $\mu\text{g INTF g}^{-1} \text{ soil } 2 \text{ h}^{-1}$	CO_2 -production $\text{mg } 100\text{g}^{-1} 7 \text{ day}^{-1}$
CHERNOZEM		
2019 spring	129.93a ± 12.93	16.94a ± 8.79
2019 autumn	134.64a ± 19.29	22.03b ± 13.12
2020 spring	129.88a ± 18.05	24.42b ± 12.17
2020 autumn	137.72a ± 17.35	22.96b ± 11.79
Average in two years	133.04	21.59
ARENOSOLS		
2019 spring	66.71ab ± 10.82	13.72a ± 8.20
2019 autumn	77.58ab ± 15.43	15.03ab ± 7.35
2020 spring	57.90a ± 12.11	17.08ab ± 10.49
2020 autumn	85.53b ± 11.09	17.68b ± 8.23
Average in two years	71.93	15.88
SOLONETZ		
2019 spring	161.50a ± 22.04	16.38a ± 14.34
2019 autumn	274.08b ± 8.73	21.02b ± 12.73
2020 spring	183.55a ± 14.84	20.16ab ± 10.85
2020 autumn	342.18c ± 16.98	18.86ab ± 11.54
Average in two years	240.32	19.10

Based on the studies of Szeder et al., 2008, dehydrogenase is an index that expresses the microbiological activity in the soil. Soils of grassland create a special environment for the organisms living in them. The large root system

of grassland provides a significant source of organic matter for microorganisms (Kátaí and Veres, 2003). The measured dehydrogenase enzyme activity of the soils also contributes to this, which also proved to be highest in the Solonetz soil. This enzyme activity was lowest on the sand soil.

Regarding the CO₂ production, significant differences were determined among the two years. The CO₂ production was the highest on the Chernozem (average value of 21.59 mg 100g⁻¹ soil), on Solonetz soil (19.10 mg 100g⁻¹ soil) and the lowest CO₂ production was registered in the humus sand soil (15.88 mg 100g⁻¹ soil). In the study, the production of CO₂ presented in most cases, higher values in autumn, except for the 2nd year of study in Chernozium soil (Table 1).

Following the analysis of possible correlations, those soil values and properties that showed a similar correlation in both test years were highlighted.

Among the examined parameters, correlations were found in the case of the Solonetz soil. Close positive correlation was found between the dehydrogenase enzyme and microscopic fungi ($r = 0.909$; 0.955); between the total number of bacteria and soil respiration ($r = 0.830$; 0.885) (Fig. 2).

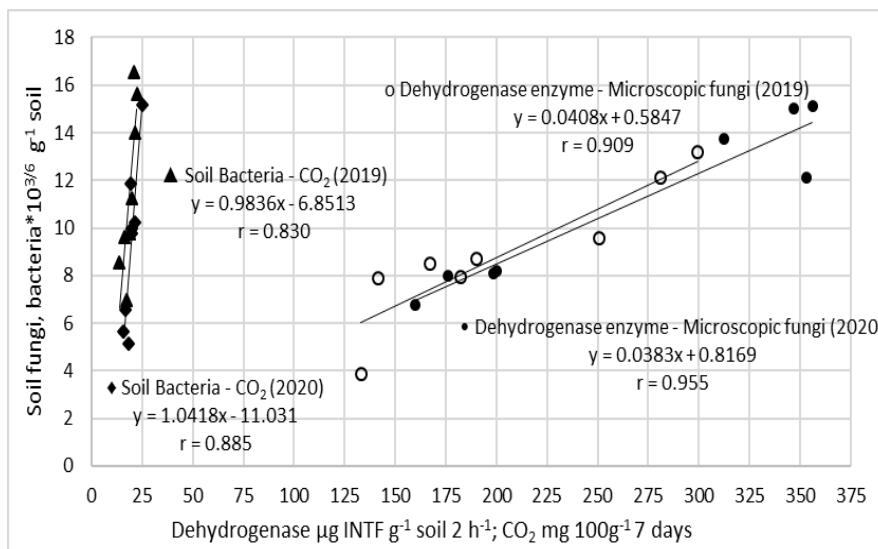


Fig. 2. Close positive (*Pearson type*) correlations on Solonetz soil between some examined microbial parameters ($n = 8$) (2019 - 2020)

On Solonetz soil was found also medium positive correlation between soil moisture content and total number of bacteria ($r = 0.537$; 0.654). In the case of Chernozem soil, only one positive correlation was found in both years, between the soil moisture content and the total number of bacteria ($r = 0.718$; 0.869) (Fig. 3).

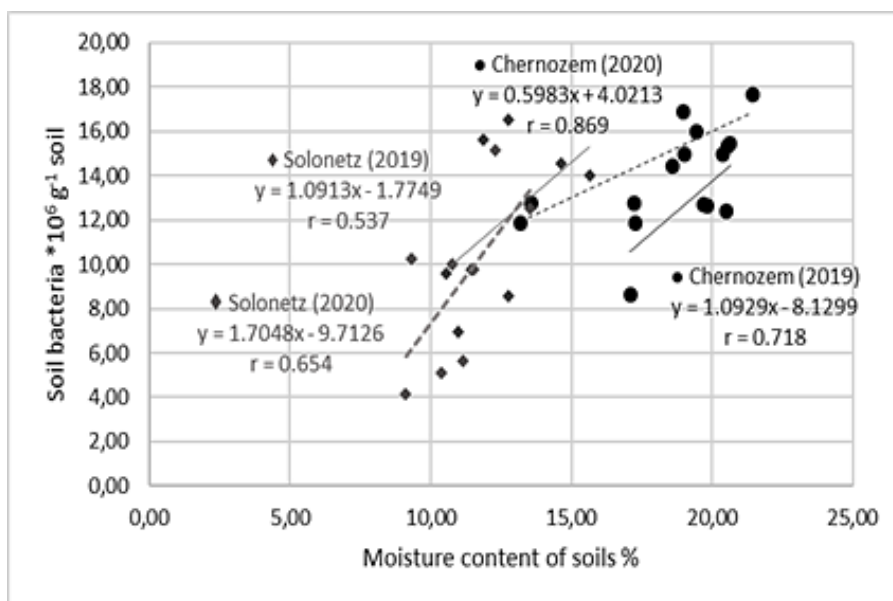


Fig. 3. Correlations (*Pearson type*) on Solonetz and Chernozem soils between soil moisture content and total number of bacteria ($n=8$) (2019-2020)

In the case of sandy soil, were not found correlations between the biological soil properties, in the both years of study.

According to the measurements of Szili - Kovács et al., 2011, there was a significant difference, between the spring and autumn samplings, in most of the measured soil biological parameters.

CONCLUSIONS

Total number of bacteria, total number of fungi and dehydrogenase activity, among the CO₂ production, were studied, in different soil types (Chernozems, Arenosols and Solonetz) and in different soil cultivation. The crop type influenced the soil biological properties.

The soil moisture content at the time of sampling was 11-19 %, in second year decreased in all three areas, significantly in the sand area. The moisture content was a determining factor of soils in the development of microbiological parameters (we proved a positive correlation between moisture content and total number of bacteria on Solonetz and Chernozem soils).

The measured dehydrogenase enzyme activity of the soils, proved to be highest in the Solonetz soil and this enzyme activity was lowest on the sand soil.

The CO₂ production in soils was the highest on the Chernozem, but it was almost similar with the case of the Solonetz soil in the grassland area.

The humus of sand had the lowest CO₂ production. Significant differences were found among the three soils regarding the CO₂ production.

In our study the higher total number of bacteria was measured in the spring; in autumn the number of microscopic fungi, dehydrogenase activity and CO₂ production were higher.

Based on the measured properties, this study proved that the soil biological activity remained more dynamic under the natural grassland ecosystem.

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