PROCEEDINGS & ABSTRACTS

ISSN 1848-5456

7th international scientific/professional conference

AGRICULTURE IN NATURE AND ENVIRONMENT PROTECTION

Vukovar, Republic of Croatia, 28th –30th May 2014

AGROGLAS
Biweekly magazine for agriculture,
food production, rural living and animal keeping

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7th international scientific/professional conference

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Published:	Glas Slavonije d.d., Osijek
Publisher:	Ivan Šimić, ing.
Editors in Chief:	prof. dr. sc. Mirjana Baban Doc. dr. sc. Boris Đurđević
Tehnical and graphical Editor:	Davorin Palijan, dipl. dizajner
Printed by:	Glas Slavonije d.d., Osijek
Edition:	200
ISSN	1848-5456

under the auspices / pod pokroviteljstvom

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izvorni znanstveni rad /original scientific paper

Labile soil organic carbon relationship with the microbial soil properties

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Abstract

The purpose of this study was to explain relationship of labile soil organic carbon and microbiological properties of chernozem soil. Soil samples from plow layer of different winter wheat based cropping systems and native sod were analysed. Higher content of labile soil organic carbon was found on the native sod compared with the agricultural experimental plots. Regading microbiological activity chernozem has showed respectable values as long-term intensive agricultural utilization was conducted. Hot water extractable carbon was found to be correlated with the total number of the microorganisams, DHA, oligonitrophilic bacteria and actinomycetes, but not with the fungi.

Key words: micobiological activity, cropping systems, winter wheat, soil organic matter

Introduction

The presence of the specific groups of the microorganisms in soil is responsible for the processes of synthesis or degradation of organic and inorganic matter that could impact soil fertility (Milosevic et al., 1997), and contribute to soil physical regime. Generally, availability of the fresh OM content is a limiting factor for the microbial populations, because it is a source of energy for their metabolism (Milosevic et al., 2000). However, ecological conditions could also hamper microbial development as well as available nitrogen. According to the authors Tintor et al. (2009) on the intensively used arable soils, excessive use of fertilizers and pesticides is responsible for the soil acidification and changes in microbial population. In addition to that the use of heavy machinery and a large number of passes led to soil compaction and poor aeration, and thus reduce the number of aerobic microorganisms and their activity. The number and activity of microorganisms was significantly altered in the soil under monoculture compared with the rotation cropping (Jarak et al., 1999). Growing crops in monoculture is associated with the accumulation of root exudates that favor development of certain microorganisms. Jarak et al. (1993) also found high microbiological activity in chernozem regardless to cropping technology due to the favorable chemical and physical soil properties, while its enzymatic activity increased under crop rotation. Commonly, microorganisms could compete plants for the nutrients in soil, and yield could be significantly reduced on the soils with lower fertility

(Šeremešić, 2012). Various microorganisms can be manipulated to produce beneficial effects for agriculture and the environment, e.g., rhizobia to increase plant available N, mycorrhizal associations to assist nutrient and water uptake, or biological control of plant pests to reduce chemical inputs. This diversity is influenced by almost all crop and soil management practices, including the type of crops grown. Regarding the interaction of soil organic matter and microbial activity soil labile carbon is considered as carbon pool related with activity and abundance of microorganisams. Therefore labile OM is the most dynamic reservoir of the organic carbon in the soil (Janzen et al., 1998) and an important indicator of the soil quality (Bremer et al., 1995). Usually this fraction makes up only 1-5% of the total soil OM and it is fundamentally linked with the changes in the rhizosphere. In sustainable systems of crop production number and activity of different microbes could be considered as the indicator soil degradation intensity or soil health.

The aim of this paper is to access the relationship between labile soil organic matter content and microbiological properties of chernozem soil.

Material and methods

The study was conducted at the crop rotation experiment (Plodoredi) and the IOSDV Experiment (International organic nitrogen long-term Fertilization experiment) located at the Rimski Šančevi Experimental Station of the Institute of Field and Vegetable Crops in Novi Sad (N 45° 19`, E 19° 50`). The following treatments were analyzed: 4-year rotation (sugar beet/spring barley/corn/wheat) with manure 40t ha^{-1} (BØ); 4-year rotation + 100 kg N ha^{-1} (B2), 4-year rotation NPK + 200 kg N ha^{-1} without crop residues (A4), 4-year rotation NPK + 200 kg N ha^{-1} with crop residues (C4), unfertilized 2-year rotation (N2), unfertilized 3-year rotation (N3), wheat monoculture + 100 kg N ha^{-1}(MO), fertilized 2-year rotation + 100 kg N ha^{-1} (Đ2), fertilized 3-year rotation + 100 kg N ha^{-1} (Đ3), native sod – control (NV). The trials were established on a chernozem soil. Conventional tillage practice including moldboard plough, harrow disc, and cultivator was performed every year. Harvest residues were incorporated by ploughing. Winter wheat sowing was done in October (20–30. X) with seeding rate of 250–270 kg ha–1. During the observed period leading wheat varieties were grown. The soil samples (0-20 cm) used in this study were taken in 2007-2009 period, after winter wheat harvest (july). To separate the labile fraction of the hot water extractable organic matter (HWOC) in the soil the modified Ghani (2003) procedure was used. The samples were taken in a disturbed state, and were kept in the laboratory air-dried, up until the moment the analysis was performed. For the purpose of determining the soil OM content in the soil samples, the titrimetric Tyrin method was used and the soil OM content was calculated by multiplying the C content with the correction factor f=1,724 (USDA, 1996).

The distribution of soil microorganisms was assessed on the basis of indirect dilution method on appropriate nutritive media. The total number of microorganisms was determined on soil agar. Number of fungi was determined on Czapek - Dox growth medium and number of actinomycetes on a synthetic medium. The number of ammonifiers were determined on mesopepton agar – MPA, the number of azotobacter on nitrogen-free medium using „fertile drops“ method and N-fixing bacteria on Fiodor medium. Incubation temperature was 28°C, while incubation time depended on the tested group of microorganisms. All microbiological analyses were performed in three replications and the average number of microorganisms was calculated at 1,0 g absolutely dry soil. Dehydrogenase activity was determined according to the method of Thalmann (1968). The data analyzed were statistically assessed using the analysis of the variance method on a significance level of α=0,05, and the LSD test was used for individual comparisons of the treatments' means.

Results and disscusion

The obtained results indicate that OM differ significantly at the investigated crop rotation systems. Among investigated cropping systems higher total OM content in soil were found in B2>NV>BØ>C4>A4>MO>D3>D2>N3>N2 treatment, respecively (Šeremešić, 2012). The total HWOC content might be an indicator of general soil fertility as there is more HWOC in the soil with the higher OM content, due to the processes of intensive transformation of the fresh OM (Figure 1). Since HWOC is considered as an indicator that reflects the microbiological activity to a great extent, the differences which exist between the treatments can derive from the soil biogenesis (Sparling, et al., 1998; Šeremešić et al., 2013). Based on that, it is assumed that the number of the microorganisms was not a limiting factor in the soil, but accessibility of the substrate for the microbiological degradation.

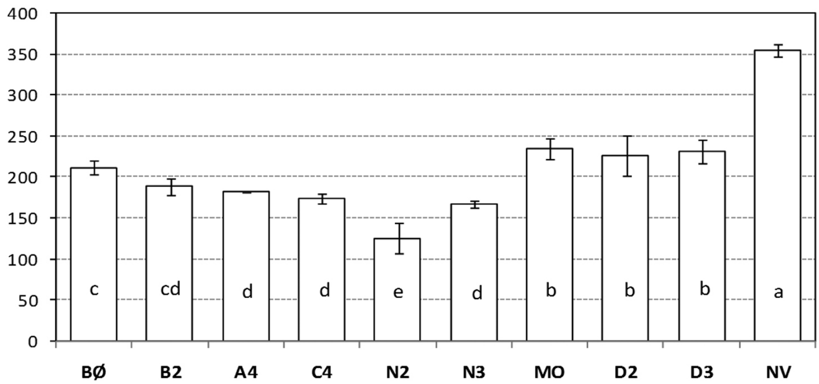

Figure 1: Hot water extractable carbon (HWOC) in soil samples

Total number of micoorgnisams was higher in soil taken under native vegetation and lower number was found on the plot were crop residues were removed (Table 1). Obtain results emphasized the importance of crop residue incorporation for maintaining soil microbial activity. Azotobacter activity was found to be higher at 3-year fertilized rotation and lowest at the unfertilized plots. This could be explained with the nitrogen from previous crops that remain in the soil that accelerate azotobacter acitity. According to research by Ladd and Paul (1973) and Camiña et al. (1998) there is a positive correlation between the total number of microorganisms in the soil and the activity of the enzyme dehydrogenase. Higher dehydrogenase activity indicates a higher rate of respiration, and the intense mineralization of fresh organic matter and humus. Activity of this enzyme in monoculture wheat on average was the highest, which is contrary to previous research conducted at the same experiment (Đuric et al., 2004). Beese et al. (1994) examined the enzymatic activity of the soil on which wheat is grown in crop rotation and monoculture and found lower activity compared with the enzymatic activity of the soil without vegetation.

Table 1: Micobiological soil propeties of the investigated cropping systems natural sod

Treatments	Total number	Azotobacter	Dehidrogenze	Oligonitophilic	Ammonifiers	Fungi	Actino-mycetess
	(x107g-1)	(x102g-1)	(µg TPF g-1)	(x105g-1)	(x107g-1)	(x105g-1)	(x105g-1)
BØ	193,5	137,7	331,5	150,3	62,2	8,3	56,8
B2	288,2	125,9	436,3	218,7	61,7	14,2	56,7
A4	32,0	103,4	389,2	188,5	32,0	12,0	41,7
C4	194,4	99,1	490,2	203,7	194,2	18,9	60,7
N2	279,6	66,6	376,4	206,9	279,6	21,6	57,3
N3	256,5	48,8	627,2	226,2	350,1	22,4	65,6
MO	205,2	236,1	797,2	191,7	275,0	20,1	53,3
D2	345,6	71,8	540,1	407,0	237,4	27,1	55,6
D3	365,9	276,2	396,3	315,1	276,2	25,8	51,8
NV	462,3	71,6	1044	593,5	211,4	27,9	25,9
Fertilized	238,5	152.0	508,2	254,1	174,4	19,6	53,3
Manure	240,8	131,8	383,9	184,5	61,9	11,2	56,75
Unfertilized	268,0	57,7	501,8	216,5	314,8	22,0	61,45

The obtained values of DHA in monoculture and NV indicate that environmental conditions had influenced microbial activity due to favorable moisture on these plots at the time of sampling. Higher number of the oligonitrophilic bacteria was found at the soil under natural vegetation whereas lower number was in cropping systems were manure was applied. Oligonitrophilic bacteria are major indicators of the soil nitrogen regime. They showed high sensibility to increasing N fertilization rates (Mandić et al, 2013). The increasing number of microorganisms ammonifiers (microorganisms that decompose organic nitrogen compounds) were observed in the unfertilized treatments (N3 and N2) since N mineralization was excluded. Similar results were obtained in the Đurić et al. (2004) study on the same experimental site. Number of fungi was higher in the 2-year fertilized rotation and lower in soil samples from 4-year rotation where manure was applied. Higher number of actinomycetess was determined in the unfertilized 3-year rotation whereas lower number was found 3-year fertilized rotation.

Hot water extractable carbon content was found to be significantly correlated with the total number of the microorganisams, DHA, oligonitrophilic bacteria and actinomycetes (Table 2). Generally, synthesis and protection of soil organic matter is related with soil fungi (Six et al., 2001; Riling et al., 2002). However, in our study the enriched labile fraction is more related with the microbial activity, therefore we assume that the enriched carbon fraction on chernozem is less dependent on fungi compared to other studies. This could be explained with higher pH value and Ca2+ content in the soil. The complexity of HWOC indicates that its formation is related with the root activity, the fresh organic matter production (root exudates), manipulation with plant residue and also ecological condition (temperature and available water) necessary for microbial development.

Table 2: Correlattion of HWOC and micobiological soil propeties

	SOC	Total number	Azotobacter	DHA	Oligonitophilic	Ammonifiers	Fungi	Actino-mycetes
SOC	1	0,59*	0,17	0,76**	0,81**	0,00	0,42	-0,78**
Total number		1	-0,01	0,49	0,80**	0,47	0,77**	-0,29
Azotobacter			1	-0,1	-0,19	0,04	-0,03	0,01
DHA				1	0,69*	0,37	0,56	-0,57
Oligonitophilic					1	0,24	0,75**	-0,7**
Ammonifiers						1	0,78**	0,25
Fungi							1	-0,23
Actino-mycetess								1

Conclusion

Our study showed that labile hot water extractable carbon content was correlated with the total number of the microorganisams, DHA, oligonitrophilic bacteria and actinomycetes. Number of fungi was less associated with labile organic carbon as theire number was lower in soil with higher pH values. Moreover, carbon enrichment in soil derives from the root activityand the fresh organic matter availability. To maintain and to preserve higher level of soil organic carbon crop residue must be regularly incorporated with fertilizers.

Acknowledgment

This study is part of the TR031072 project financially supported by the Ministry of Education and Science of the Republic of Serbia.

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Odnos između labilnog organskog ugljika i mikrobioloških svojstava tla

Sažetak

Cilj ovoga rada je da se objasni odnos između labilnog organskog ugljika tla i mikrobioloških svojstava na černozemu. Analizirani su uzorci tla uzorkovani iz oraničnog sloja različitih sustava obrade kod ozime pšenice i nativnog poljskog pokrivača. Veći sadržaj labilnog organskog ugljika utvrđen je kod nativnog poljskog pokrivača uspoređujući ga sa poljoprivrednim eksperimetalnim površinama. Također, černozem je imao usporenu mikrobiološku aktivnost dok god se vršila intenzivna dugoročna poljoprivredna proizvodnja. Ugljik analiziran ekstrakcijom toplom vodom bio je u korelaciji sa ukupnim brojem mikroorganizama, DHA oligotrofnim bakterijama i aktinomicetama, ali ne i gljivama.

Ključne riječi: mikrobiološka aktivnost, sustav obrade tla, ozima pšenica, organska tvar tla