COMPARATIVE EVALUATION OF SOIL TYPES WITH DIFFERENT PROPERTIES

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Abstract: *The aim of research work was to determine the most important physical, chemical and microbiological properties of five different soil types - erubase, rendzina, solonchak, meadow solonetz, and calcareous chernozems - located in Hungary and make a comparison among the properties. The first four soil types have extreme physical and chemical properties, all was natural grassland, the fifth one was a cultivated chernozem soil from a fertilization experiment, and the control and two different dosages of fertilizer treatments were used for investigation. In order to measure the effect of relief on soil properties, two soil samples were taken from every soil type, one from a higher, one from the deeper exposure, except the calcareous chernozem. Results were evaluated and among the soil parameters significant differences were measured at 5%-level in the majority of the cases. Large differences were experienced among the properties, especially in the texture, pH, humus and nutrient content. The texture was measured from sandy loam to heavy clay; pH-values were from acidic to alkaline. Microelement content generally was higher in the natural soil, than in the cultivated ones, especially the zinc and manganese content. Regarding the microbiological properties of soils, the quantity of soil microorganisms (total number of bacteria and microscopic fungi) was higher in soils with native vegetation, than in the cultivated soils. Parallel with it, the measured enzymes activities – phosphatase, saccharase, urease and catalase - also were generally higher in the natural soils, than in the cultivated ones, one exception is the salt effected solonchak soil. In contrast with it, the numbers of two important physiological groups of bacteria - cellulose decomposing and nitrifying bacteria - were higher in the cultivated soils. When we compared the different results within one soil type, higher number of microorganisms and more intensive microbial activity was measured in the soil from higher exposure, than in soil from deeper exposure. It means that the microrelief has great importance in the occurrence and activity of living organisms of soil. The soil properties restrict hardly the possibilities of plant production, grassland or forests could be found in those places, where some soil physical and chemical properties are extreme, but at the same time these soils have high microbiological activity.*

Key words**:** *Physical and chemical features of soils, plant covering, micro- and mezorelief, occurrence of soil microorganisms, microbial activity of soils, soil enzymes.*

INTRODUCTION

The primary aim of the sustainable plant growing is to reach the optimal yield production with good quality, besides the application of environmental friendly technologies. Natural ecological factors and the different agrotechnical methods influence these expectations. Among the ecological factors, the physical, chemical and microbiological properties of soil have great importance (KÁTAI, 1992; ROBERTSON, et al., 1997), but these properties are influenced by micro and mezorelief (BASTIDA et al., 2006; SANTRUCKOVA et al., 2004). Without ecological knowledge the rational soil cultivation, the preservation of soil fertility, sustainable agricultural production is unimaginable. Fields without cultivation are used as pasture, grassland or forest is on it. These soils generally have some extreme properties which are not, or hardly able to tolerate by culture plants in some aspects.

In Hungary till 1980, the nutrient content of cultivated soils increased due to the satisfactory fertilization, so good quality and proper quantity of yield was harvested regularly (BOCZ 2001). In the 1990, the utilization of fertilizers drastically decreased (PEPÓ 2007), later a little increase was experienced and at present there is a stagnancy in it. Nowadays the nutriment balance is negative because only half quantities of nutrient are compensated back to the soil, which are harvested by yield (SÁRVÁRI & BOROS, 2009). Life conditions of organisms living in soil are favourably affected by the reasonable agrotechnical technologies (VIRÁG, 1981; ZVYGINTSEV, 1987; KÁTAI 2006, 2010; KOVALEV & KOVALEVA, 2011).

MATERIAL AND METHODS

In the research work the physical, chemical and microbiological properties of five different soils (erubase, rendzina, solonchak, meadow solonetz, and calcareous chernozems) were examined and compared. Among the five soil types, four soils were natural fields, and have extreme physical and chemical properties in some aspects. The fifth soil type was a cultivated chernozem soil from a fertilization experiment, and the control and two different dosages of fertilizer treatments were used for investigation.

The fertilization experiment was set up in 1983 on calcareous chernozem, at the eastern part of Hajdúsági region. The plant culture was corn monoculture without irrigation, in this paper the effect of three treatments [control, middle dose ($N_{120}P_{90}K_{90}$), and large dose ($N_{240}P_{180}K_{180}$)], were evaluated. The provenance, relief relation and vegetation can be seen in table 1. Soil samples were taken in June, 2006.

Table 1.

The place of origin, relief and vegetation of the soils examined

Number of soils	Type of soil	Provenance of soil	Relief	Vegetation
1.	Erubase	Nagymező	crest	grassland
2.	Erubase	Nagymező	bottom of slope	grassland
3.	Rendzina	Pilis	higher exposure	grassland
4.	Rendzina	Pilis	deeper exposure	grassland
5.	Solonchak	Apajpuszta	higher exposure	salt marsh grass *Puccinellia limosa*
6.	Solonchak	Apajpuszta	deeper exposure	whitetop *Lepidium draba*
7.	Meadow solonetz	Hortobágy	higher exposure	hard fescue *Festuca pseudovina*
8.	Meadow solonetz	Hortobágy	deeper exposure	*Camphorosma ovata*
9.	Calcareous chernozem controll	Látókép	normal exposure	maize *Zea mays*
10.	Calcareous chernozem $N_{120}P_{90}K_{90}$	Látókép	normal exposure	maize *Zea mays*
11.	Calcareous chernozem $N_{240}P_{180}K_{180}$	Látókép	normal exposure	maize *Zea mays*

Each sample was air-dried for physical and chemical analysis from part soil moisture was determined. The physical, chemical and microbiological investigations were made in the laboratories of the Institute of Agrochemistry and Soil Science. Plasticity index was determined according to *Arany* (BUZÁS, 1993). Humus content, lime content, and pH were measured (BUZÁS, 1988). The plant available macro elements, phosphorous and potassium content was measured from AL (ammonium-lactate) extraction from soils (GEREI, 1970).

Number of colony forming units (CFU) of cultivable microorganisms and microscopic fungi was determined from ten-fold dilution series of fresh soil samples in Petri dishes (SZEGI, 1979). Aerobic cellulose decomposing and nitrifying bacteria were measured by POCHON &

TARDIEUX (1962) method. The phosphatase activity was measured by KRÁMER-ERDEI (1959 cit. SZEGI, 1979), the saccharase activity after FRANKENBERGER (1983), the urease activity was measured on the basis of ammonia evolution (SZEGI, 1979); the catalase activity was measured by SZEGI (1979).

RESULTS AND DISCUSSIONS

The more important physical, chemical and microbiological properties of the examined soils can be seen in table 2-4.

On the bases of the more important physical, chemical properties, the erubase soil (1., 2.) had extreme quantity of clay, with high quantity of water content and water holding capacity in both two sampling place. The texture of rendzina (3.,4.) was clay loam, the determined moisture content was lower by 12-16%, than it was in the erubase soils. It is important to notice, that moisture content of erubase and rendzina soils were higher in the soil samples origin from the higher exposure places. These soils originated from the Northern Middle Mountain and Pilis, at about 800 m altitude. Due to the mezorelief and zone significant differences were measured among the moisture content of soils. The texture of solonchak soil (5., 6.) was sandy-loam, loam, the meadow solonetz (7., 8.) had loam, clay-loam category, while the texture of the three calcareous soil was loam. The moisture content of the solonchak, meadow solonetz and chernozem soils were very low at the time of investigation.

Table 2.

Physical and chemical features of the soils examined

Number of soils	Arany-type plasticity index	Moisture content m/m %	pH		Hydrolytic acidity (y_1)	Water solubility salt %	Na_2CO_3 %	$CaCO_3$ %
			dH_2O	M KCl				
1.	76	40,96	6,56	5,92	19,25	0	0	0
2.	65	37,84	5,17	3,98	50,00	0	0	0
3.	47	28,89	6,45	5,56	11,75	0	0	0
4.	45	21,48	5,19	3,99	41,50	0	0	0
5.	37	8,35	9,49	8,92	-	0,58	0,30	19,40
6.	38	9,83	9,12	8,46	-	1,03	0,18	15,80
7.	41	8,62	6,68	5,40	15,75	0,09	0	0
8.	45	10,88	8,32	7,41	-	0,58	0,14	2,1
9.	41	7,80	8,03	7,35	-	0,02	0	9,0
10.	41	7,67	7,92	7,34	-	0,02	0	9,2
11.	42	6,96	7,98	7,33	-	0,03	0	7,9
LSD5%	3,60	0,21	0,28	0,15	0,51	0,0051	0,009	0,07

On the bases of chemical properties of soils (table 2.) both the erubase and both rendzina soil, higher pH was measured at the higher exposure soil sample (1., 3). The pH values of deeper exposure of these soil types were strongly acid, and in these soils the hydrolytic acidity was extremely high. It was indicated in advance by the big differences between the two pH-values. The pH of solonchak soil with high salt content (5., 6.) is strongly basic, caused by the considerable quantity of soda and lime content. The higher exposure of meadow solonetz soil (7) had slightly acid pH, it due to the leaching of salt content. At the same time the deeper exposure soil sample (8) showed slightly basic pH with higher salt content and less quantity of soda and lime content. The pH of calcareous chernozem soils originating from fertilization experiment (9., 10., 11.) was slightly basic, lime content of these soils was about 8-9%.

Regarding the nutrient store, nutrient supplier ability, and some element content of soils are seen in the table 3.

The largest quantity of humus was found in the erubase (1., 2.) soils. Rich in humus the rendzina soil (3., 4.) too with 4-6% humus content. Humus content of the two salt effected soils (5., 6., 7., 8.) is nearly similar with 1,76-2,81% humus. On the bases of humus content the calcareous soil could be qualified to middle supplied with 2,53 - 2,81% humus.

Both the erubase soils (1., 2.) and both rendzina (3., 4.) contained a large quantity of ammonium-nitrogen due to the huge amount of humus and the low pH-value. Considerable ammonium nitrogen was measured in the two meadow solonetz soils (7., 8) too. The higher exposure erubase soil (1.) had relatively large quantity of nitrate nitrogen, this parameter is less in the deeper exposure erubase (2.) and rendzina soils (3., 4.). It is interesting that the solonchak soils (5., 6.) and the cultivated calcareous chernozems (9., 10., 11.) had the nearly same quantity of nitrate nitrogen (4,5-5,8; 4,7-8,7).

On the bases of ammonium-lactate soluble (AL) phosphorus the examined soils could be qualified to poor supplied category, except the chernozems. Considerable quantity of phosphorus content was measured in the treatments of fertilization experiment, where the increasing doses of fertilizer were shown up (612-739 P_2O_5 mg kg^{-1}). Evaluation the soils according to the easily available potassium, the examined soils generally had middle supplied category in potassium. The doses of potassium fertilizer could be shown up in the result (272-421 K_2O mg kg^{-1}), but much less, than in case of phosphorus.

Table 3.

Humus - available nutrient and some important element contents of the examined soils

Number of soil	Humus %	NO_3-N mg kg^{-1}	NH_4-N mg kg^{-1}	P_2O_5 mg kg^{-1}	K_2O mg kg^{-1}	Mg mg kg^{-1}	Na mg kg^{-1}	Zn mg kg^{-1}	Cu mg kg^{-1}	Mn mg kg^{-1}
1.	7,40	19	14	84	221	242	23	18,0	4,5	200
2.	6,52	1,6	21	57	92	50	20	11,7	2,0	170
3.	5,90	3,5	36	123	179	119	22	8,4	1,2	360
4.	4,08	2,8	18	63	336	234	18	5,4	1,5	510
5.	1,76	5,8	<0,2	69	194	38	2938	1,1	1,8	55
6.	1,80	4,5	0,7	102	102	50	3231	1,0	1,8	53
7.	2,18	1,0	8,4	136	136	331	770	4,0	6,3	325
8.	1,98	4,5	9,4	497	497	256	3717	1,0	7,0	250
9.	2,53	4,7	2,3	612	272	283	39	2,2	3,0	35
10.	2,61	5,0	2,9	691	294	306	39	2,3	2,8	30
11.	2,81	8,7	1,7	739	421	292	52	2,5	3,0	33
LSD5%	0,43	0,54	0,89	4,1	10,13	11,9	33,9	4,2	0,67	23,3

Among the elements the quantity of magnesium, sodium, zinc, cooper, and manganese was measured from soils. The largest quantity of magnesium was measured in the meadow solonetz (7., 8.) soils (256-331 Mg mg kg^{-1}), while the less quantity was determined in the solonchak soils (5., 6.).

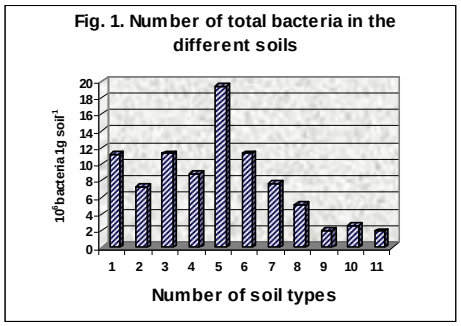
Regarding the sodium content of soils, by far the largest quantity of sodium was measured in the two solonchak soils and especially the deeper exposure meadow solonetz (770-3717 mg kg^{-1}). This result was close correlation with the water soluble salt content of soils. The sodium content was between 18-52 mg kg^{-1} in the other soils.

The largest quantity of zinc content (11,7-18 mg kg^{-1}) was measured in the erubase (1., 2.) soils but considerable zinc was determined in the rendzina (3., 4.) soil too. In the soils

from fertilization experiment, only about one eight quantity of zinc could be measured (2,2-2,5 mg kg^{-1}). The less quantity zinc was shown in the salt effected soils.

The largest quantity of cooper content (11,7-18 mg kg^{-1}) was measured in the meadow solonetz soils (7., 8.) followed by the erubase (1., 2.) and chernozem (9., 10., 11.) soils. Fewer quantity of copper was shown in the rendzina (3., 4.) and solonchak (5., 6.) soils. Regarding this microelement, there weren't so large differences among the results, than in the other microelements.

The largest quantity of manganese was measured (360-510 mg kg^{-1}) in the rendzina (3., 4.) and the meadow solonetz (250-325 mg kg^{-1}) soils (7., 8.), and only about one tenth of these quantities of manganese could be shown (30-35 mg kg^{-1}) in the calcareous chernozem soils (9., 10., 11.). The manganese plays an important role in the metabolism processes, so we have to face the deficiency of this microelement in the cultivated soils of fertilization experiment.



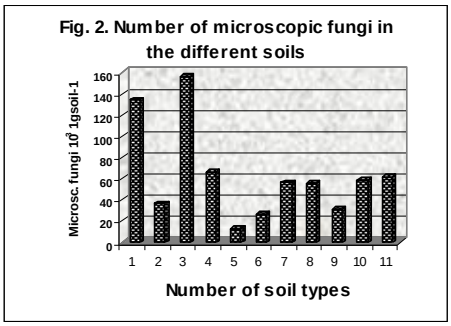


Figure1, 2: Number of bacteria and microscopic fungi in the different soils

Parameters concerning to the population dynamic of soil microorganisms, the total number of bacteria, microscopic fungi, aerobic cellulose decomposing and nitrifying bacteria and four enzymes' activity were evaluated.

In figure 1. The total number of bacteria is shown. The bacteria number was larger by one order in the natural soils, e.g. in the erubase, rendzina and solonchak soil, than it was in the soils from fertilization experiment. Generally larger bacterium numbers were measured in the soil samples originating from the higher exposure places.

The number of microscopic fungi was by far the largest in the erubase (1., 2.) and rendzina (3., 4.) soils. The less number of microscopic fungi was found in the solonchak soil (5., 6.) due to the basic pH (Fig. 2.).

Larger quantity of aerobic cellulose decomposing and nitrifying physiological groups of bacteria were determined in the calcareous chernozem soils, despite of the few quantity of moisture content of these soil samples (Table 4.). Some thousand cellulose decomposing bacteria were shown in the solonchak soil, some thousand nitrifying bacteria in the erubase soil. In the other soils the numbers of these two physiological groups of bacteria were in minor quantity, hardly some hundreds. When the cultivated soils have proper moisture content the bacteria number generally could be much more (KÁTAI, 2006).

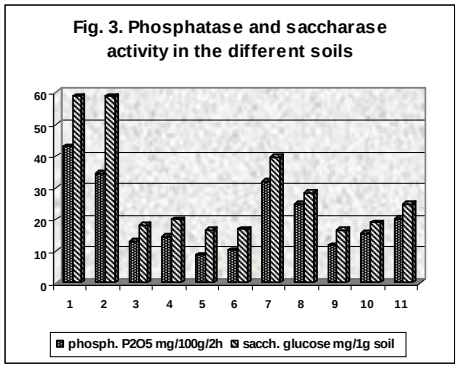
Regarding the microbiological activity of soils, four enzymes activity – phosphatase, saccharase, urease, and catalase – was measured. (Fig. 3. and 4.) In reference to the four soil enzymes the largest enzymes' activities were determined in the erubase soils (1., 2.). In the gradiation the meadow solonetz was the following examined soil, where the phosphatase, saccharase, urease and catalase activity had the second largest values. Among the natural soils

the less phosphatase, saccharase, and urease activity were determined in the soils of rendzina (3., 4.), and the solonchak (5., 6.).

Table 4.

The quantitative changes of microorganisms in different soils

Number of soils	Number of bacteria $*10^6$/g soil	Number of microscopic fungi $*10^3$/g soil)	Cellulose decomposing bacteria $*10^3$/g soil	Nitrifying bacteria $*10^3$/g soil
1.,	11,55	134,15	0,42	3,53
2.,	7,28	36,34	0,12	0,69
3.,	11,26	156,00	0,21	0,14
4.,	8,85	66,14	0,12	0,65
5.,	19,36	13,32	3,30	0,28
6.,	11,28	26,40	2,20	0,28
7.,	7,63	56,42	0,55	0,27
8.,	5,11	56,06	0,33	0,39
9.,	2,05	31,50	6,49	2,4
10.,	2,65	58,50	5,30	9,2
11.,	1,90	62,00	8,34	28,0
LSD5%	2,94	10,45	0,14	0,09



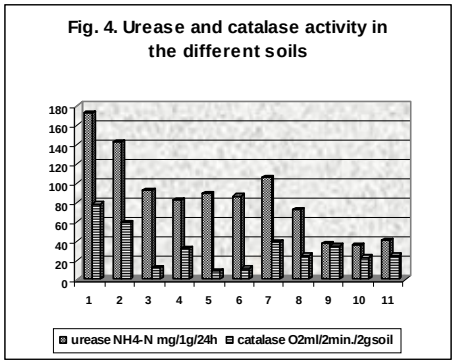


Figure3, 4: Enzymes' activities in the different soils

Comparing the results in the chernozem soils, in the fertilized treatments a moderate increase was experienced in the activities of phosphatase and saccharase, at the same time the catalase activity decreased compared to the control. The urease activity was the less in the cultivated chernozem soils among the five soil types. The catalase activity was nearly the same in the meadow solonetz and chernozem soils.

According to the decreasing scale in phosphatase and saccharase enzyme activities the following order can be put up: erubase soil> meadow solonetz> calcareous chernozem> rendzina> solonchak; the decreasing scales in urease and catalase enzyme activities: erubase soil> meadow solonetz> rendzina> solonchak> calcareous chernozem.

CONCLUSIONS

The extreme soil properties manifested in the texture, it was from sandy-loam to heavy clay, the pH from strongly acidic to strongly basic. In the strongly acid soil the hydrolytic acidity was tremendous, in the strongly basic soils the lime and soda was in high quantity. The largest quantity of sodium was measured in the solonchak soils and especially the

deeper exposure meadow solonetz, this property confirm the salt effected character of soil. This result was close correlation with the water soluble salt content.

The largest quantity of humus was found in the erubase soil, but the rendzina also was rich in humus. Humus content of the two salt effected soils was nearly similar; the calcareous soil could be qualified to middle supplied in humus. On the bases of ammonium-lactate soluble (AL) phosphorus the examined soils could be qualified to poor supplied category, except the chernozems. Considerable quantity of phosphorus and potassium content was measured in the treatments of fertilization experiment, where the increasing doses of fertilizer were shown up.

Among the microelements the quantity of zinc and manganese showed the largest differences between the soils. Large quantity was measured in the erubase, rendzina and meadow solonetz soils and very few in the calcareous chernozem soils. As these microelements play important roles in the metabolism processes, we have to face the deficiency of these microelements in the cultivated soils of fertilization experiment.

Generally the quantity of microorganisms occurring in the examined soils (total number of bacteria and microscopic fungi) was higher in the soils with some extreme properties and originating from natural fields. The total number of bacteria was larger by one order in the erubase, rendzina and solonchak soil, than it was in the soils from fertilization experiment. The largest quantity of microscopic fungi was found in the erubase and rendzina soils, the less in the salt effected soil. While larger number of aerobic cellulose decomposing and nitrifying physiological groups of bacteria was found in the cultivated soils.

The enzymes activities generally were higher in the natural soils than in the cultivated ones. In reference to the four soil enzymes the largest enzymes' activities were determined in the erubase soils. Among the natural soils the less phosphatase, saccharase, and urease activity were determined in the soils of rendzina and solonchak. The catalase activity was nearly the same in the meadow solonetz and chernozem soils. Regarding the results of chernozem soils, in the fertilized treatments a moderate increase was experienced in the activities of phosphatase, saccharase, urease, at the same time the catalase activity decreased compared to the control.

Generally it can be stated that more intensive microbiological activity was experienced in soils from the higher exposure places in every four natural soil implicated by the numbers of bacteria and microscopic fungi as well as four enzymes activities. So the micro-relief has very important role in the occurrence and activity of living organisms of soils.

In soils with extreme properties the possibility of plant cultivation is limited; they can be used for grassland and afforestation, but these soils generally have significant microbiological activity.

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