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Changes in Soil Characteristics in a Mono- and Triculture Long-term Field Experiment

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Nutrient management, irrigation and crop rotation are important parts of plant production technologies, which influence the physical, chemical features, and the biological status of soil, and the ability of the soil community to maintain or restore the soil's production function (SWIFT, 1994). Finally, the soil is the habitat for a diverse community of microorganisms and invertebrate animals, all of which play some role in determining the primary productivity of agro-ecosystems. Long-term experiments are suitable for studying such effects of field operation (POWLSON & JOHNSTON, 1994).

Long-term studies of changes in the biological status in relation to crop production and other components of field operation still have a priority in soil research (SWIFT, 1994). Mention should be made of the analysis of the relationships among biological activities, soil properties and soil management (BRUSSAARD, 1994; FILEP & SZILI-KOVÁCS, 2005).

Soil microbial studies in long-term fertilization experiments (HICKISCH & MÜLLER, 1990; MÜLLER, 1991; HOUOT & CHAUSSOD, 1995; KAUTZ et al., 2004; RAIESI, 2004; LI-XIU et al., 2005) have verified that a balanced nutrient supply of both macro- and microelements (CSATHÓ & RADIMSZKY, 2005) positively affects the energy and material transformation processes in the soil, its biodynamics, as well as plant development. Soil nutrient deficiency and unbalanced fertilizer applications have a negative effect on yield quantity, and also on the diversity of microbial communities and the total microbial biomass in the soil (SZILI-KOVÁCS & TÖRÖK, 2005; ZHANG et al., 2005).

The amount, the composition and the activity of soil microbes are also influenced by the fact whether the crops are grown in monoculture or crop rotation. KREZEL (1977), MARTYNIUK and WAGNER (1978), ELLIOTTE and LYNCH (1994), VIPPER (1999), PALMA et al. (2000) and SELVI et al. (2005) found that in general crop rotation was more favourable for soil microbial processes than monoculture. In monoculture, not only the amount of microbes (KARTVELISVILI, 1983), but the microbial activity of the soil (CO_2-production, cellulose decomposing and enzyme activities) (JAMAR, 1984; GAWRONSKA et al., 1990) is also reduced significantly.

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According to the results of a long-term fertilization experiment going on for more than 30 years on meadow soil (Hajdúböszörmény) KÁTAI and HELMECZI (1995) stated that the total number of bacteria, the amounts of nitrifying and cellulose decomposing bacteria were lower in fertilized monoculture than in fertilized triculture. Whereas in both cultures, the larger fertilizer doses resulted in a higher amount of microbes, but reduced the activity of some enzymes.

In the 6^{th} and 7^{th} year of an other long-term experiment carried out on calcareous chernozem (Debrecen-Látókép), the number of nitrifying bacteria increased considerably due to fertilization in triculture. Larger fertilizer doses stimulated the phosphatase and catalase activity as well. The saccharase and urease activity were higher in monoculture and triculture, respectively (KÁTAI, 1999).

In the present study the influences of fertilization, mono- and triculture, irrigated and non-irrigated systems on the physical, chemical and microbiological soil properties were studied in the 16^{th} and 17^{th} years of the fertilization long-term experiment carried out at Debrecen-Látókép, mentioned above.

Materials and Methods

The fertilization experiment was set up in 1983 in the east part of the Hajdúság loess region, at Debrecen-Látókép on a calcareous chernozem soil. Five fertilization treatments (control, low, low–medium, medium–high and high fertilizer doses) were studied under non-irrigated (A) and irrigated (B) conditions in monoculture and triculture. In triculture the crop rotation was pea–winter wheat–maize. In the maize triculture, winter wheat and maize were grown in 1999 and 2000, respectively. The treatments of the experiment are shown in Table 1.

Table 1

Fertilization treatments of the maize monoculture and triculture under non-irrigated (A) and irrigated (B) conditions (Long-term experiment, Debrecen-Látókép, 1999–2000)

Fertilization rate	A. Non-irrigated conditions		B. Irrigated conditions	
	Treatment number	Fertilizer dose, kg/ha	Treatment number	Fertilizer dose, kg/ha
Maize monoculture				
Control	1.	0	11.	0
Low dose	2.	N_{60} P_{45} K_{45}	12.	N_{60} P_{45} K_{45}
Low–medium dose	3.	N_{120} P_{90} K_{90}	13.	N_{120} P_{90} K_{90}
Medium–high dose	4.	N_{180} P_{135} K_{135}	14.	N_{180} P_{135} K_{135}
High dose	5.	N_{240} P_{180} K_{180}	15.	N_{240} P_{180} K_{180}
Maize triculture				
Control	6.	0	16.	0
Low dose	7.	N_{60} P_{45} K_{45}	17.	N_{60} P_{45} K_{45}
Low–medium dose	8.	N_{120} P_{90} K_{90}	18.	N_{120} P_{90} K_{90}
Medium–high dose	9.	N_{180} P_{135} K_{135}	19.	N_{180} P_{135} K_{135}
High dose	10.	N_{240} P_{180} K_{180}	20.	N_{240} P_{180} K_{180}

Samples were taken in 1999 and 2000, once a year for physical and chemical, three times a year (spring, summer, autumn) for microbiological analyses. These analyses were done in four replicates. The results were evaluated by variance analysis, where it was possible. The examined soil parameters were as follows:

– physical characteristics: moisture content, clay and silt content, hygroscopicity according to Kuron, plasticity according to Arany;

– chemical characteristics: pH(H_2O), pH(KCl) (BALLENEGGER & DI GLÉRIA, 1962), hydrolytic acidity (FILEP, 1988), organic carbon and nitrogen content (TYURIN, cit. FILEP, 1988), AL-soluble phosphorous and potassium content (GEREI, 1970), nitrate nitrogen content (FELFÖLDY, 1987);

– microbiological characteristics: total number of bacteria and number of microscopic fungi by plate dilution method, number of nitrifying and cellulose-decomposing bacteria (POCHON & TARDIEUX, 1962), CO_2-production (WITKAMP, 1966 cit. SZEGI, 1979), microbial biomass-C by fumigation extraction method (KUHNERT-FINKERNAGEL, 1995), phosphatase (KRÁMER–ERDEINÉ, cit. SZEGI, 1979), saccharase (FRANKENBERGER & JOHANSON, 1983), catalase (SZEGI, 1979) and urease (modified method by KEMPERS, cit. FILEP, 1988) activity.

Results and Discussion

The results of the study on the influence of fertilization, irrigation and crop rotation – mean values of two years – are shown in Tables 2–5.

Table 2

Changes in some physical soil properties in the maize monoculture and triculture treated with fertilizers under irrigated and non-irrigated conditions (Long-term experiment, Debrecen-Látókép, 1999–2000)

A. Non-irrigated conditions					B. Irrigated conditions				
Treatment number	Clay + silt, %	hy	K_A	Moisture content, %	Treatment number	Clay + silt, %	hy	K_A	Moisture content, %
Maize monoculture									
1.	36.40	2.24	38.0	12.27	11.	36.10	2.30	38.0	15.18
2.	36.90	2.22	38.5	12.08	12.	37.05	2.26	38.0	14.55
3.	35.50	2.18	39.0	11.29	13.	36.74	2.38	39.0	14.99
4.	36.85	2.24	38.0	12.41	14.	37.52	2.40	38.5	14.88
5.	37.34	2.18	38.5	12.55	15.	36.82	2.28	39.0	14.70
Maize triculture									
6.	37.40	2.13	39.0	11.59	16.	36.60	2.28	38.0	14.90
7.	38.42	2.28	40.0	11.72	17.	36.67	2.32	38.5	15.62
8.	36.95	2.40	38.5	11.53	18.	36.96	2.38	39.0	15.95
9.	37.24	2.28	37.0	11.73	19.	37.50	2.18	39.5	15.84
10.	35.20	2.16	39.0	11.40	20.	38.35	2.15	40.0	15.37

hy: Hygroscopicity according to Kuron; K_A: Upper limit of plasticity according to Arany

According to the analyses of soil physical characteristics (Table 2), it can be stated that the examined soil was of loam texture and the soils of the various treatments were homogeneous. Obviously, the moisture content of irrigated plots was higher by about 2–4%.

The application of higher fertilizer doses reduced both pH(H_2O) and pH(KCl) values (Table 3). In some cases this reached an almost one unit reduction as compared to the control. The pH of soils decreased until reaching medium–high fertilizer doses and did not change considerably in the case of high doses. The values of hydrolytic acidity increased with rising fertilizer doses. Especially high values occurred in treatments with low–medium or higher doses.

Table 3

Changes in some chemical soil parameters in the maize monoculture and triculture treated with fertilizers under irrigated and non-irrigated conditions (Long-term experiment, Debrecen-Látókép, 1999–2000)

Treatments	pH		Hydrolytic acidity	Organic C	Nitrate N	AL-soluble	
						P_2O_5	K_2O
	H_2O	KCl		$g \cdot kg^{-1}$	$mg \cdot kg^{-1}$		
A. Non-irrigated conditions							
Maize monoculture							
1.	6.71	5.63	5.94	14.4	7.4	48.60	222.0
2.	6.51	5.40	6.86	13.3	7.8	85.55	241.0
3.	6.21	5.24	12.38	13.6	16.2	148.30	277.0
4.	5.87	5.09	17.45	14.6	10.4	181.75	306.5
5.	6.03	4.89	11.09	13.8	16.5	216.20	346.0
Maize triculture							
6.	6.75	5.89	7.56	14.1	8.4	36.15	187.0
7.	6.26	5.47	8.58	13.5	22.0	51.05	197.0
8.	6.02	5.13	9.73	13.9	47.0	86.25	212.0
9.	5.98	5.04	17.42	14.0	48.0	119.80	250.5
10.	5.91	4.92	13.06	12.6	46.0	122.40	231.5
B. Irrigated conditions							
Maize monoculture							
11.	6.44	5.37	8.54	12.7	4.1	47.60	156.0
12.	6.23	5.16	11.78	13.0	10.6	62.30	156.0
13.	5.91	4.98	13.07	12.9	7.0	81.30	174.0
14.	5.61	4.66	13.57	13.7	12.8	114.90	193.0
15.	5.75	4.69	18.18	13.3	11.8	140.25	210.0
Maize triculture							
16.	6.32	5.35	8.54	14.8	6.6	29.35	241.0
17.	6.31	5.18	9.48	13.7	14.5	59.60	247.0
18.	6.11	5.23	8.19	13.5	15.0	107.40	255.0
19.	5.90	4.89	16.14	14.9	31.8	148.50	287.0
20.	5.80	4.85	14.43	15.3	32.8	165.05	282.0
$LSD_{5\%}$	0.24	0.21	3.22	–	–	14.68	15.74

Only slight differences were found among organic carbon contents of the various treatments. Higher nitrate nitrogen, AL-soluble phosphorus and potassium contents were measured in plots treated with medium or high fertilizer doses.

Under irrigated conditions, in both the maize mono- and triculture lower phosphorus contents were determined in the case of lower fertilizer doses as compared to the corresponding non-irrigated treatments. At higher fertilization rates, the phosphorus content was higher in the monoculture than in triculture treatments.

In the case of the non-irrigated maize monoculture, the AL-soluble potassium content was relatively higher than in other corresponding treatments. The values were significantly higher in irrigated and non-irrigated monoculture treatments than in the corresponding treatments of the triculture.

Table 4

The influence of fertilization, irrigation and crop rotation on soil microorganisms in the long-term experiment (Debrecen-Látókép, 1999–2000)

Treat-ments	Number of bacteria	Nitrifying bacteria	Cellulose decom-posing bacteria	Microscopic fungi
	($\times 10^{6}$ g^{-1})	($\times 10^{3} \cdot g^{-1}$)		
		A. Non-irrigated conditions		
		Maize monoculture		
1.	4.78	2.35	0.54	47.25
2.	3.73	3.50	0.77	50.25
3.	2.98	5.70	2.30	53.25
4.	3.20	6.50	2.27	62.25
5.	3.90	9.25	1.90	59.00
		Maize triculture		
6.	4.63	2.95	0.95	66.75
7.	5.00	4.45	1.90	65.00
8.	6.00	7.20	3.00	52.25
9.	7.98	13.50	3.30	55.25
10.	9.73	6.75	3.90	52.25
		B. Irrigated conditions		
		Maize monoculture		
11.	4.60	5.20	1.40	45.00
12.	4.23	5.20	2.40	43.00
13.	5.53	6.35	2.40	36.50
14.	6.43	9.75	3.00	51.25
15.	14.28	12.00	3.50	30.25
		Maize triculture		
16.	4.00	3.50	2.80	43.75
17.	4.40	13.50	5.20	36.75
18.	6.16	12.60	7.00	56.50
19.	7.64	20.00	10.50	50.25
20.	10.20	26.00	28.00	51.75
$LSD_{5\%}$	3.06	–	–	19.61

The influence of the studied field operations on the amount of microbes is shown in Table 4. The total number of germs was the lowest in the maize monoculture. Medium–high and high fertilizer doses significantly increased the total number of germs in both irrigated monoculture and triculture and non-irrigated triculture.

Due to fertilization the amount of nitrifying bacteria increased in all treatments. Irrigation obviously stimulated the propagation of bacteria. A higher amount of bacteria was found in the triculture treatments than in the corresponding ones of the monoculture.

The number of cellulose decomposing bacteria was relatively low in most of the cases, it increased considerably in the medium or high fertilizer dose treatments in irrigated triculture.

No significant differences were established in the amount of microscopic fungi between the corresponding treatments of monoculture and triculture. Neither fertilization, nor irrigation had an unambiguous effect.

Changes in the microbial activity of the soil were evaluated via the changes in the CO_2 production, the amount of microbial biomass C, and enzyme activities (Table 5). The CO_2 production of soils was generally lower under non-irrigated than under irrigated conditions. In the non-irrigated triculture CO_2 production increased in treatments receiving higher fertilizer doses. In irrigated monoculture, CO_2 production was balanced, while in triculture fertilization had a stimulating effect on it.

Due to fertilization the amount of microbial biomass C increased in both cropping systems and irrigation treatments. Smaller values were recorded under non-irrigated than irrigated conditions. Significant differences were measured primarily in the irrigated treatments receiving high fertilizer doses.

As a result of fertilization, a significant increase was detected in the phosphatase as well as urease activity in both crop rotations and irrigation treatments. A stimulating effect was observed at low and medium fertilizer doses, while the enzyme activity decreased considerably in the case of high rates. When comparing the corresponding treatments of the crop rotations, it can be stated that higher values were obtained in triculture than in monoculture.

Under non-irrigated conditions in triculture, the saccharase enzyme activity was significantly higher than in the corresponding treatments of the monoculture. At high fertilizer doses, a reduction in enzyme activity was observed.

Catalase activity was reduced primarily by medium and high fertilizer doses. There were no significant differences in catalase activity either between the two crop rotations or between the irrigation treatments.

When comparing the results of the 6^{th} and 7^{th} years of the fertilization experiment with those of the 16^{th} and 17^{th} years, it can be seen that the former (1989–1990) and latter (1999–2000) soil microbiological examinations showed similar trends in the case of several parameters.

At both times, the number of germs slightly increased due to fertilization. Fertilizer doses increased the amount of nitrifying bacteria. The increase was greater in triculture than in monoculture. Higher values were measured in the high dose treatments of triculture under irrigation. The amount of cellulose decomposing bacteria showed a similar trend as that of nitrifying bacteria.

Table 5
The effect of fertilization, irrigation and crop rotation on soil microbiological activity in the long-term experiment at Debrecen-Látókép (1999–2000)

Treat-ments	CO_2-production (CO_2 mg·100g^{-1} ·14days^{-1})	Microbial biomass-C (µg·g^{-1})	Phosphatase activity (P_2O_5 mg· 100g^{-1}·2h^{-1})	Urease activity (NH_4-N mg·g^{-1} ·24h^{-1})	Sac-charase activity (glucose mg·g^{-1} ·24h^{-1})	Catalase activity (O_2 ml· 2g^{-1}·2min^{-1})
A. Non-irrigated conditions						
Maize monoculture						
1.	3.99	58.13	9.83	12.19	16.65	25.5
2.	3.86	72.84	13.46	16.12	15.43	23.75
3.	3.59	70.89	17.58	20.09	15.93	20.25
4.	3.66	89.47	18.34	24.28	16.65	19.75
5.	3.10	88.49	13.24	16.63	14.95	17.00
Maize triculture						
6.	3.96	57.36	14.55	30.08	18.75	24.75
7.	3.58	75.12	17.04	38.15	19.00	20.25
8.	4.31	74.30	19.32	40.65	18.88	20.25
9.	4.69	95.04	21.16	30.91	18.75	15.00
10.	8.46	104.14	14.43	24.71	16.67	13.50
B. Irrigated conditions						
Maize monoculture						
11.	6.22	100.76	14.45	20.56	14.95	23.75
12.	6.44	98.60	16.06	25.41	14.70	21.25
13.	4.51	86.12	15.41	27.52	17.15	20.50
14.	5.40	116.24	13.89	29.06	14.95	14.50
15.	5.49	127.88	18.55	29.07	15.95	14.75
Maize triculture						
16.	3.92	70.20	16.94	33.14	17.43	26.75
17.	6.08	100.34	18.88	33.33	18.38	24.25
18.	4.10	85.90	18.40	43.15	15.68	20.75
19.	6.72	125.66	18.23	35.16	15.68	19.00
20.	6.51	141.77	16.12	22.28	14.20	15.75
$LSD_{5\%}$	2.14	32.4	2.54	3.19	2.14	3.54

Microbial biomass C, introduced in the latter examination series, proved to be a sensitive indicator of soil microbial processes.

Irrigation generally had a favourable effect on the amount of microbes and soil microbiological processes.

A higher number of nitrogen-fixing and cellulose decomposing bacteria and a higher activity of phosphatase, saccharase and urease enzymes were detected in triculture than in monoculture (KÁTAI, 1999).

Summary

The effects of fertilization, irrigation and crop rotation on the major soil parameters and microbiological soil properties were studied at Debrecen-Látókép in the 16th and 17th years of the fertilization experiment on calcareous chernozem soil. The results can be summarized as follows:

In the examination period the moisture content of the experimental soil increased by 2–3% due to irrigation.

With increasing fertilizer doses, the pH value of soils reduced both in aqueous and *M* KCl suspension, but it did not change considerably at medium and high fertilizer doses. The hydrolytic acidity increased with decreasing pH values. The nitrate-N, AL-soluble phosphorus and potassium contents increased gradually with increasing fertilizer doses.

Among the soil microbial parameters, the total number of germs increased slightly, while the amount of nitrifying bacteria was significantly higher due to fertilization.

As a result of *fertilization*, a significant increase was detected in the phosphatase and urease activity in both crop rotations and irrigation treatments. The activity of saccharase and catalase was reduced at medium and high fertilizer doses.

In addition to changing the moisture content of soils irrigation increased the total number of germs and the amount of nitrifying and cellulose decomposing bacteria. Irrigation provided more favourable conditions for CO_2 production, increasing the microbial biomass C content and for the functioning of phosphatase and urease enzymes.

In triculture the number of nitrogen-fixing and cellulose decomposing bacteria was higher than in monoculture, especially in the case of medium and high fertilizer doses. The activity of phosphatase, saccharase and urease enzymes was significantly higher in triculture than in monoculture.

Key words: soil characteristics, amount of microbes and microbial activity, fertilization, irrigation, crop rotation

References

BALLENEGGER, R. & DI GLÉRIA, J., 1962. Soil and Fertilizer Analysis Methods. (In Hungarian) Mezőgazdasági Kiadó. Budapest.

BRUSSAARD, L., 1994. Interrelationships between biological activity, soil properties and soil management. In: Soil Resilience and Sustainable Land Use. (Eds.: GREENLAND, D. J. & SZABOLCS, I.) 309–329. CAB International. Wallingford.

CSATHÓ, P. & RADIMSZKY, L. 2005. The environment and agronomic NPK nutrient balance of Hungarian agriculture between 1901 and 2000. (In Hungarian) Agrokémia és Talajtan. **54.** 217–234.

ELLIOTTE, L. F. & LYNCH, J. M., 1994. Biodiversity and soil resilience. In: Soil Resilience and Sustainable Land Use. (Eds.: GREENLAND, D. J. & SZABOLCS, I.) 353–364. CAB International. Wallingford.

FELFÖLDY, L., 1987. Biological Water Qualification. (In Hungarian) 4th ed. Vízügyi Hidrológia. Vol. 16. Vízgazdálkodási Intézet. Budapest.

FILEP, GY., 1988. Soil Analysis. (In Hungarian) Lecture Notes. University of Agricultural Sciences. Debrecen.

FILEP, T. & SZILI-KOVÁCS, T., 2005. Effect of liming on the microbial biomass in two acidic sandy soils. (In Hungarian) Agrokémia és Talajtan. **54.** 139–148.

FRANKENBERGER, W. T. & JOHANSON, J. B., 1983. Method of measuring invertase activity in soils. Plant and Soil. **74.** 301–311.

GAWRONSKA, A., KULINSKA, D. & WOJTKOWIAK, D., 1990. Long-term monoculture of maize versus biological properties of soil. Agrokémia és Talajtan. **39.** 430–432.

GEREI, L., (Ed.), 1970. Methods for Soil Science and Agrochemistry. (In Hungarian) OMMI. Budapest.

HICKISCH, B. & MÜLLER, G. JR., 1990. Effect of fertilization on microorganisms in a long-term field experiment. Agrokémia és Talajtan. **39.** 415–418.

HOUOT, S. & CHAUSSOD, R., 1995. Impact of field operation on the size and activity of the microbial biomass in a long-term field experiment. Biology and Fertility of Soils. **19.** (4) 309–316.

JAMAR, D., 1984. Effect du type d'explitation agricole sur les propriétés des sols cultivés. Rev. Agric., Bruxelles. **37.** 1205–1215.

KARTVELISVILI, L. G., 1983. Vliyanie productov razlozheniya raznocachestvennih rastitel′nih ostatkoc na microfloru substrata pri monocul′ture pshenici. Bull. VNII S. h. Mikrobiol., Leningrad. **37.** 31–34.

KAUTZ, T., WIRTH, S. & ELLMER, F., 2004. Microbial activity in a sandy arable soil is governed by the fertilization regime. European Journal of Soil Biology. **40.** (2) 87–94.

KÁTAI, J., 1999. Changes in soil microbiological characteristics in long-term fertilization experiment. (In Hungarian) Agrokémia és Talajtan. **48.** 348–358.

KÁTAI, J. & HELMECZI, B., 1995. The effect of fertilization and crop rotation on soil microbiological processes. (In Hungarian) Debreceni Agrártudományi Egyetem Tudományos Közleményei. **31.** 169–177.

KREZEL, Z., 1977. The effect of crop rotation on the biological activity of light-textured soil. In: Proc. 7th Meeting on Soil Biology and Conservation of the Biosphere. (Ed.: SZEGI, J.) 145–150. Akadémiai Kiadó. Budapest.

KUHNERT-FINKERNAGEL, R., 1996. Biomass-C by fumigation–incubation technique. In: Methods in Soil Biology. (Eds.: SCHINNER, F. et al.) 52–56. Springer Verlag. Berlin– Heidelberg.

LI, X. Y. et al., 2005. Effect of different fertilization systems on soil microbe and its relation to soil fertility. Scientia Agricultura Sinica. **38.** 1591–1599.

MARTYNIUK, S. & WAGNER, G. H., 1978. Quantitative and qualitative examination of soil microflora associated with different management systems. Soil Sci. **125.** (6) 343–350.

MÜLLER, G., 1991. Soil microbiological aspects of agroecology and intensive agricultural production. (In Hungarian) Agrokémia és Talajtan. **40.** 263–272.

PALMA, R. M. et al., 2000. Chemical and biochemical properties as potential indicators of disturbances. Biology and Fertility of Soils. **32.** 381–384.

POCHON, J. & TARDIEUX, P., 1962. Techniques D' analyse en microbiologie du sol. Collection "Technivues de Base". Éditions de la Tourelle. St. Mandé.

POWLSON, D. S. & JOHNSTON, A. E., 1994. Long-term field experiments: their importance in understanding sustainable land use. In: Soil Resilience and Sustainable Land Use (Eds.: GREENLAND, D. J. & SZABOLCS, I.) 367–394. CAB International Wallingford.

RAIESI, F., 2004. Soil properties and N application effects on microbial activities in two winter wheat cropping systems. Biology and Fertility of Soils. **40.** (2) 88–92.

SELVI, D. et al., 2004. Microbial population and biomass in rhizosphere as influenced by continuous intensive cultivation and fertilization in an Inceptisol. Journal of the Indian Society of Soil Science. **52.** (3) 254–257.

SWIFT, M. J., 1994. Maintaining the biological status of soil: a key to sustainable land management. In: Soil Resilience and Sustainable Land Use (Eds.: GREENLAND, D. J. & SZABOLCS, I.) 235–258. CAB International. Wallingford.

SZEGI, J., 1979. Methods for Soil Microbiological Analysis. (In Hungarian) Mezőgazdasági Kiadó. Budapest.

SZILI-KOVÁCS, T. & TÖRÖK K., 2005. Effect of carbon addition on the soil microbial activity and biomass on abandoned sandy fields. (In Hungarian) Agrokémia és Talajtan. **54.** 149–162.

VIPPER, H., 1999. The effect of crop rotations of different agrobiological value on soil qualities and yield of crops. Transactions of the Estonian Agricultural University. Agronomy. No. 203. 183–188.

ZHANG, Q. C., WANG, G. H. & FANG, B., 2005. Influence of fertilization treatment on nutrients uptake by rice and soil ecological characteristics of soil microorganism in paddy field. Acta Pedologica Sinica. **42.** (1) 116–121.