Relationships between enzymatic activities and chemical indicators in a brown luvic soil

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Abstract. Actual and potential dehydrogenase and phosphatase activities and nitrate, ammonium and mobile phosphorus contents were determined in the 0–20–, 20–40– and 40–60–cm layers of a brown luvic soil submitted to a complex tillage and crop rotation experiment.

Each activity and each chemical content in both non-tilled and conventionally tilled soil under crops of both rotations decreased with increasing sampling depth. It was found that no-till – in comparison with conventional tillage – resulted in significantly higher soil enzymatic activities and nitrate, ammonium and mobile phosphorus contents in the 0–20– and in significantly lower activities and chemical contents in the deeper layers. The soil under maize or wheat was more enzyme-active in the 6– than in the 2–crop rotation. In the 2–crop rotation, higher enzymatic activities were registered under wheat than under maize; nitrate and ammonium contents were significantly higher under wheat excepting mobile phosphorus content. In the 6–crop rotation, higher enzymatic activities were registered under wheat; nitrate and mobile phosphorus contents were significantly higher under maize, while ammonium content was significantly higher under wheat. There were positive correlations between enzymatic activities and chemical indicators under each crop of both rotations.

Keywords: *ammonium, dehydrogenase, nitrate, phosphatase, phosphorus*

Introduction

Soil enzymes are important for catalyzing innumerable reactions necessary for life processes of microorganisms in soils (Baligar et al. 1999), decomposition of organic residues, cycling of nutrients and formation of organic matter and soil structure (Deng & Tabatabai 2004; Kandeler et al. 1999).

Although enzymes are primarily of microbial origin it can also be originate from plants and animals (Frey et al. 1999). These enzymes are constantly being synthesized, could be acumulated, inactivated and/or decomposed in the soil, assuming like this, great importance for the agriculture for their role in the recycling of the nutrients (Balota et al. 2003, 2004).

Soil enzyme activities have successfully discriminated between a wide range of soil management practices (Lovell et al. 1996). The measurement of soil enzymes can be used as indicative of the biological activity or biochemical process. Soil enzyme activities have potential to provide a unique integrative biological assessment of soils because of their relationship to soil biology, easy of measurement, and rapid response to changes in soil management (Tang 1987).

In continuation of our investigations (Samuel et al. 2000, 2005; Samuel & Vicaş 2005) we studied some enzymatic activities and their correlations with chemical properties in a brown luvic soil submitted to a complex tillage and crop rotation experiment at the Agricultural Research and Development Station in Oradea (Bihor county).

Our results are in good agreement with the literature data reviewed by (Dick 1992; Dick et al. 1994; Dormaar & Lindwall 1989; Spiers & Mc Gill 1989; Ştefanic et al. 1984) and constitute novelties for enzymological characterization of a brown luvic soil submitted to complex management practices.

Material and Methods

The ploughed layer of the studied brown luvic soil is of a mellow loam texture and it has a pH value of 5.5.

The experimental started in 1992. The experimental field occupying 3.84 ha was divided into plots and subplots for comparative study of no-till and conventional tillage and rotations of 2– and 6–crops. The crops of the two rotations were specified in Table 1.

Each plot consisted of two subplots representing the no-till and conventional tillage variants. The plots (and subplots) were installed in three repetitions.

In October 2005, soil was sampled from the 0–20–, 20–40– and 40–60–cm depths of the subplots under maize and wheat crops of both rotations. The soil samples were allowed to air-dry, then ground and passed through a 2–mm sieve and, finally, used for enzymological analyses.

Actual and potential dehydrogenase activities were determined according to the methods describe in (Drăgan-Bularda 2000). The reaction mixtures consisted of 3.0 g soil, 0.5 ml TTC (2,3,5- triphenyltetrazolium chloride) and 1.5 ml distilled water or 1.5 ml glucose. All reaction mixtures were incubated at 37º C for 24 hours. After incubation, the triphenylformazan produced was extracted with acetone and was measured spectrophotometrically at 485 nm.

Phosphatase activity was measured in unbuffered reaction mixtures. The reaction mixtures consisted of 2.5 g soil, 2 ml toluene (antiseptic), 10 ml distilled water and 10 ml 0.5 % substrate solution. Reaction mixtures without soil or without substrate solution were the controls. All reaction mixtures were incubated at 37º C for 2 hours. After incubation, the phenol released from the substrate under the action of phosphatase was determined spectrophotometrically (at 614 nm) based on the colour reaction between phenol and 2,6-dibromoquinone-4-chloroimide (Schinner et al. 1996).

Dehydrogenase activities are expressed in mg of triphenylformazan (TPF) produced from 2, 3, 5-triphenyltetrazolium chloride (TTC) by 10 g of soil in 24 hours, whereas phosphatase activity is expressed in mg phenol / g soil / 2 hours. Chemical indicators were determined according to the methods described in (Schinner et al. 1996). The activity values were submitted to statistical evaluation by the two *t*-test (Sachs 1968) and the correlations between the enzymatic activities and chemical indicators were determined according to the methods described in (Kiss et al. 1990).

Table 1 Crops of the two rotations

Year	Rotation of 2 crops		Rotation of 6 crops					
	Plots		Plots					
2005	1	2	1	2	3	4	5	6
	Maize	Wheat	Maize	Soybean	Wheat	Maize (FYM)	Clover	Oats-clover

* (FYM) – (farmyard - manured)

Results and Discussions

Results of the enzymological analyses and chemical properties are presented in Tables 2 and 3, and those of the statistical evaluation are summarised in Tables 4 and 5. Figures 1, 2 and 3 show correlations between enzymatic activities and chemical indicators.

Variation of the enzymatic activities and chemical properties in dependence of sampling depth

It is evident from Table 2 that each enzymatic activity decreased with sampling depth under each crop of both rotations. In addition, Table 4 shows that the mean values of each of the three activities in both non-tilled and conventionally tilled subplots also decreased with increasing soil depth.

The chemical indicators also, decreased with increasing soil depth.

The effect of tillage practices on the enzymatic activities and chemical properties in soil

Each of the three enzymatic activity determined was significantly higher (at least at $p < 0.02$) in the upper (0–20–cm) layer of the no-tilled subplots than in the same layer of the conventionally tilled subplots. The reverse was true in the deeper (20–40– and 40–60–cm) layers. These findings are also valid for chemical indicators under each crop of both rotations.

Table 2 The effects of soil management practices on enzymatic activities in a brown luvic soil

Soil enzymatic activity*	Soil depth (cm)	Rotation of 2 crops**				Rotation of 6 crops			
		Maize		Wheat		Maize		Wheat	
		N.t.	C.t.	N.t.	C.t.	N.t.	C.t.	N.t.	C.t.
ADA (mg TPF/10g soil/24 hours)	0-20	4.68	4.50	7.36	6.02	5.76	4.88	7.76	6.80
	20-40	2.68	3.10	4.84	5.20	2.86	3.52	5.01	5.60
	40-60	1.12	1.80	1.36	1.84	1.02	1.84	2.80	3.01
PDA (mg TPF/10g soil/24 hours)	0-20	23.52	22.36	22.96	21.20	24.12	22.96	25.20	23.20
	20-40	15.68	16.52	14.08	15.40	16.44	17.48	15.28	18.96
	40-60	2.52	3.36	5.32	5.72	5.64	7.00	5.60	6.76
UPA (mg phenol/10g soil/24 hours)	0-20	0.368	0.302	0.384	0.342	0.375	0.309	0.402	0.397
	20-40	0.255	0.268	0.233	0.245	0.236	0.269	0.259	0.275
	40-60	0.139	0.160	0.140	0.169	0.142	0.172	0.154	0.190

* ADA – Actual dehydrogenase activity
PDA – Potential dehydrogenase activity
UPA – Phosphatase activity measured in unbuffered reaction mixtures

**N.t. – No-till
C.t. – Conventional tillage

Table 3 The effects of soil management practices on chemical properties in a brown luvic soil

Chemical indicators	Soil depth (cm)	Rotation of 2 crops*				Rotation of 6 crops			
		Maize		Wheat		Maize		Wheat	
		N.t.	C.t.	N.t.	C.t.	N.t.	C.t.	N.t.	C.t.
$N\text{-}NO_3$ (mg N / kg soil)	0-20	0.43	0.40	0.43	0.40	0.61	0.49	0.45	0.43
	20-40	0.30	0.33	0.36	0.38	0.40	0.43	0.36	0.40
	40-60	0.17	0.28	0.16	0.23	0.22	0.23	0.23	0.25
$N\text{-}NH_4$ (mg N / kg soil)	0-20	1.24	1.20	1.18	1.14	1.28	1.26	1.26	1.25
	20-40	0.58	0.62	0.73	0.88	0.72	0.79	0.88	0.92
	40-60	0.35	0.37	0.33	0.35	0.31	0.36	0.36	0.37
P_2O_5 (mg P_2O_5 / kg soil)	0-20	12.4	12.2	12.6	12.1	13.7	14.6	14.6	13.8
	20-40	11.2	11.6	9.8	11.6	12.3	13.8	10.5	12.1
	40-60	8.8	9.4	7.8	8.9	9.4	9.8	9.0	10.2

* N.t. – No-till
C.t. – Conventional tillage

Table 4 Significance of the differences between enzymatic activities in a brown luvic soil submitted to different management practices

Management practices	Soil enzymatic activity*	Soil depth (cm)	Mean activity values in management practices			Significance of the differences
			a	b	a-b	
No-till (a) versus conventional tillage (b)	ADA	0-20	6.39	5.55	0.84	0.01 > p > 0.002
		20-40	3.84	4.35	-0.51	0.002 > p > 0.001
		40-60	1.57	2.12	-0.55	0.001 > p > 0.0001
	PDA	0-20	23.95	22.43	1.52	0.02 > p > 0.01
		20-40	15.37	17.09	-1.72	0.02 > p > 0.01
		40-60	4.77	5.71	-0.94	0.001 > p > 0.0001
	UPA	0-20	0.382	0.337	0.045	0.001 > p > 0.0001
		20-40	0.245	0.264	-0.019	0.002 > p > 0.001
		40-60	0.143	0.172	-0.029	0.0001 > p
The same crop in the two rotations						
Maize in 2–crop rotation (b) versus maize in 6–crop rotation (b)	ADA	0-60	2.98	3.31	-0.33	0.10 > p > 0.05
	PDA		13.98	15.61	-1.63	0.05 > p > 0.02
	UPA		0.248	0.250	-0.002	0.02 > p > 0.001
Wheat in 2–crop rotation (b) versus in wheat 6–crop rotation (b)	ADA	0-60	4.44	5.16	-0.72	0.02 > p > 0.01
	PDA		14.11	15.83	-1.72	0.02 > p > 0.01
	UPA		0.252	0.279	-0.027	0.01 > p > 0.002
Different crops in the same rotation						
2–crop rotation Maize (a) versus wheat (b)	ADA	0-60	2.98	4.44	-1.46	0.05 > p > 0.02
	PDA		13.98	14.11	-0.13	0.01 > p > 0.002
	UPA		0.248	0.252	-0.004	0.02 > p > 0.001
6–crop rotation Maize (a) versus wheat (b)	ADA	0-60	3.31	5.16	-1.85	0.001 > p >0.0001
	PDA		15.61	15.83	-0.22	0.05 > p > 0.002
	UPA		0.250	0.279	-0.029	0.10 > p > 0.05

* ADA – Actual dehydrogenase activity; PDA – Potential dehydrogenase activity; UPA – Phosphatase activity measured in; unbuffered reaction mixtures

Table 5 Significance of the differences between chemical indicators in a brown luvic soil submitted to different management practices

Management practices	Chemical indicators	Soil depth (cm)	Mean activity values in management practices			Significance of the differences
			a	b	a-b	
No-till (a) versus conventional tillage (b)	$N\text{-}NO_3$	0-20	0.48	0.43	0.05	p > 0.10
		20-40	0.36	0.39	-0.03	0.01 > p > 0.05
		40-60	0.20	0.25	-0.05	p > 0.10
	$N\text{-}NH_4$	0-20	1.24	1.21	0.03	0.05 > p > 0.02
		20-40	0.73	0.80	-0.07	0.10 > p > 0.05
		40-60	0.34	0.36	-0.02	0.10 > p > 0.05
	P_2O_5	0-20	13.33	13.18	0.15	0.05 > p > 0.02
		20-40	10.95	12.28	-1.33	0.02 > p > 0.01
		40-60	8.75	9.58	-0.83	0.02 > p > 0.01
The same crop in the two rotations						
Maize in 2– crop rotation (b) versus maize in 6– crop rotation (b)	$N\text{-}NO_3$	0-60	0.32	0.40	-0.08	0.01 > p > 0.002
	$N\text{-}NH_4$		0.73	0.79	-0.06	0.05 > p > 0.02
	P_2O_5		10.93	12.27	-1.34	0.02 > p > 0.01
Wheat in 2– crop rotation (b) versus wheat in 6– crop rotation (b)	$N\text{-}NO_3$	0-60	0.33	0.40	-0.02	0.05 > p > 0.02
	$N\text{-}NH_4$		0.77	0.84	-0.07	0.02 > p > 0.01
	P_2O_5		10.47	11.70	-1.23	0.01 > p > 0.002
Different crops in the same rotation						
2–crop rotation Maize (a) versus wheat (b)	$N\text{-}NO_3$	0-60	0.32	0.33	-0.01	0.10 > p > 0.05
	$N\text{-}NH_4$		0.73	0.77	-0.04	0.50 > p > 0.10
	P_2O_5		10.93	10.47	-0.46	0.02 > p > 0.01
6–crop rotation Maize (a) versus wheat (b)	$N\text{-}NO_3$	0-60	0.40	0.35	0.05	0.05 > p > 0.10
	$N\text{-}NH_4$		0.79	0.84	-0.05	0.10 > p > 0.05
	P_2O_5		12.27	11.70	-0.57	0.01 > p > 0.002

The effect of crop rotations on the enzymatic activities and chemical properties in soil

For evaluation of this effect, the results obtained in the three soil layers analysed in the two subplots of each plot were considered together.

whereas in the soil under wheat each activity was significantly higher (at least at $p < 0.02$) in the 6– than in the 2–crop rotation.

Chemical indicators were significantly higher (at least at $p < 0.05$) in the 6– than in the 2–crop rotation.

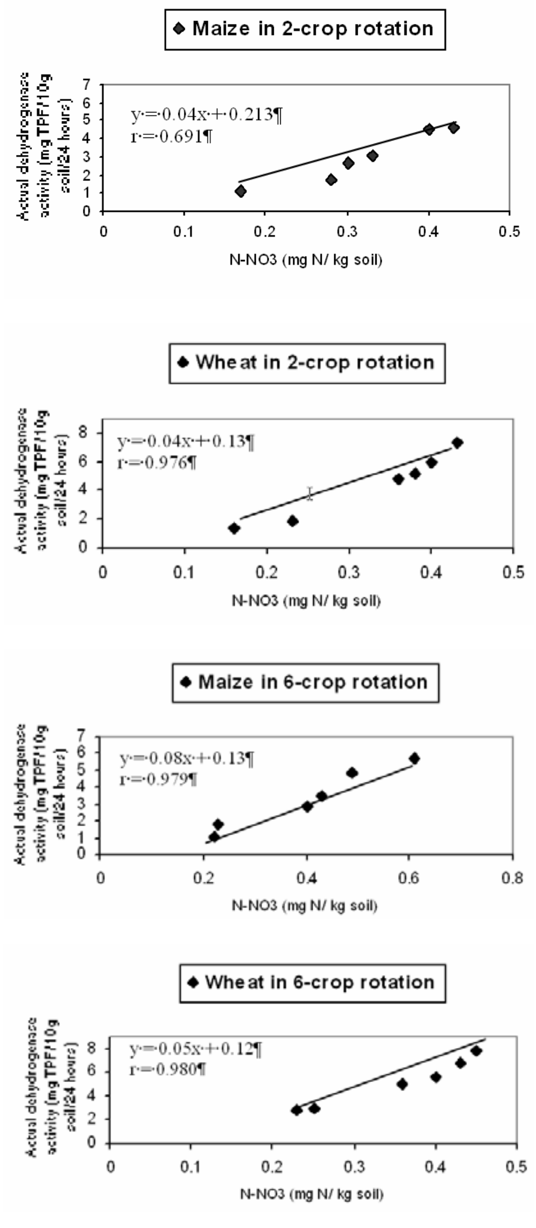

Figure 1 Correlation between actual dehydrogenase activity and nitrate content

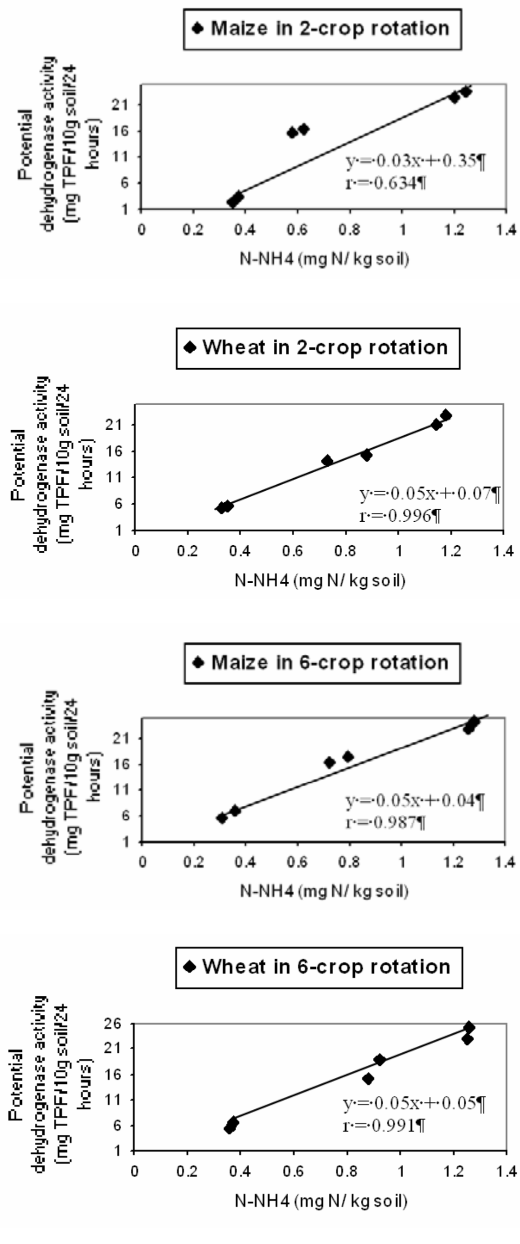

Figure 2 Correlation between potential dehydrogenase activity and ammonium content

The soil enzymological and chemical effects of the same crop in the two rotations

As maize and wheat were crops in both rotations, it was possible to compare their effect on soil enzymatic activities and chemical properties. The soil under both crops was more enzyme-active in the 6– than in the 2–crop rotation. But in the soil under maize, the difference between the two rotations was unsignificant ($p > 0.05$) only in the case of actual dehydrogenase activity,

The soil enzymological and chemical effects of different crops in the same rotation

The 2–crop rotation. Actual and potential dehydrogenase and phosphatase activities were significantly higher (at least at $p < 0.05$), in the wheat soil than in the soil under maize. In the case of chemical indicators, only phosphorus content was significantly higher ($p < 0.02$), in the maize soil than in the soil under wheat, while nitrate and ammonium contents were unsignificantly higher ($p > 0.05$ and $p > 0.10$, respectively), in the soil under wheat.

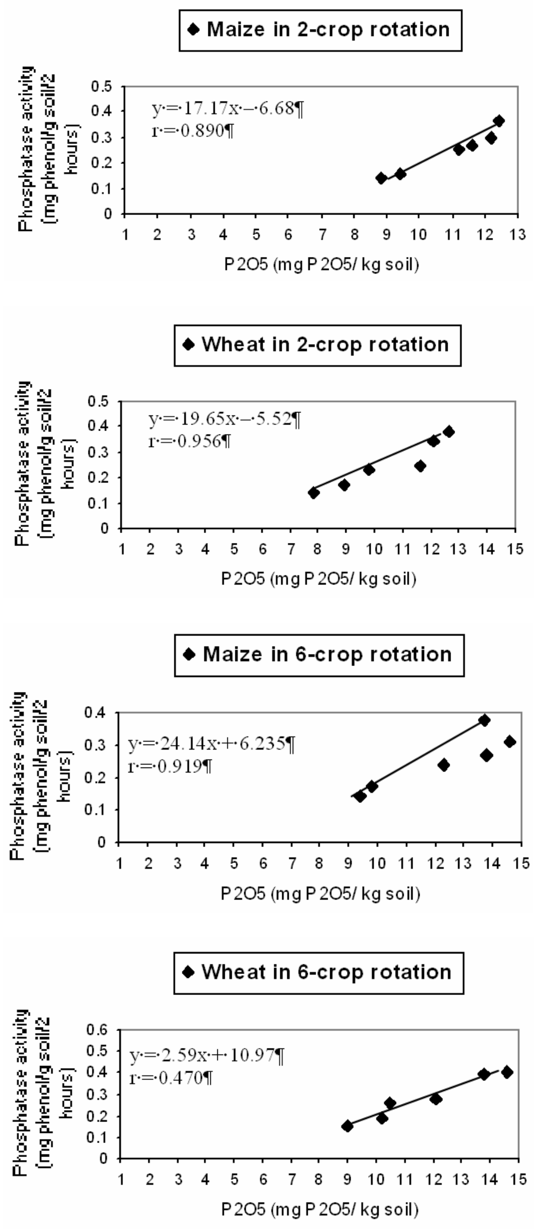

Figure 3 Correlation between phosphatase activity and mobile phosphorus content

The 6–crop rotation. Actual and potential dehydrogenase activities were significantly higher ($p < 0.001$ and $p < 0.05$, respectively), while phosphatase activity was unsignificantly higher ($p > 0.05$) in the wheat soil than in the soil under maize.

Regarding chemical indicators nitrate and phosphorus contents were higher in the soil under maize, whereas ammonium content was higher in the soil under wheat.

Correlations between enzymatic activities and chemical indicators

We have determined the correlations between actual dehydrogenase activity and nitrate content (Figure 1), potential dehydrogenase activity and ammonium content (Figure 2), phosphatase activity and phosphorus content (Figure 3), under maize and wheat crops of both rotations. It was found that each of the three enzymatic activity was positively correlated ($r = 0.470$ to $r = 0.996$) with the chemical indicators.

Conclusions

The soil enzymatic activities and the chemical indicators decreased with increasing sampling depth.

No-till – in comparison with conventional tillage - resulted in higher enzymatic activities in the (0–20–cm) and in lower activities in the 20–40– and 40–60–cm soil layers under each crop of both rotations. These findings are valid for chemical indicators.

The 6–crop rotation – as compared to the 2–crop rotation – led, in general to higher enzymatic activities and nitrate, ammonium and phosphorus contents in the soil layers under maize or wheat.

Each of the three enzymatic activity was positively correlated with the chemical indicators.

References

Baligar, V.C., Wright, P.J., Fageria, N.K., Pitta, G.V.E. (1999): Enzyme activities in cerrado soils of Brazil. Commun. Soil Sci. Plant Anal., 30: 1551-1560.

Balota, E.L., Colozzi, A., Andrade, D.S., Dick, R.P. (2003): Microbial biomass in soils under different tillage and crop rotation systems. Biol. Fertil. Soils., 38: 15-20.

Balota, E.L., Colozzi, A., Andrade, D.S., Dick, R.P. (2004): Long – term tillage and crop rotation effects on microbial biomass and C and N mineralization in a Brazilian Oxisol. Soil Till. Res., 77: 137-145.

Deng, S.P., Tabatabai, M.A. (2004): Effect of tillage and residue management on enzyme activities in soils. Biol. Fertil. Soils., 24: 141-146.

Dick, R. P. (1992): A review: long-term effects of agricultural systems on soil biochemical and microbial parameters. Agric. Ecosyst. Environ., 4: 25-36.

Dick, R. P., Sandor, J. A., Eash, N. S. (1994): Soil enzyme activities after 1500 years of terrace agriculture in the Colca Valley, Peru. Agric. Ecosyst. Environ., 50: 123-131.

Dormaar, J. F., Lindwall, C. W. (1989): Chemical differences in dark brown luvic chromozomic Ap horizons under various conservation tillage systems. Can. J. Soil Sci., 69: 481-488.

Drăgan-Bularda, M. (2000): Lucrări practice de microbiologie generală. Univ. Babeş-Bolyai, Cluj-Napoca.

Frey, S.D., Elliot, E.T., Paustian, K. (1999): Bacterial and fungal abundance and biomass in conventional and no-tillage agroecosystems along two climatic gradients. Soil Biol. Biochem., 31: 573-585.

Kandeler, E., Tsckerko, D., Spiegel, H. (1999): Long-term monitoring of microbial biomass, N mineralisation and enzyme activities of a chernozem under different tillage management. Biol. Fertil. Soils., 28: 343-351.

Kiss, S., Paşca, D., Drăgan-Bularda, M., Cristea, V., Blaga, G., Crişan, R., Muntean, V., Zborovschi, E., Mitroescu, S. (1990): Enzymological analysis of lead and zinc mine spoils submitted to biological recultivation. "Stud. Univ. Babeş-Bolyai", Biol., 35 (2): 70-79.

Lovell, R. D., Jarvis, S. C., Bardgett, R. D. (1995): Soil microbial biomass and activity in long-term grassland: effects of management changes. Soil Biol. Biochem., 27: 969-975.

Schinner, F., Öhlinger, R., Kandeler, E., Margesin, R. (1996): Methodes in Soil Biology. Springer, Berlin.

Sachs, L. (1968): Statistiche Auswertungsmethoden. Springer, Berlin.

Samuel, A. D., Drăgan-Bularda, M., Domuţa, C. (2005): Enzymatic activities in a brown luvic soil. “Stud. Univ. Babeş-Bolyai”, Biol., 50 (1): 119-125.

Samuel, A. D., Kiss, S., Sandor, M. (2000): Phosphatase activities in a brown luvic soil. “Stud. Univ. Babeş-Bolyai”, Biol. 45 (2): 91-99.

Samuel, A. D., Vicaş, S. (2005): The effects of soil management practices on the dehydrogenase activities in a brown luvic soil. Buletin USAMV – CN, 61: 211-216.

Spiers, G. A., Mc Gill, W. B. (1989): Effects of phosphorus addition and energy supply on acid phosphatase activity in soils. Soil Biol. Biochem., 11: 3-8.

Ştefanic, G., Eliade, G., Chirnogeanu, I. (1984): Researches concerning a biological index of soil fertility. Fifth Symp. on Soil Biology (Iaşi, 1981), Rom. Natl. Soc. Soil Sci., Bucharest, 35-45.

Tang, S. (1987): Microbiological characteristics and biological activity of albic soils. Acta Pedol. Sin., 24: 239-247.