FIELD MANAGEMENT EFFECTS ON SOIL ENZYME ACTIVITIES

Alina Dora Samuel[1] , Cornel Domuța[2] , Cornelia Ciobanu[2], Maria Şandor[2]

ABSTRACT

Agricultural practices that reduce soil degradation and improve agricultural sustainability are needed particularly for preluvosoil. No-tillage planting causes minimal soil disturbance and combined with crop rotation may hold potential to meet these goals. Soil enzyme activities can provide information on how soil management affects the soil potential to perform processes, such as decomposition and nutrient cycling. Soil enzyme activities (actual and potential dehydrogenase and catalase) were determined in the 0–20, 20–40 and 40–60 cm layers of a preluvosoil submitted to a complex experiment including tillage (no-till and conventional tillage), crop rotation (2 and 6 years crop rotations) and fertilization [mineral (NP) fertilization and farmyard-manuring], for three years, from 2005 to 2007. Each activity in both non-tilled and conventionally tilled soil under all crops of both rotations decreased with increasing sampling depth. No-till – in comparison with conventional tillage – resulted in significantly higher soil enzymatic activities in the 0–20 and in significantly lower activities 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 recorded under wheat than under maize. The enzymatic indicators of soil quality were calculated from the values of enzymatic activities determined in the plots of the 6 crop rotation. This means that by determination of enzymatic activities, valuable information can be obtained regarding fertility status of soils. It should be emphasized that farmyard-manuring of maize – in comparison with mineral (NP) fertilization – led to a significant increase in each of the three enzymatic activities determined.

Key words: catalase, crop rotation, dehydrogenase, preluvosoil, tillage.

INTRODUCTION

The degradation of plant and animal matter, involving the release and binding of nutrients and trace elements is one of the most important functions of soil organisms. The microorganisms are important for the enzymatic degradation of the complex organic substances to nutrients and for the release of nutrients and trace elements from the mineral soil fraction.

Soil microorganisms, the living component of the soil, usually occupy less than 1% of the soil volume, while their number and efficiency are very high. The number and activity of soil microorganisms are dependent on crop, soil type, soil treatment, soil cultivation as well as on the macro- and microclimate at each location (Dalal and Mayer, 1986).

In continuation of our investigations, during which in 2000 we determined phosphomonoesterase in a preluvosoil submitted to a complex tillage, crop rotation and fertilization experiment at the Agricultural Research-Development Station in Oradea (Bihor County), now we report on the determination of actual and potential dehydrogenase and catalase activities in this soil.

The first enzymological data on this soil were published by Ştefanic and his collaborators (Ştefanic et al., 1984; Ştefanic and Picu, 1989). They studied the soil enzymological effect of mineral (NP) fertilization and liming and found that catalase activity was higher while dehydrogenase, invertase and phosphatase activities were lower in the NP-fertilized and limed soil samples than in the unfertilized limed ones. Ştefanic also dealt with the effect of compost application and irrigation on the enzyme activities in this soil, but he published no paper on these investigations (personal communication, 1999).

Soil enzymes are important for catalyzing innumerable reactions necessary for life processes of microorganisms in soils, decomposition of organic residues, cycling of nutrients and formation of organic matter and soil structure (Deng and Tabatabai, 1997). Although enzymes are primarily of microbial origin they can also originate from plants and animals. These enzymes are constantly being synthesized, could be accumulated, inactivated and / or decomposed in the soil, and have a great importance for the agriculture, due to their role in recycling the nutrients (Dick et al., 1988, 1994; Dick and Daniel, 1987).

Soil enzymes activities have successfully discriminated between a wide range of soil management practices (Dick, 1992, 1997). Although there is a lot of information that show the relation between soil management and soil enzymes activities, very little is known about these effects in preluvosoil. In this context, the measurement of soil enzymes can be used as

---

[1] University of Oradea, Department of Plant Biology, Oradea, Bihor County, Romania, e-mail: samuelalina@rdslink.ro
[2] Agricultural Research-Development Station Oradea, Oradea, Bihor County, Romania

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, ease of measurement, and rapid response to changes in soil management.

MATERIAL AND METHODS

The ploughed layer of the studied preluvosoil is of mellow loam texture, it has a pH value of 5.5, medium humus (2.32%) and P (22 ppm) contents, but it is rich in K (83 ppm).

The experiment 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, rotations of 2 and 6 crops, and mineral (NP) fertilization and farmyard-manuring.

The crops of the two rotations are specified in table 1. Each plot consisted of two subplots representing the no-till and conventional tillage variants. The plots were annually NP-fertilized at rates of 120 kg N/ha and 90 kg of P/ha, excepting in each year, a maize plot (in the 6 crop rotation) which received farmyard manure (50 t/ha) instead of mineral fertilizers. The plots (and subplots) were installed in three replications.

In October 2005, 2006 and 2007 soil was sampled from all subplots. Sampling depths were 0–20, 20–40 and 40–60 cm. The soil samples were allowed to air-dry, then ground and passed through a 2 mm sieve and, finally, used for enzymological analyses.

Table 1. The studied 2 and 6 crop rotations

Year	2-crop rotation		6-crop rotation					
	Plot		Plot					
	1	2	1	2	3	4	5	6
2005	Maize	Wheat	Wheat	Soybean	Maize	Maize (FYM)*	Clover	Oats - clover
2006	Wheat	Maize	Soybean	Oats- clover	Maize	Wheat	Maize (FYM)	Maize
2007	Maize	Wheat	Maize	Maize(FYM)	Clover	Maize	Soybean	Wheat

*(FYM) – (farmyard-manured).

Actual and potential dehydrogenase activities were determined according to the methods described in Drăgan-Bularda (1983) and Őhlinger (1996). 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 solution, respectively, for potential dehydrogenase. All reaction mixtures were incubated at 37° C for 24 hours. After incubation, the triphenylformazan produced was extracted with acetone and was measured spectrophotometrically at 485 nm. Dehydrogenase activities were expressed in mg of triphenylformazan (TPF) produced (from 2,3,5-triphenyltetrazolium chloride, TTC) by 10 g of soil in 24 hours.

Catalase activity was determined using the permanganometric method (Drăgan-Bularda, 1983); the reaction mixtures consisted of 3.0 g soil, 2 ml H_2O_2 3% and 10 ml phosphate buffer. It suffered incubation at 37ºC for 1 hour. Catalase activity was recorded as mg H_2O_2 decomposed by 1 g of soil in 1 hour.

The activity values were submitted to statistical evaluation by the *t*-test (Sachs, 2002).

RESULTS AND DISCUSSION

Results of the determination of enzymatic activities are presented in tables 2-4, and those of the statistical evaluation are summarized in tables 5-6.

Variation of soil enzymatic activities in dependence of sampling depth

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

Table 2. The effects of soil management practices on enzymatic activities in 2005

Soil enzy-matic activity*	Soil depth (cm)	Rotation of 2 crops**				Rotation of 6 crops											
		Maize		Wheat		Wheat		Soybean		Maize		Maize (FYM) ***		Clover		Oats-clover	
		N.t.	C.t.	N.t.	C.t.	N.t.	C.t.	N.t.	C.t.	N.t.	C.t.	N.t.	C.t.	N.t.	C.t.	N.t.	C.t.
ADA	0-20	4.68	4.50	7.36	6.02	7.76	6.80	7.56	6.72	5.76	4.88	5.82	5.12	6.16	5.32	8.68	6.16
	20-40	2.68	3.10	4.84	5.20	5.01	5.60	4.08	4.81	2.86	3.52	2.52	3.92	4.04	4.36	3.36	4.48
	40-60	1.12	1.80	1.36	1.84	2.80	3.01	1.40	2.52	1.02	1.84	1.40	2.40	2.24	2.80	2.40	3.90
PDA	0-20	23.52	22.36	22.96	21.20	25.20	23.20	26.60	20.90	24.12	22.96	27.16	25.48	24.92	20.72	29.68	23.24
	20-40	15.68	16.52	14.08	15.40	15.28	18.96	16.40	17.72	16.44	17.48	17.92	18.48	12.60	12.88	14.52	15.40
	40-60	2.52	3.36	5.32	5.72	5.60	6.76	7.00	7.56	5.64	7.00	6.01	6.72	4.88	5.60	5.20	6.36
CA	0-20	1.27	1.17	1.86	1.52	1.98	1.77	1.42	1.23	1.44	1.37	1.73	1.68	1.43	1.39	2.15	1.73
	20-40	0.62	1.06	1.17	1.45	1.37	1.49	1.11	0.90	1.02	1.16	1.05	1.10	0.93	1.27	0.74	1.59
	40-60	0.25	0.53	0.59	0.62	0.62	0.34	0.22	0.57	0.27	0.55	0.49	0.65	0.56	0.46	0.53	1.34

Table 3. The effects of soil management practices on enzymatic activities in 2006

Soil enzy-matic activity*	Soil depth (cm)	Rotation of 2 crops**				Rotation of 6 crops											
		Wheat		Maize		Soybean		Oats-clover		Maize		Wheat		Maize (FYM)***		Maize	
		N.t.	C.t.	N.t.	C.t.	N.t.	C.t.	N.t.	C.t.	N.t.	C.t.	N.t.	C.t.	N.t.	C.t.	N.t.	C.t.
ADA	0-20	6.40	5.18	7.14	6.62	6.18	5.18	6.76	5.18	7.24	6.92	6.66	5.54	7.54	7.02	7.18	6.78
	20-40	4.54	4.88	5.32	5.52	3.36	4.20	2.66	3.50	5.14	5.45	3.08	4.92	5.66	5.84	4.94	5.31
	40-60	1.84	1.94	1.66	2.26	1.96	2.05	1.76	1.96	1.41	1.54	1.84	1.96	1.78	2.10	1.26	2.24
PDA	0-20	21.98	20.92	20.50	19.12	25.96	29.24	22.88	24.00	26.24	21.90	23.74	22.54	27.62	22.04	24.98	19.74
	20-40	15.18	15.96	14.50	16.52	17.36	18.62	13.36	14.56	16.44	17.52	15.26	16.68	17.18	18.28	14.42	15.21
	40-60	3.24	3.92	4.21	4.52	6.76	7.00	5.38	6.26	4.76	5.06	4.44	5.84	5.50	6.34	5.28	5.60
CA	0-20	1.93	1.60	1.80	1.73	1.80	1.70	1.74	1.63	1.86	1.83	2.06	1.73	2.23	2.00	2.20	2.94
	20-40	1.40	1.48	1.13	1.28	1.32	1.43	1.19	1.25	1.25	1.36	1.32	1.53	1.60	1.66	1.56	1.63
	40-60	0.69	1.00	0.74	0.93	0.76	0.86	1.05	1.08	0.88	1.01	0.73	1.09	0.94	1.04	0.93	0.97

Table 4. The effects of soil management practices on enzymatic activities in 2007

Soil enzy-matic activity*	Soil depth (cm)	Rotation of 2 crops**				Rotation of 6 crops											
		Maize		Wheat		Maize		Maize (FYM)***		Clover		Maize		Soybean		Wheat	
		N.t.	C.t.	N.t.	C.t.	N.t.	C.t.	N.t.	C.t.	N.t.	C.t.	N.t.	C.t.	N.t.	C.t.	N.t.	C.t.
ADA	0-20	5.86	5.33	7.31	6.04	6.88	5.48	7.74	7.08	6.12	4.93	6.75	6.12	7.87	7.30	7.65	7.29
	20-40	2.87	2.98	4.31	4.44	3.44	4.84	5.08	5.31	3.34	4.06	3.06	3.57	5.29	5.48	4.95	5.18
	40-60	1.12	1.71	1.57	1.87	1.92	2.40	2.04	2.14	1.24	1.93	1.81	2.02	2.26	2.59	2.23	2.43
PDA	0-20	22.73	22.35	23.05	22.87	23.89	23.12	27.45	26.66	.23.00	22.48	22.95	22.55	28.19	27.20	24.62	24.28
	20-40	15.16	16.52	15.26	16.39	15.81	16.03	17.17	17.28	14.16	15.21	15.54	16.61	17.68	18.04	17.14	17.65
	40-60	4.18	4.72	5.20	5.42	4.65	5.29	6.62	6.72	4.29	4.78	4.64	5.31	7.10	7.14	5.97	5.99
CA	0-20	1.75	1.58	1.83	1.76	1.87	1.81	2.00	1.94	1.79	1.69	1.85	1.75	2.05	1.97	1.91	1.87
	20-40	1.23	1.43	1.32	1.38	1.33	1.48	1.55	1.58	1.37	1.45	1.41	1.51	1.54	1.58	1.50	1.56
	40-60	0.67	0.75	0.76	0.82	0.71	0.76	0.83	0.85	0.62	0.69	0.68	0.71	0.80	0.83	0.76	0.79

* ADA – Actual dehydrogenase activity.
PDA – Potential dehydrogenase activity.
CA – Catalase activity.

**N.t. – No-till.
C.t. – Conventional tillage.
***(FYM) – (farmyard-manured).

The effect of tillage practices on enzymatic activities in soil

Each of the three enzymatic activities determined was significantly (at least at $p < 0.02$) higher in the upper (0-20 cm) layer of the non-tilled subplots than in the same layer of the conventionally tilled subplots. The reverse was true (at least at $p < 0.05$) in the deeper (20-40 and 40-60 cm) layers. These findings are also valid for subplots under each crop of both rotations (Table 5).

Our observation is in agreement with other studies. For example Balota et al. (2004) observed that soil management which uses traditional plowing to prepare the land may reduce soil organic matter and microbial activity.

Consequently, agricultural practices aiming toward less soil degradation are needed to improve soil quality, and agricultural sustainability. No-tillage, planting with minimal soil disturbance combined with crop rotation protects the soil against degradation (Dick, 1984).

Tillage alters soil structure exposing more organic matter to microbial attack while no-tillage practices stimulate the formation and stabilization of macro aggregates, which represent an important mechanism for protection and maintenance of soil organic matter, besides other effects such as more stable temperature and changes in the distribution of organic matter and nutrients in the soil (Doran, 1980; Griffith et al., 1988; Gupta and Germida, 1988).

Table 5. Significance of the differences between enzymatic activities in a preluvosoil under different tillage practices

Tillage practices	Soil enzymatic activity*	Year	Soil depth (cm)	Mean activity values in tillage practices			Significance of the differences
				a	b	a-b	
No-till (a) versus conventional tillage (b)	ADA	2005	0-20	6.72	5.69	1.03	$0.01 > p > 0.002$
			20-40	3.67	4.37	-0.70	$0.002 > p > 0.001$
			40-60	1.72	2.51	-0.79	$0.001 > p > 0.0001$
		2006	0-20	6.89	6.05	0.84	$0.002 > p > 0.001$
			20-40	4.34	4.95	-0.61	$0.02 > p > 0.01$
			40-60	1.69	2.01	-0.32	$0.05 > p > 0.02$
		2007	0-20	7.02	6.07	0.95	$0.001 > p > 0.0001$
			20-40	4.04	4.48	-0.44	$0.01 > p > 0.002$
			40-60	1.77	2.14	-0.37	$0.002 > p > 0.001$
	PDA	2005	0-20	25.52	22.51	3.01	$0.02 > p > 0.01$
			20-40	15.36	16.61	-1.25	$0.02 > p > 0.01$
			40-60	5.27	6.14	-0.87	$0.001 > p > 0.0001$
		2006	0-20	24.24	22.44	1.80	$0.01 > p > 0.002$
			20-40	15.46	16.67	-1.21	$0.0001 > p$
			40-60	4.95	5.57	-0.62	$0.01 > p > 0.002$
		2007	0-20	24.49	23.94	0.55	$0.001 > p > 0.0001$
			20-40	15.99	16.72	-0.73	$0.01 > p > 0.002$
			40-60	5.33	5.67	-0.34	$0.01 > p > 0.002$
	CA	2005	0-20	1.66	1.48	0.18	$0.01 > p > 0.002$
			20-40	1.00	1.25	-0.25	$0.01 > p > 0.002$
			40-60	0.44	0.63	-0.19	$0.02 > p > 0.01$
		2006	0-20	1.95	1.78	0.17	$0.01 > p > 0.002$
			20-40	1.35	1.45	-0.10	$0.001 > p > 0.0001$
			40-60	0.84	1.00	-0.16	$0.01 > p > 0.002$
		2007	0-20	1.88	1.80	0.08	$0.001 > p > 0.0001$
			20-40	1.41	1.50	-0.09	$0.01 > p > 0.002$
			40-60	0.73	0.78	-0.05	$0.001 > p > 0.0001$

* ADA – Actual dehydrogenase activity; PDA – Potential dehydrogenase activity; CA – Catalase activity.

The effect of crop rotations on enzymatic activities in soil

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

The soil enzymological effect of the same crop in the two rotations

As maize and wheat were crops in both rotations, it was possible to compare the soil enzymological effect of the 2 and 6 crop rotations. The soil under both crops was more enzyme-active in the 6 than in the 2 crop rotation (Table 6).

In the soil under maize, the difference between the two rotations was significant (at least at 0.05) excepting actual dehydrogenase and catalase activities in 2005 which were insignificantly higher ($p > 0.05$). In the soil under wheat, each activity was significantly higher (at least at $p < 0.05$) in the 6 than in the 2 crop rotation.

Table 6. Significance of the differences between enzymatic activities in a preluvosoil under different crop rotations

Crop rotation practices	Soil enzymatic activity*	Year	Soil depth (cm)	Mean activity values in crop rotation practices			Significance of the differences
				a	b	a-b	
The same crop in the two rotations							
Maize in 2 crop rotation (a) versus maize in 6 crop rotation (b)**	ADA	2005	0-60	2.98	3.31	-0.33	0.10>p>0.05
		2006	0-60	4.75	4.62	0.13	0.05>p>0.02
		2007	0-60	3.31	3.89	-0.58	0.01>p>0.002
	PDA	2005	0-60	13.99	15.61	-1.62	0.05>p>0.02
		2006	0-60	13.23	15.32	-2.09	0.05>p>0.02
		2007	0-60	14.28	14.60	-0.32	0.01>p>0.002
	CA	2005	0-60	0.82	0.97	-0.15	0.10>p>0.05
		2006	0-60	1.27	1.37	-0.10	0.001>p>0.0001
		2007	0-60	1.24	1.32	-0.08	0.02>p>0.01
Wheat in 2 crop rotation (a) versus wheat in 6 crop rotation (b)	ADA	2005	0-60	4.44	5.16	-0.72	0.02>p>0.01
		2006	0-60	4.13	4.00	0.13	p>0.10
		2007	0-60	4.26	4.79	-0.53	0.002>p>0.001
	PDA	2005	0-60	14.11	15.83	-1.72	0.02>p>0.01
		2006	0-60	13.53	14.75	-1.22	0.01>p>0.002
		2007	0-60	14.70	15.95	-1.25	0.002>p>0.001
	CA	2005	0-60	1.20	1.26	-0.06	0.02>p>0.01
		2006	0-60	1.35	1.41	-0.06	0.01>p>0.002
		2007	0-60	1.31	1.40	-0.09	0.05>p>0.02
Different crops in the same rotation **2 crop rotation**							
Maize (a) versus wheat (b)	ADA	2005	0-60	2.98	4.44	-1.46	0.05>p>0.02
		2006	0-60	4.75	4.13	0.62	0.02>p>0.01
		2007	0-60	3.31	4.26	-0.95	0.02>p>0.01
	PDA	2005	0-60	13.98	14.11	-0.13	0.01>p>0.002
		2006	0-60	13.23	13.53	-0.30	0.01>p>0.002
		2007	0-60	14.28	14.70	-0.42	0.02>p>0.01
	CA	2005	0-60	0.82	1.20	-0.38	0.10>p>0.05
		2006	0-60	1.27	1.35	-0.08	0.01>p>0.002
		2007	0-60	1.24	1.31	-0.07	0.01>p>0.002

* ADA – Actual dehydrogenase activity.
PDA – Potential dehydrogenase activity.
CA – Catalase activity.

** Maize (plot 3) in 2006; maize (plot 4) in 2007.

The soil enzymological effect of different crops in the same rotation

The 2 crop rotation. Actual and potential dehydrogenase activities were significantly higher (at least at $p < 0.05$ and $p < 0.02$, respectively), excepting actual dehydrogenase activity in 2006, while catalase activity was insignificantly higher ($p > 0.05$) only in 2005 under wheat than under maize (Table 6).

The 6 crop rotation. Significant ($p < 0.05$ to $p < 0.001$) and insignificant ($p > 0.05$ to $p > 0.10$) differences were registered in the soil enzymatic activities depending on the kind of enzymatic activity and the crop. Based on these differences the following decreasing orders of the enzymatic activities could be established in the soil of the six plots in the three consecutive years:

- in 2005:
  - actual dehydrogenase activity: wheat > oats-clover > soybean > clover > maize (FYM) > maize;
  - potential dehydrogenase activity: maize (FYM) > soybean > wheat > oats-clover > maize > clover;
  - catalase activity: oats-clover > wheat > maize (FYM) > clover > maize > soybean.
- in 2006:
  - actual dehydrogenase activity: maize (FYM) > maize (plot 6) > maize (plot 3) > wheat > soybean > oats-clover ;
  - potential dehydrogenase activity: soybean > maize (FYM) > maize (plot 3) > wheat > oats-clover > maize (plot 6);
  - catalase activity: maize (plot 6) > maize (FYM) > wheat > maize (plot 3) > oats-clover > clover > soybean.
- in 2007:
  - actual dehydrogenase activity: soybean > wheat > maize (FYM) > maize (plot 1) > maize (plot 4) > clover;
  - potential dehydrogenase activity: soybean > maize (FYM) > wheat > maize (plot 1) > maize (plot 4) > clover;
  - catalase activity: soybean > maize (FYM) > maize (plot 1) > wheat > maize (plot 4) > clover.

It is evident from these orders that each of the six plots presented different values of the five soil enzymatic activities. Consequently, these orders do not make it possible to establish an enzymatic hierarchy of the plots, which takes into account each activity for each plot. For establishing such a hierarchy, we have applied the method suggested by Samuel et al. (2000). Briefly, by taking the maximum mean value of each activity as 100% we calculated the relative activities (as percentage). The sum of the relative activities is the enzymatic indicator which is considered as an index of the biological quality of the soil in a given plot. The higher the enzymatic indicator of soil quality, the higher the position of plots is in the hierarchy. The results obtained (Figure 1) show that the different hierarchies of the six plots as registered in 2005, 2006 and 2007 may be related to the different nature of crops and kind of fertilizers (mineral NP or farmyard manure).

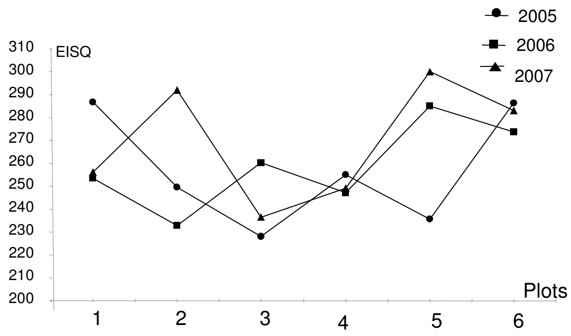

Figure 1. Enzymatic indicators of soil quality in plots of the 6 crop rotation

Our results on a preluvosoil are consistent with previous studies on other soils. Crop rotations that have diverse crop sequences can also be important for maintaining and improving soil quality. Crop rotations change the soil habitat due to differences in extracted nutrients, depth of roots, amount of residue remaining in soil and differences in their components (Breakwell and Turco, 1990; Dick et al., 1988). Crop rotations can stimulate soil biodiversity and biological activity, as compared with monoculture.

Soil management as no-tillage and crop rotations are important practices, which can reduce soil erosion, conserve organic matter and water and stimulate microbial activity (Angers et al., 1993; Canarutto et al., 1995).

The effect of fertilization on the enzymatic activities in soil

The two maize plots in the 6 crop rotation could serve for comparing the soil enzymological effect of mineral (NP) fertilization and farmyard-manuring. One can see from tables 2-4 that the enzymatic activities were always higher in the 20-40 and 40-60 cm layers of the farmyard-manured subplots in comparison with the subplots that received mineral (NP) fertilizers. In concordance with these findings (Figure 1) shows that the farmyard-manured maize plot occupies higher positions, whereas the other maize plots are placed on lower positions in the hierarchy of plots in the 6 crop rotation.

CONCLUSIONS

Although the ecological significance of specific soil enzymes activities is still debatable there are several works which show, in a clear way, the effects of soil management in enzyme activities. The increase in soil enzyme activities may be the result of soil physical and chemical changes, so there is a direct expression on microbial biomass and soil enzyme activities. One argument, which can explain the increase in soil enzyme activities due to tillage, is that NT can improve the microbial habitat. Long-term tillage alters soil structure and can increase the losses of organic matter, because of tillage disrupt soil aggregates exposing more organic matter to microbial attack. The formation and stabilization of macro aggregates under NT soil represent an important mechanism for the protection and maintenance of soil organic matter, which can be lost under CT practices. Thus, macro aggregates provide an important microhabitat for microbial activity. Higher organic matter levels support greater microbial activity because of greater supplies of energy and nutrients. Additionally, greater humus content could facilitate incorporation of soils enzymes into the soil matrix, allowing stabilization of higher content of exoenzymes in soils, because humus compounds are important in forming soil enzyme complexes.

REFERENCES

Angers, D.A., Bissonnette, N., Légére, A., Samson, N., 1993. Microbial and bio-chemical changes induced by rotation and tillage in a soil under barley production. Canadian Journal of Soil Science, 73: 39-50.

Balota, E.L., Kanashiro, M., Filho, A.C., Andrade, D.S., Dick, R.P., 2004. Soil enzyme activities under long-term tillage and crop rotation systems in subtropical agro-ecosystems. Brazilian Journal of Microbiology, 35: 300-306.

Breakwell, D.P., Turco, R.F., 1990. Nutrient and phytotoxic contributions of residues to soil in no-till continuous corn ecosystems. Biology and Fertility of Soils, 8: 328-334.

Canarutto, S., Mazzoncini, M., Perna, A., Cervelli, S., 1995. The effect of reduction of inputs on phosphatase activity, organic carbon content and water stability index in a corn cultivated soil. Fresenius Environmental Bulletin, 4: 291-296.

Dalal, R.C., Mayer, R.J., 1986. Long-term trends in fertility of soils under continuous cultivation and cereal cropping in Southern Queensland. I. Overall changes in soil properties and trends in winter cereal yields. Australian Journal of Soil Research, 24: 265-279.

Deng, S.P., Tabatabai, M.A., 1997. Effect of tillage and residue management on enzyme activities in soils. Biology and Fertility of Soils, 24: 141-146.

Dick, W.A., 1984. Influence of long-term tillage and crop rotation combinations on soil enzyme activities. Soil Science Society of America Journal, 48: 569-574.

Dick, R.P., 1992. A review: long-term effects of agricultural systems on soil biochemical and microbial parameters. Agriculture, Ecosystems and Environment, 40: 25-36.

Dick, R.P., 1997. Soil enzyme activities as integrative indicators of soil health. In: Pankhurst, C.E., Doube, B.M., Gupta, V.V.S.R. (Eds.). Biological Indicators of Soil Health CAB International: 121-156.

Dick, W.A., Daniel T.C., 1987. Soil chemical and biological properties as affected by conservation tillage: Environmental impacts. In: Logan, T.J. Davidson, J.M., Baker, J.L. (Eds.). Effects of Conservation tillage on Groundwater Quality: Nitrates and Pesticides. Lewis Publishers, Inc., Chelsea, Michigan: 125-147.

Dick, R.P., Myrold, D.D., Kerle, E.A., 1988. Microbial biomass and soil enzyme activities in compacted and rehabilitated skid trail soils. Soil Science Society of America Journal, 52: 512-516.

Dick, R.P., Rasmussen, P.E., Kerle, E.A., 1988. Influence of long-term residue management on soil enzyme activities in relation to soil chemical properties of a wheat-fallow system. Biology and Fertility of Soils, 6: 159-164.

Dick, R.P., Sandor, J.A., Eash, N.S., 1994. Soil enzyme activities after 1500 years of terrace agriculture in the Colca Valley, Peru. Agriculture, Ecosystems and Environment, 50: 123-131.

Doran, J.W., 1980. Soil microbial and biochemical changes associated with reduced tillage. Soil Science Society of America Journal, 44: 756-771.

Drăgan-Bularda, M., 1983. Lucrări practice de microbiologie generală. (Practical studies of microbiology). Universitatea Babeş-Bolyai, Cluj-Napoca: 163-167.

Griffith, D.R., Kladivko, E.J., Mannering, J.V., West, T.D., Parsons, S.D., 1988. Long-tillage and rotation effects on corn growth and yield on high and low organic matter, poorly drained soil. Agronomy Journal, 80: 599-605.

Gupta, V.V.S.R., Germida, J.J., 1988. Distribution of microbial biomass and its activity in different soil aggregate size classes as affected by cultivation. Soil Biology and Biochemistry, 20: 777-786.

Őhlinger, R., 1996. Dehydrogenase activity with the substrate TTC. In: Schinner, F., Őhlinger, R., Kandeler, E., Margesin, R., (Eds.), Methods in Soil Biology. Springer, Berlin: 241-243.

Samuel, A.D., Kiss, S., Sandor, M., 2000. Phosphatase activities in a brown luvic soil. Studia Universitatis Babeş-Bolyai, Biologia, 45 (2): 91-99.

Sachs, L., 2002. Der Statistik Test. In: Sachs, L. (Ed.), Angewandte Statistik Anwerdung statisticher Methoden. Springer, Berlin: 189-195.

Ştefanic, G., Eliade, G., Chirnogeanu, I., 1984. Researches concerning a biological index of soil fertility. Fifth Symposium on Soil Biology (Iaşi, 1981). Journal of the Romanian National Society of Soil Science, Bucharest: 35-45.

Ştefanic, G., Picu, I., 1989. Modul de afânare anuală a solului şi unele modificări biotice, enzimatice şi agrochimice constatate în cernoziomul cambic irigat de la I.C.C.P.T. Fundulea. Proceeding of National Conference of Soil Science (Piteşti, 1988). Journal of the Romanian National Society of Soil Science, Bucharest: 169-174.