DEHYDROGENASE: AN INDICATOR OF BIOLOGICAL ACTIVITIES IN A PRELUVOSOIL

Alina Dora SAMUEL

University of Oradea, Department of Plant Biology, Str. Armatei Romane, 5, 410087 Oradea,
Corresponding author: samuelalina@rdslink.ro

Abstract: *The metabolic activity of soil microorganisms is essential for organic matter turnover. The metabolization and immobilization of inorganic nutrients and trace elements are also mainly a result of microbial activities. Metabolic activities are determined by the species composition, which in turn is influenced by the available litter, the soil type and other environmental conditions. Special enzymes catalyze the organic matter turnover. These enzymes are produced by the organisms and act intra- or extracellularly. Soil enzymes include a wide spectrum of oxidoreductases, transferases, hydrolases and lyases. The dehydrogenase activity of a soil is thus the result of the activity of different dehydrogenases, which are an important component of the enzyme system of all microorganisms. Actual and potential dehydrogenase activities were determined in the 0-20, 20-40 and 40-60 cm layers of a brown luvic soil submitted to a complex tillage, crop rotation and fertilisation experiment. Dehydrogenase activities in both non-tilled and conventionally tilled soil under all 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 in the 0-20 cm layer 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 registered under wheat that under maize. In the 6–crop rotation, the enzymatic indicators of soil quality decreased, depending on the nature of crops and kind of fertilisers (mineral NP or farmyard manure), in the following order: farmyard manured maize > minerally fertilised (m.f) wheat > m.f. maize plot 6 > m.f. soybean > m.f. maize plot 3 > m.f. oats-clover mixture. Farmyard manuring of maize in comparison with its mineral (NP) fertilisation led to a significant increase in each activity.*

Key words: *dehydrogenase, preluvosoil, crop rotation, fertilizers*

INTRODUCTION

The effects of cultivation on soil biology (KANDELER and MURER,1993; BANDICK and DICK, 1999) can be modified by the type of tillage management that is used. Conservation tillage practices that have various degrees of soil disturbance and that leave significant amounts of plant residue on the soil surface can affect biological properties of soils (MUBARAK et al., 2005). No-tillage systems result in an increase in the concentration of nutrients, organic matter and pesticides at the soil surface (KIRCHNER et al., 1993; LANGER and GUNTHER, 2002; SAMUEL, 2009a).

Studies have shown that crop rotations have significantly higher levels of microbial biomass (TAYLOR et al., 2002) and soil enzyme activities (DICK et al., 1994) than cropping sequences that are either continuously monocultured or have more limited crop rotations. Continuous monoculturing of a single crop species typically results in reduction of crop yields in comparison to the same species in rotation (DICK, 1992) and these reductions usually are not associated with fertility or pest interactions.

In general, management practices that increase inputs of organic residue, plant or animal manures, increase biological activity (SCHULZ, 2004). Addition of farmyard manure, usually increases microbial biomass and soil enzyme activities (CANARUTTO et al., 1995; CLARHOLM and ROSENGREN-BRINCK, 1995) over soils that have not received any organic or inorganic amendments. However, when comparisons have been made between soils amended with farmyard manure or organic fertilisers, there have been mixed results which vary with cropping system and biological index. Thus management practices that increase incorporation of organic residue typically increase biological activity. Use of inorganic fertiliser can increase the plant biomass production which in turn increases the amount of residue returned to the soil and stimulates biological activity (BALOTA et al., 2003; DENG and TABATABAI, 1997).

MATERIALS AND METHODS

The ploughed layer of the studied brown luvic soil 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 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, rotations of 2 and 6 crops, and mineral (NP) fertilisation 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-fertilised 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 fertilisers. The plots (and subplots) were installed in three repetitions.In October 2009, 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.

Actual and potential dehydrogenase activities were determined according to the methods describe in (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 37º C for 24 hours. After incubation, the triphenylformazan produced was extracted with acetone and was measured spectrophotometrically at 485 nm. 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.

The enzymatic activity values were submitted to statistical evaluation by the two-way t-test (SACHS, 2002).

RESULTS AND DISCUSSION

Results of the enzymological analyses are presented in Table 1, and those of the statistical evaluation are summarised in Table 2.

Variation of soil enzymatic activities in dependence of sampling depth

It is evident from Table 1 that each enzymatic activity decreased with sampling depth in both subplots under all crops of both rotations. In addition, Table 2 shows that the mean values of each of the five activities in both non-tilled and conventionally tilled subplots also decreased with increasing soil depth.

The effect of tillage practices on the enzymatic activities in soil

Each of the two enzymatic activities determined was significantly higher (at least at $p < 0.002$) 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 $p < 0.01$) in the deeper (20–40– and 40–60–cm) layers. These findings are also valid for subplots under each crop of both rotations.

The effect of crop rotations on the enzymatic activities 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.

Table 1

Significance of the differences between enzymatic activities in a preluvosoil 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 20-40 40-60	6.89 4.34 1.69	6.05 4.95 2.01	0.84 -0.61 -0.32	0.002 > p > 0.001 0.02 > p > 0.01 0.05 > p > 0.02
	PDA	0-20 20-40 40-60	24.24 15.46 4.95	22.44 16.67 5.57	1.80 -1.21 -0.62	0.01 > p > 0.002 0.0001 > p 0.01 > p > 0.00
The same crop in the two rotations						
Maize in 2– crop rotation (b) versus maize in 6– crop rotation (b)	ADA PDA	0-60	4.75 13.53	4.62 14.75	-0.33 -1.22	0.10 > p > 0.05 0.01 > p > 0.02
Wheat in 2– crop rotation (b) versus in wheat 6– crop rotation (b)	ADA PDA	0-60	4.13 14.11	4.00 15.83	0.13 -1.72	p > 0.10 0.02 > p > 0.002
Different crops in the same rotation						
2– crop rotation Maize (a) versus wheat (b)	ADA PDA	0-60	4.75 13.23	4.13 13.53	0.62 -0.30	0.02 > p > 0.01 0.01 > p > 0.002
6– crop rotation Maize (a) versus maize(FYM)** (b)	ADA PDA	0-60	4.62 15.32	4.99 16.16	-0.37 -0.84	0.01 > p >0.002 0.01 > p > 0.002

* ADA – Actual dehydrogenase activity. PDA – Potential dehydrogenase activity.
**(FYM) – (farmyard-manured).

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. In the soil under maize, the difference between the two rotations was significant ($p < 0.05$) in the both of dehydrogenase activities whereas in the soil under wheat, only potential dehydrogenase activity was significantly higher ($p < 0.01$) in the 6– than in the 2–crop rotation. Actual dehydrogenase activity was unsignificantly higher ($p > 0.10$) in the 2–crop rotation.

The soil enzymological effect of different crops in the same rotation

The 2–crop rotation. Actual dehydrogenase activity was significantly higher ($p < 0.02$), in the maize soil than in the soil under wheat whereas potential dehydrogenase activity was higher ($p < 0.01$), in the wheat soil than in the soil under maize

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

actual dehydrogenase activity: maize (FYM) > maize plot 3 > maize plot 6 > wheat > soybean > oats-clover;

potential dehydrogenase activity: soybean > maize (FYM) > maize plot 3 > wheat > oats-clover > maize plot 6.

It is evident from these orders that each of the six plots presented either a maximum or a minimum value of the two soil enzymatic activities

Consequently, these orders do not make it possible to establish such 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 in (SAMUEL, 2009b). Briefly, by taking the maximum mean value of each activity as 100% we have calculated the relative (percentage) activities. 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. Table 3 shows that the first three positions are occupied by those plots in which dehydrogenase activities were the highest. Thus, position 1 was occupied by the minerally fertilised wheat plot, whereas the farmyard-manured maize plot and the minerally fertilised legumes (soybean and clover) were placed on the positions 3, 4 and 5, respectively. The minerally fertilised maize plot occupied the last position could be considered as the least enzyme-active soil.

The effect of fertilisation 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) fertilisation and farmyard-manuring. One can see from Table 1 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 had received mineral (NP) fertilisers. When the three soil layers were considered together (Table 2), each of the enzymatic activities was found to be significantly higher (at least at $p < 0.01$) in the farmyard-manured plot than in the minerally fertilised plot. In concordance with these findings, Table 3 shows that the farmyard-manured maize plot occupies position 3, whereas the other maize plot is placed on the last position in the hierarchy of plots in the 6–crop rotation.

Table 2

Enzymatic indicators of soil quality in plots of the 6–crop rotation

Position	Plot	Enzymatic indicator of soil quality
1	Farmyard-manured maize	488.44
2	Minerally fertilised (M.f.) wheat	452.63
3	M.f. maize plot 6	449.14
4	M.f. soybean	445.44
5	M.f. maize plot 3	431.26
6	M.f. oats-clover mixture	416.69

Our results are in good agreement with the literature data reviewed by (BALOTA et al., 2003; LULU and INSAM, 2000; SHERWOOD and UPHOFF, 2000) and constitute novelties for the enzymological characterization of a preluvosoil submitted to complex management practices.

CONCLUSIONS

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

No-till – in comparison with conventional tillage - resulted in higher enzymatic activities in the 0–10– and 10–20–cm layers and in lower activities in the 20–30– and 30–40–cm soil layers under each crop of both rotations.

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

Farmyard-manuring in comparison with mineral fertilisation proved to be more efficient in increasing enzymatic activities in soil layers under maize in the 6-crop rotation.

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