ARCHIVES OF ENVIRONMENTAL PROTECTION

vol. 38 no. 1 pp. 75 - 82 2012

VERSITA

PL ISSN 2083-4772
DOI: 10.2478/v10265-012-0006-8

IMPACT OF THE TILLAGE SYSTEM ON THE SOIL ENZYMATIC ACTIVITY

ELŻBIETA JOLANTA BIELIŃSKA[1]*, AGNIESZKA MOCEK-PŁÓCINIAK[2]

[1]University of Life Sciences in Lublin, Institute of Soil Science and Environment Management
ul. Leszczyńskiego 7, 20-069 Lublin, Poland
[2]University of Life Science in Poznań, Department of General and Environmental Microbiology
ul. Szydłowska 50, 60-656 Poznań
*Corresponding author's e-mail: elzbieta.bielinska@up.lublin.pl

Keywords: Soil, tillage system, enzymatic activity.

Abstract: The aim of this study was to determine the effect of the soil tillage system on soil enzymatic activity. The performed investigations, employing two soil tillage systems: classical (ploughing) and simplified (no-tillage), were carried out on Luvisols and Arenosols differing typologically, with regard to their kind and species. The activity of the following five enzymes was determined in soil samples: dehydrogenases, acid phosphatase, alkaline phosphatase, urease and protease. The applied enzymes tests turned out to be good indicators differentiating the examined soil objects depending on the employed tillage system. The employment of the simplified tillage system stimulated significantly the activity of the analysed enzymes irrespective of the soil type. This effect was particularly apparent in the top layer (0–10 cm) of the soil. An exceptionally wide range of activity was obtained for dehydrogenases indicating the usefulness of this group of enzymes for the evaluation of changes in the soil environment under the influence of the soil tillage system. The observed activity stimulation of the examined enzymes was accompanied by advantageous changes in soil chemical conditions.

INTRODUCTION

Soil cultivation systems, from the classical (ploughing) to the extremely simplified, have an effect on the physical, chemical and biological properties of soils [1, 5, 15]. The choice of an appropriate tillage system is mainly dependent on the local soil conditions, climate and type of crop [8]. Biological processes that determine soil fertility and productivity are chiefly linked to the micro-organisms and the enzymes that they release [18, 19, 25]. The monitoring of the pedosphere, applying methods based on enzymatic tests, enables the complex evaluation of the changes which take place in the soil environment under the influence of the tillage system employed [1, 2, 5, 11, 23]. Changes in the activity of soil enzymes reflect environmental imbalances which impact the soil as well as the plants [4, 16]. The basic advantages of the biological methods of evaluating the soil environment condition, based on enzymatic labelling, is not only an opportunity to carry out serial analyses but, first and foremost, the ability to present generally the influence of numerous factors or to assess parameters impossible to be determined by other means, such as the elements of cell metabolism [4]. The purpose of the investigations was to determine the impact of the cultivation system on the enzymatic activity of soils differing typologically [3].

These investigations have been planned as the continuation of earlier research [5]. The following study may become the basis for forecasting trends in changes to habitation conditions which occur in connection with the cultivation system.

MATERIALS AND METHODS

The investigations were carried out in western Poland within the area of the Greater Poland region, on the Karolew farm, covering an area of approximately 2500 hectares, where the land has been cultivated using a simplified method for over ten years, and within the adjacent fields covering an area of 3–4 hectares (privately owned farms) which employ traditional methods of crop production. The Karolew farm, owned by Poznan University of Life Sciences, is located in the district of Borek Wielkopolski, poviat of Gostyń (51°55' N; 17°15' E). According to the regional classification of Europe, the area belongs to Wysoczyzna Kaliska (318.12) [13].

This region, being beyond the extent of the Baltic glaciation, is composed of boulder clays with a strongly weathered surface layer and clayey sands of glacial origin. Locally, there are also occasional sands with low clay content deposited on unconsolidated sands of glacial or alluvial origin. Typologically, they are identified as Luvisols and Arenosols.

The climate of the region is shaped by the conflicting air masses from the Atlantic Ocean, Eastern Europe and Asia, modified by strong Arctic or Mediterranean influences, therefore causing highly changeable weather conditions. The prevalence of winds from the west indicates a greater impact of the oceanic climate, bringing milder winters but cooler summers than those typical of central and eastern Poland. The average long-term temperatures in this region range from -2.8 to -1.5°C in January, from 17.6 to 18.0°C in July and from 7.5 to 8.4°C for the whole year. Greater Poland region belongs to the areas of the least rainfall in Poland, with a long-term average of 500–600 mm [6]. The rainfall pattern is not favourable for agriculture due to frequent dry spells in spring time, especially in May and June. Similarly low rainfall amounts in the winter months, from October to February, often do not redress water deficits caused by evapotranspiration, which is usually higher than the rate of rainfall during vegetation season.

Comparative investigations of the enzymatic activity, taking into account two tillage systems: classical (ploughing) and simplified (no-tillage), were performed on soils differing typologically, with regard to their kind and species: Luvisols and Arenosols. The objectives of the investigations were 8 soil profiles of similar or identical features and related morphological structure under classic cultivation (CL, privately owned farms – 4 profiles) and simplified (SI, the Karolew farm – 4 profiles).

Both farming systems use crop rotation. The doses of mineral fertilizers are adjusted to the requirements of the plants and the soil properties.

Soil samples were collected in October 2009 in the following profiles: Luvisols – 1CL and 2SI, 5 CL and 6SI, 7 CL and 8 SI; Arenosols – 3CL and 4 SI, from the layers: 0–10, 10–20 and 20–30 cm. The study covered fields sown with winter wheat. The activity of five enzymes was marked in the soil samples: dehydrogenases [24], acid phosphatase and alkaline phosphatase [22], urease [26] and protease [14]. Additionally, the basic chemical properties of the investigated soils were indicated: pH reaction in 1 mol $KCl \cdot dm^{-3}$ (ISO

10390) and the content of the following elements: organic carbon (ISO 14235), crude nitrogen (ISO 13878), available forms of potassium and phosphorus [9].

Statistical analyses were performed using Statistica 6.0 PL program.

RESULTS AND DISCUSSION

The soils under the classic tillage system (objects: 1 CL, 3 CL, 5 CL, 7 CL) gave a slightly acidic to neutral reaction, and the soils under the simplified farming (objects 2 SI, 4 SI, 6 SI, 8 SI) from acidic to slightly acidic (Table 1).

Table 1. Some chemical properties of soils

Profile No.	Layer	pH	OC	TN	OC:TN	P	K
	(cm)	KCl	(%)			(mg·kg^{-1})	
1 CL	0-10	6.6	0.82	0.09	9.1	162.8	95.3
	10-20	6.7	0.79	0.08	9.8	159.2	55.9
	20-30	6.4	0.41	0.04	10.2	158.3	25.1
2 SI	0-10	5.3	1.55	0.14	11.0	395.1	467.5
	10-20	6.1	0.99	0.10	9.9	229.6	200.4
	20-30	6.2	0.78	0.08	9.7	202.7	138.3
3 CL	0-10	6.4	0.86	0.09	9.5	260.4	192.8
	10-20	6.8	0.78	0.08	9.7	249.2	179.1
	20-30	6.5	0.39	0.04	9.7	263.5	112.9
4 SI	0-10	5.2	1.19	0.11	10.8	423.9	312.7
	10-20	5.8	0.95	0.09	10.5	359.1	202.3
	20-30	6.1	0.62	0.06	10.3	296.5	179.2
5 CL	0-10	5.9	1.21	0.12	10.0	169.6	190.4
	10-20	6.2	1.02	0.10	10.2	153.2	150.8
	20-30	5.8	0.74	0.07	10.5	137.0	116.1
6 SI	0-10	5.1	1.65	0.15	11.0	288.5	279.4
	10-20	5.4	1.44	0.13	11.0	160.9	211.0
	20-30	5.5	1.36	0.12	11.3	117.3	153.2
7 CL	0-10	6.0	1.19	0.12	9.9	166.1	204.6
	10-20	6.2	0.98	0.10	9.8	121.2	111.9
	20-30	6.1	0.79	0.08	9.8	104.2	92.3
8 SI	0-10	5.5	1,65	0.16	10.3	231.5	269.4
	10-20	6.1	1,24	0.12	10.3	168.9	129.7
	20-30	6.2	1.10	0.10	11.0	110.8	99.2
$LSD_{0.05}$			0.22	0.02	0.8	55.8	36.2

Explanations: CL – classical tillage system; SI – simplified tillage system; OC – organic carbon; TN – total nitrogen; P and K – available phosphorus and potassium forms

The increase in the acidity of the soils cultivated employing the simplified method was connected with the significant intensity of biochemical processes in the soil environment (Table 2).

Table 2. Enzymatic activity of soils (Dh – dehydrogenases in $cm^3\ H_2 \cdot kg^{-1} \cdot d^{-1}$, Pac – acid phosphatase and Pal – alkaline phosphatase in in mmol $PNP \cdot kg^{-1} \cdot h^{-1}$, Ur – urease in mg $N\text{-}NH_4^+ \cdot kg^{-1} \cdot h^{-1}$, Pr – protease in mg $tyrosine \cdot g^{-1} \cdot h^{-1}$)

Profile No.	Layer (cm)	Dh	Pac	Pal	Ur	Pr
1 CL	0-10	3.9	78.3	92.9	26.3	14.3
	10-20	3.5	69.2	84.7	24.5	11.2
	20-30	2.4	47.9	52.8	9.8	7.6
2 SI	0-10	8.5	126.7	174.5	46.5	21.8
	10-20	7.7	82.1	115.6	27.1	15.4
	20-30	2.8	70.4	61.4	8.5	7.2
3 CL	0-10	2.2	69.8	52.3	11.4	10.4
	10-20	1.4	59.5	36.4	7.6	9.2
	20-30	0.9	35.9	26.1	4.3	6.5
4 SI	0-10	6.6	101.3	72.6	18.8	15.3
	10-20	5.1	76.6	61.7	10.1	11.2
	20-30	1.1	58.4	42.8	5.2	6.9
5 CL	0-10	4.2	112.5	81.2	24.3	16.1
	10-20	3.8	110.3	66.3	10.6	13.2
	20-30	2.6	75.0	48.5	4.3	8.6
6 SI	0-10	9.3	154.1	156.1	39.4	21.2
	10-20	8.5	127.9	123.7	13.2	15.3
	20-30	3.1	96.2	61.6	5.1	9.1
7 CL	0-10	4.3	126.4	62.9	22.4	15.9
	10-20	3.9	120.9	41.5	10.7	14.1
	20-30	2.6	109.1	38.4	4.9	8.7
8 SI	0-10	9.8	174.5	116.9	36.5	20.4
	10-20	9.1	140.2	90.3	12.9	15.8
	20-30	3.0	131.3	51.2	5.4	9.2
$LSD_{0.05}$		0.6	23.9	17.5	2.8	4.3

Explanations: CL – classical tillage system; SI – simplified tillage system

The products of the organic matter transformation (including CO_2 and low molecular organic acids), the number of which is related to the metabolic activity of micro-organisms and the enzymes they release, significantly impact soil acidity [12]. On the majority of the examined objects the pH_{KCl} values in the top layer (0–10 cm) were lower than in deeper zones (10–20 and 20–30 cm).

The content of organic carbon and total nitrogen in the soils under the simplified cultivation system was markedly larger than in those soils under the classic method. Statistically significant differences were only noted in the case of Luvisols (objects: 1–2, 5–6, 7–8), mainly in their top (0–10 cm) layer (Table 1). The amounts of organic carbon and total nitrogen in the 0–10 and 10–20 cm layers of the studied soils were notably larger than in the 20–30 cm layer (Table 1).

In the top (0–10 cm) layer of the soil samples, the C:N ratio was significantly higher where the simplified cultivation system was employed than those from specimens coming from the classic system (Table 1).

The content of available phosphorus in the soils was very high: 104.2–263.5 $mg \cdot kg^{-1}$ from objects under the classic system and 110.8–423.9 under the simplified farming system. A statistically significant increase in this form of phosphorus under the influence of applying limited cultivation was noted primarily in the top (0–10 cm) layer of the soils (Table 1). The vertical distribution of phosphorus, which is a low mobility element, was clearly dependent on the cultivation system. Under the classic system, with a typical tillage method and annual soil displacement during cultivation, the content of available phosphorus forms in the analysed soil layers (0–10, 10–20, 20–30 cm) was similar. Under the simplified system, the content of this component in the top layers (0–10 cm) was several times larger than in the 20–30 cm layers (Table 1).

The available potassium contents in the top layer of the soils under the simplified system were at high levels (269.4–467.5 $mg \cdot kg^{-1}$), and in the remaining soils at low and medium levels (25.1–211.0 $mg \cdot kg^{-1}$) (Table 1). Similarly to the available phosphorus analysis, the statistically significant increase of this form of potassium under the limited cultivation was noted mainly in the top layer of the soils. For all the studied objects, the amount of available potassium in the soils decreased markedly with depth (Table 1). The available forms of this element, due to their solubility, are exposed to leaching.

The activity of all the examined enzymes was visibly lower in those soils cultivated in a traditional way than in the soils where the simplified system was employed (Table 2). Causing changes in a vertical distribution, chemical composition and the size of the organic substance particles as well as aquatic and aerial conditions in the soil environment, traditional cultivation impacts both the enzymatic activity and the biomass of micro-organisms [5, 7, 21]. The investigations of Schulten and others [21] have indicated that the increase in the size of the particles and the complexity of the organic matter bonds in the soil under traditional farming (tillage system) is accompanied by a substantial decrease (within the range of 60–80%) in the activity of the enzymes taking part in the transformation cycle of C, N and P.

The research showed a statistically significant impact by the simplified cultivation system on the increase in the activity of dehydrogenases and alkaline phosphatase in the 0–10 and 10–20 cm layers, and the acid phosphatase, urease and protease only in the top layer (0–10 cm). From the ecological point of view, the high enzymatic activity in the top layer of the soils under the simplified tillage system that could be observed during this study over a period of three consecutive years [5] may provide evidence for a strengthening of soil condition. Numerous data from reference sources [7, 20, 21] confirm that the beneficial influence of the simplified tillage system on enzymatic activity is particularly apparent in the top layer of the soils.

The enzyme activity in the top layers of the soil under the simplified system was higher, approximately: dehydrogenases by 50–70%, acid phosphatase and alkaline phosphatase by 30–50%, urease by 40% and protease by 20–30% in comparison to the soil cultivated traditionally. An exceptionally wide range of activity was obtained for dehydrogenases, indicating the usefulness of this group of enzymes for the evaluation of changes in the soil environment under the influence of the soil tillage system. The stimulation in activity of the examined enzymes was accompanied by markedly higher content of C_{org} and N_{og} in the top layers of the soils than in the case of traditional farming (Table 1). These investigations indicated that the activity of the examined enzymes positively correlated with the content of $C_{org.}$: r = 0.88-0.91, where $p \leq 0.001$. These data again demonstrate that the level of activity of soil enzymes is mostly determined by the content of organic matter. This is in connection with the dynamic development of micro-organisms due to the abundance of easily accessible energy substances.

By and large, Luvisols (objects: 1–2, 5–6, 7–8) were marked by a higher enzymatic activity than Arenosols (objects 3–4), (Table 2). All soil types have a characteristic composition of specific enzymes and an inherent enzymatic activity level. The differences in the forming of enzymatic activity in various soil types mostly result from the fact that each soil type, depending on its origin and developmental conditions, is distinct with regard to the content of organic matter, granulometric composition and micro-organic activity [10].

CONCLUSIONS

1. The enzymatic tests proved to be good indicators for differentiating soil objects where different tillage systems are applied.
2. The employment of the simplified tillage system stimulated significantly the activity of the examined enzymes, irrespective of the soil type, which, from the practical perspective, has a great significance for the recognition of the processes releasing the nutritional elements of plants.
3. An exceptionally wide range of activity was obtained for dehydrogenases, indicating the usefulness of this group of enzymes for the evaluation of changes in the soil environment under the influence of the soil tillage system.
4. In top layers the activity stimulation of the examined enzymes was accompanied by advantageous changes in soil chemical properties. It provides evidence that introducing limitations in cultivation entails positive changes in the essential elements of the fertility of these soils.

REFERENCES

[1] Bandick A.K., R.P. Dick: *Field management effects on soil enzyme activities*, Soil Biol. Biochem., **31**, 1471−1479 (1999).

[2] Bielińska E.J., A. Mocek-Płóciniak: *Field management effects on soil enzyme activities*, Archives of Environmental Protection, **35**, 3, 101−107 (2009).

[3] Bielińska E.J., J. Pranagal: *Enzymatic activity as an indicator of degradation of agriculturally used silty soils* (in Pollish with English summary), Rocz. Glebozn., **57**, 1/2, 41−49 (2006).

[4] Bielińska E.J., J. Pranagal: *Enzymatic activity of soil contaminated with triazine herbicides*, Polish J. of Environ. Stud., **16**, 2, 295−300 (2007).
[5] Bielińska E.J., A. Mocek, M. Paul-Lis: *Impact of the tillage system on the enzymatic activity of typologically diverse soils*, Journal of Research and Applications in Agricultural Engineering, **53** (3), 10−13 (2008).
[6] CSO (Central Statistical Office): *Environment 2009. Statistical information and elaborations* (in Polish with English summary), Statistical Publishing Establishment, Warsaw, pp. 540 (2009).
[7] Curci M., M.D.R. Pizzigallo, C. Crecchio, R. Mininni, P. Ruggiero: *Effect of conventional tillage on biochemical properties of soils*, Biol. Fertil. Soils, **25**, 1, 1−6 (1997).
[8] Domżał H., A. Słowińska-Jurkiewicz: *The effect of different tillage systems for winter wheat cultivation on morphological structure of soil arable layer* (in Polish with English summary), Fragmenta Agronomica, **4**, 18−33 (1995).
[9] Egner H., H. Riehm, W.R. Domingo: *Untersuchungen über die chemische Bodenanalyse als Grunlage für die Beurteilung des Nährstoffzustandes der Böden: II Chemische Extraktions-methoden zur Phosphor- und Kalium bestimmung*, Kungl. Lantbrukshögskolans Annaler, **25**, 204−209 (1960).
[10] Gianfreda L., J.M. Bollag: *Influence of natural and anthropogenic factors on enzyme activity in soil*, Soil Biochemistry. G. Stotzky, J.M. Bollag (red.) Marcel Dekker, New York, **9**, 123−135, (1996).
[11] Haynes R.J., K.L. Knight: *Comparison of chemical properties, enzyme activities, levels of biomass N and aggregate stability in the soil profile under conventional and no-tillage in Canterbury, New Zealand*, Soil and Tillage Research, **14**, 3, 197−208 (1989).
[12] Kelly E.F., O.A. Chadwick, T.E. Hiliński: *The effect of plants on mineral weathering*, Biogeochemistry, **42**, 21−53 (1998).
[13] Kondracki J.: *Regional geography of Poland* (in Polish), Wydawnictwo Naukowe PWN, Warsaw, pp. 440, (2000).
[14] Ladd N., J.H.A. Butler: *Short-term assays of soil proteolytic enzyme activities using proteins and dipeptide derivatives as substrates*, Soil Biol. Biochem., **4**, 19−30 (1972).
[15] Lipiec J., J. Kuś, A. Słowińska-Jurkiewicz, A. Nosalewicz: *Soil porosity and water infiltration as influenced by tillage methods*, Soil&Tillage Research, **89**, 210−220 (2006).
[16] Margesin R., A. Zimmerbauer, F. Schinner: *Monitoring of bioremediation by soil biological activities*, Chemosphere, **40**, 339−346 (2000).
[17] Maurel M., J. Ricard: *The evolution of catalytic function*, Phys. Life Rev., **3**, 56−64 (2006).
[18] Niewiadomska A., H. Sulewska, A. Wolna-Maruwka, J. Klama: *Effect of organic fertilization on development of proteolytic bacteria and activity of proteases in the soil for cultivation of maize (Zea mays L.)*, Archives of Environmental Protection, **36**, 2, 47−56 (2010).
[19] Nortcliff S.: *Standardisation of soil quality attributes*, Agricult. Ecos. Environ., **88**, 161−168 (2002).
[20] Samuel A., S. Kiss, M. Sandor: *Phosphatase activities in a brown luvic soil*, Studia Universitatis Babes Bolyai, Biologia, **45**, 1, 91−99 (2000).
[21] Schulten H.R., C.M. Montreal, M. Schnitzer (1995): *Effect of long-term cultivation on the chemical structure of soil organic mater*, Naturwissenschaften, **81**, 1, 42−44 (1995).
[22] Tabatabai M.A., J.M. Bremner: *Use of p-nitrophenyl phosphate for assay of soil phosphatase activity*, Soil Biol. Biochem., **1**, 301−307 (1969).
[23] Taylor J.P., B. Wilson, M.S. Mills, R.G. Burns: *Comparison of microbial number and enzymatic activities in surface soils and subsoil using various techniques*, Soil Biol. Biochem., **34** (3), 387−401 (2002).
[24] Thalmann A.: *Zur Methodik der Bestimmung der Dehydrogenase Aktivität in Boden mittels Triphenyltetrazoliumchlorid (TTC)*, Landwirtsch. Forsch., **21**, 249−258 (1968).
[25] Tian Y., X. Zhang, J. Liu, Q. Chen, L. Gao: *Microbial properties of rhizosphere soils as affected by rotation, grafting, and soil sterilization in intensive vegetable production systems*, Scient. Horticult., **123**, 139−147 (2009).
[26] Zantua M.I., J.M. Bremner: *Comparison of methods of assaying urease activity in soils*, Soil Biol. Biochem., **7**, 291−295 (1975).

WPŁYW SYSTEMU UPRAWY NA AKTYWNOŚĆ ENZYMATYCZNĄ GLEB

Celem pracy było określenie wpływu systemów uprawy na aktywność enzymatyczną gleb. Analizowano dwa systemy uprawy roli: tradycyjny (płużny) i uproszczony (bezorkowy) na glebach płowych i arenosolach.

W próbkach glebowych analizowano aktywność pięciu enzymów: dehydrogenaz, kwaśnej i alkalicznej fosfatazy, ureazy oraz proteazy. Testy enzymatyczne okazały się dobrymi wskaźnikami różnicującymi badane obiekty glebowe w zależności od systemu uprawy roli. Stosowanie uprawy uproszczonej stymulowało istotnie aktywność analizowanych enzymów, niezależnie od typów gleby. Szczególnie szeroki zakres aktywności uzyskano dla dehydrogenaz, co wskazuje na przydatność tej grupy enzymów do oceny zmian zachodzących w środowisku glebowym pod wpływem systemu uprawy roli. Ponadto w powierzchniowych warstwach stymulacji aktywności badanych enzymów towarzyszyły korzystne zmiany właściwości chemicznych gleb.