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ENZYMATIC ACTIVITY OF NICKEL-CONTAMINATED SOIL

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Summary. The present study was carried out on the soil from a three-year pot experiment, conducted between 2009 and 2011 at the University of Natural Sciences and Humanities in Siedlce, in three repetitions and in an entirely randomised model. The experiment accounted for the following factors: 1 – quantity of Ni in the soil (0, 75, 150, and 225 mg kg^{-1} with the application of aqueous $NiSO_4.7\ H_2O$ solution); 2 – liming (0 and Ca by 1 Hh, as $CaCO_3$); and 3 – organic waste materials (rye straw at 4 t ha^{-1} and brown coal at 40 t ha^{-1}). Each year, 4 harvested swaths provided orchard grass – the test plant. The activity of urease, acid and alkaline phosphatase and dehydrogenases was determined in the soil sampled after each swath of grass in the third year of the experiment. It was shown that Ni at 75 mg kg^{-1}soil activated the investigated enzymes, whereas higher doses caused their statistically-proven inactivation. The lowest activity of all tested enzymes was measured in the soil into which the dose of 225 mg Ni kg^{-1} soil was introduced. Liming caused a reduction in the activity of urease and acid phosphatase and an increase in the activity of alkaline phosphatase, but it did not differentiate the activity of dehydrogenases. The impact of applied organic waste materials on the enzymatic activity soil was varied, yet in the majority of cases they showed an activating effect. Liming and straw as well as brown coal eliminated the negative impact of higher nickel doses on the activity of tested enzymes.

Key words: enzymatic activity, nickel, liming, straw, brown coal

INTRODUCTION

Soil is a bioorganic complex consisting of animate- biotic and inanimate-abiotic components, the latter consisting of water, minerals and air. Biological, chemical and physical properties of soil are defined by relationship between these components [Dick 1992]. Soil fertility and self-reproducibility are key features distinguishing it from other geological formations. What is understood as self-reproduction or soil metabolism is the entirety of biological and abiotic processes occurring in soil that provide annual renewal of components indispensable for plants to grow and develop, lost by soil in vegetation. The basis for

soil metabolism are enzymatic reactions which occur in both individual cells soil organisms or directly in soil environment [Russel 1974].

Soil enzymes are actively involved in the metabolism and catalyse processes related to the processing of matter and energy, which occur in soil [Mocek--Płóciniak 2010]. They constitute natural mediators and catalysts of numerous soil processes, such as: formation and decomposition of humic substances, biological reduction of molecular nitrogen, detoxification of xenobiotics, nitrification and denitrification [Kucharski 1997]. Soil deprived of enzyme producers barrens and becomes a dead rock within a short time.

Since the beginning of last century numerous studies on the relationship between enzymatic activity of the soil, biomass and soil fertility have been conducted [Dickson *et al*. 1975, Zantua and Bremner 1975, Dick 1992]. Based on the enzymatic activity, it is possible to develop soil fertility index, which is defined by Myśków and Kobus [1986] as a function of intensive development of various groups of microorganisms, organic matter content and total sorption capacity of the soil. Enzyme activity is determined by respective properties of the environment, including pH, temperature or substrate concentration. For most enzymes, the temperature optimum of activity is within the range of 30 to 50°C and pH close to neutral.

What is more, a substantial role in enzymatic catalysis is played by inhibitors and activators, which can inhibit enzymatic reaction both reversibly and irreversibly. Similar is the significance soil colloids for the enzymatic activity. Soil colloids bind enzymes reversibly through ion exchange, which may be accompanied by reduction or stimulation of enzymatic activity. As inhibitors of enzymatic reactions many researchers [Mocek-Płuciniak 2010, Kuziemska 2012, Styła and Sawicka 2010] list metals, such as nickel.

The conducted study aimed to determine the impact of liming, organic fertiliser – straw and waste organic material – brown coal on urease, dehydrogenase, acid and alkaline phosphatase activity in soil contaminated with different doses of nickel.

TEST MATERIAL AND METHODS

The study analysed the soil after a three-year pot experiment, carried out in an experimental facility of the University of Natural Sciences and Humanities in Siedlce, between 2009–2011. The experiment was conducted in the completely randomised system in four repetitions. The following factors were taken into account:

1. soil contamination with nickel: 0, 75, 150 and 225 mg Ni kg^{-1} soil;

2. liming: 0 Ca (without liming) and Ca according to 1 Hh (liming at a dose calculated according to 1 hydrolytic acidity of the soil);

3. organic fertilising- organic materials: without the use of organic materials (0); rye straw – at a dose of 4 t ha^{-1}, or 1.33 g kg^{-1} soil; brown coal (derived from

coal mines in Turów) – in a dose of 40 t ha^{-1}, or 13.3 g kg^{-1} soil. The chemical composition of straw and brown coal is presented in Table 1.

Table 1. Chemical composition of organic materials used in pot experiment

Component	Straw	Brown coal
	Contents	
	g kg^{-1} dry matter	
Dry matter	850	850
C	432	541
N	4.22	4.0
P	0.64	0.11
K	2.00	0.84
Ca	2.16	5.18
Mg	0.94	2.33
	mg kg^{-1} dry matter	
Ni	3.84	5.10

Analysed samples contained equal amount of dry substance, *i.e.* 850 g kg^{-1}. Rye straw contained higher amount of nitrogen, phosphorus, potassium, zinc, cadmium and lead as compared to brown coal.

Liming (as $CaCO_3$), the addition of organic waste material (brown coal and rye straw cut into chaff) and a dose of nickel (in the form of an aqueous solution of $NiSO_4 \cdot 7\ H_2O$) were introduced into the soil in November 2008. In spring 2009, orchard grass (Dactylis glomerata L.) was sown into prepared pots, each with the capacity of 15 dm^3, containing 10 kg soil. In three years of the study, four suckers (cuts) were collected every 30 days. Soil, with a granulometric composition of loamy sand, was derived from the humus level (0–20 cm) of luvisols. It is characterised by the following properties: pH in 1 mol KCl dm^{-3} – 5.5; total nitrogen content of 0.98 g kg^{-1}; organic carbon content of 7.9 g kg^{-1}; available phosphorus content of 69 mg kg^{-1} soil, available potassium 75 mg kg^{-1} soil, overall nickel Ni 5.67 mg kg^{-1} soil. During the vegetation season, soil moisture in pots was maintained at 60% of PPW.

In the third year of cultivation, in the soil sampled after each swath of grass the following were determined: urease activity by Hoffman and Teicher method [1961] based on the colorimetric determination of ammonia formed after enzymatic hydrolysis of urea, the activity of acid and alkaline phosphatase using Tabatabai and Bremner method [1969] based on the colorimetric determination of p-nitrophenol resulting from the hydrolysis of 4-nitrophenyl phosphate disodium salt, dehydrogenase activity by Casida *et al*. [1964]. The results of the study were statistically developed by analysis of variance using F-Fisher-Snedecor distribution according to the program FR Anal.var 4.1, whereas $NIR_{0.05}$ value was calculated by Tukey test. To determine the relationship between the studied traits, linear correlation analysis was additionally performed.

RESULTS AND DISCUSSION

Variable environmental conditions, including pH, organic matter and heavy metal content, modify the enzymatic activity soil [Moreno *et al*. 2003, Smejkalova *et al*. 2003, Cheng and Zhiping 2007, Kalembasa and Kuziemska 2008, 2010].

The conducted study demonstrated a significant impact of varied amounts of nickel in the soil, liming and the use of straw and brown coal on urease, acid and alkaline phosphatase, as well as dehydrogenase.

The average urease activity in the analysed soil ranged from 9.83 to 12.59 mg of $N\text{-}NH_4$ kg^{-1} h^{-1} and depended not only on factors considered in the experiment, but also on the sampling date (Tab. 2). The highest mean activity of the analysed enzyme was determined in soil sampled after swath II (12.25 mg $N\text{-}NH_4$ kg^{-1} h^{-1}), and the lowest after swath IV (10.42 mg $N\text{-}NH_4$ kg^{-1} h^{-1}). Introduction of nickel at a lowest dose (75 mg Ni kg^{-1} soil) to soil resulted in a significant activation of urease, whereas higher doses – 150 and 225 mg Ni kg^{-1} soil, resulted in its significant deactivation. This phenomenon was observed in both control objects (without the use of liming and waste organic materials) and when liming and straw or brown coal treatment was carried out. This relationship has been demonstrated in studies conducted previously [Kalembasa and Kuziemska 2008], or indicated by other authors [Wyszkowska and Wyszkowski 2004].

Liming has caused decrease in analysed enzyme activity in the soil sampled after swaths I, II, IV, however, only in the objects where waste organic material was used. Urease activity in soil was stimulated by straw and brow coal, however, significance of differences between samples and control objects was indicated only in straw. A beneficial impact of waste organic material on soil enzymatic activity was demonstrated by Krzywy-Gawrońska *et al*. [2008] in their study. Activity of dehydrogenases, which ranged (on average) between 1.10 to 1.39 mol TPF . kg^{-1}. h^{-1} and was the highest in the soil sampled after I swath and the lowest (average of 16 %) in the soil sampled after swath IV, is shown in Table 3.

Similarly to the previously discussed urease, highest average dehydrogenases activity was determined in the soil where the amount of 75 mg kg^{-1} of Ni was added. With the further increase in the amount of nickel in the soil, activity of these enzymes was significantly reduced. No effect of liming on the discussed feature was demonstrated in the study. Similar results were obtained in previous studies [Kuziemska 2012]. The results are not consistent with those obtained by Wyszkowska *et al*. [2006], where a significant increase in the activity of dehydrogenases with increasing pH was shown. Discrepancies should be associated

Table 2. Urease activity in soil (mg N-NH_4 kg^{-1} h^{-1})

Liming		0 Ca					Liming according to 1 Hh					Means
Fertilisation	Swath	Doses of nickel (mg kg^{-1} soil)				Means	Doses of nickel (mg kg^{-1} soil)				Means	
		0	75	150	225		0	75	150	225		
Without organic fertilisation	I	10.91	13.76	10.18	8.56	10.85	10.78	11.64	10.06	9.97	10.61	10.73
	II	13.21	14.17	10.72	9.06	11.79	12.97	14.10	10.36	9.90	11.83	11.81
	III	11.06	11.18	10.14	9.14	10.38	11.00	10.73	10.57	10.00	10.57	10.48
	IV	10.07	10.18	9.41	8.97	9.66	10.43	10.05	9.75	9.83	10.01	9.83
Means		11.31	12.32	10.11	8.93	10.67	11.29	11.63	10.18	9.92	10.76	10.71
Straw	I	12.17	14.29	12.63	9.98	12.27	11.40	13.42	10.41	10.39	11.40	11.84
	II	14.17	14.94	11.96	9.99	12.76	13.54	14.13	11.93	10.08	12.42	12.59
	III	11.56	11.70	10.64	10.00	10.98	11.33	11.71	10.31	10.13	10.87	10.92
	IV	11.56	11.44	10.59	9.95	10.88	11.70	11.33	10.90	10.19	11.03	10.95
Means		12.36	13.09	11.45	9.98	11.82	11.99	12.65	10.89	10.20	11.43	11.57
Brown coal	I	11.12	13.95	11.30	10.34	11.68	11.04	12.84	10.87	10.15	11.22	11.45
	II	13.63	13.59	12.27	11.31	12.70	13.23	13.42	11.25	10.09	11.99	12.35
	III	11.55	11.71	10.12	9.90	10.82	11.06	11.41	10.15	10.06	10.67	10.74
	IV	10.80	10.96	10.10	9.71	10.39	10.74	11.03	10.66	10.02	10.61	10.50
Means		11.77	12.55	10.95	10.31	11.40	11.52	12.17	10.73	10.08	11.12	11.26
Mean in experiment		11.81	12.65	10.84	9.74	11.26	11.60	12.15	10.60	10.07	11.10	11.18

$LSD_{0.05}$ for:	Swath I	Swath II	Swath III	Swath IV
doses of nickel	0.636	0.425	0.373	0.387
liming	0.336	0.225	n.i.	0.206
organic materials	0.498	0.333	0.292	0.304

Table 3. Dehydrogenase activity in soil (mmol TPF kg^{-1} h^{-1})

Liming		0 Ca					Liming to according 1 Hh					Means
Fertilization	Swath	Doses of nickel (mg kg^{-1} soil)				Means	Doses of nickel (mg kg^{-1} soil)				Means	
		0	75	150	225		0	75	150	225		
Without organic fertilisation	I	1.32	1.66	1.24	1.15	1.39	1.48	1.61	1.27	1.18	1.39	1.39
	II	1.31	1.53	1.11	1.07	1.25	1.29	1.52	1.14	1.08	1.26	1.25
	III	1.15	1.23	1.13	1.10	1.15	1.20	1.27	1.10	1.09	1.17	1.16
	IV	1.14	1.19	1.07	1.05	1.11	1.18	1.18	1.11	1.10	1.14	1.13
Means		1.28	1.40	1.14	1.09	1.23	1.29	1.39	1.13	1.11	1.23	1.23
Straw	I	1.48	1.57	1.34	1.18	1.39	1.45	1.54	1.34	1.20	1.38	1.39
	II	1.38	1.50	1.24	1.11	1.31	1.30	1.40	1.19	1.15	1.26	1.28
	III	1.20	1.24	1.14	1.09	1.17	1.22	1.28	1.19	1.10	1.20	1.18
	IV	1.21	1.27	1.11	1.10	1.17	1.20	1.27	1.17	1.12	1.19	1.18
Means		1.32	1.39	1.21	1.12	1.26	1.29	1.37	1.22	1.14	1.26	1.26
Brown coal	I	1.41	1.45	1.25	1.15	1.31	1.33	1.49	1.27	1.14	1.31	1.31
	II	1.36	1.39	1.22	1.10	1.27	1.28	1.45	1.25	1.09	1.27	1.27
	III	1.15	1.21	1.10	1.06	1.13	1.20	1.22	1.17	1.13	1.18	1.15
	IV	1.09	1.15	1.05	1.07	1.09	1.11	1.19	1.10	1.07	1.12	1.10
Means		1.25	1.30	1.15	1.09	1.20	1.23	1.34	1.20	1.11	1.22	1.21
Mean in experiment		1.28	1.36	1.17	1.10	1.23	1.27	1.37	1.18	1.12	1.23	1.23

	Swath I	Swath II	Swath III	Swath IV
$LSD_{0.05}$ for:				
doses of nickel	0.074	0.077	0.077	18.587
liming	N.I.	N.I.	N.I.	N.I.
organic materials	0.058	n.i.	N.I.	n.i.

with the fact that in the present study liming treatment was carried out nearly 4 years before sampling therefore its effect might be unnoticeable. Only for soil samples after swath I (brown coal deactivated dehydrogenases) and after swath IV has the influence of organic materials been demonstrated, in those samples the inactivating effect of brown coal and activating effect of straw was also marked.

Average activity of acid phosphatase in the tested soil ranged from 0.60 to 0.77 mmol PNP kg^{-1} h^{-1} and depended heavily on all the factors tested in the experiment, moreover, it was also dependent on sampling date (Tab. 4). The highest average activity of this enzyme was determined in the soil sampled in the second period and the smallest in soil sampled in the last one. The effect of increasing amounts of nickel in the soil on the discussed feature was comparable to the effects on, previously discussed, urease and dehydrogenases. Nickel incorporated into the soil, in the amount of 75 mg Ni kg^{-1} soil, stimulated acid phosphatase activity and higher doses resulted in a significant decrease of the activity, this observation is consistent with the results obtained from experiments conducted prior to the present study [Kalembasa and Kuziemska 2008] as well as obtained by Wyszkowska and Wyszkowski [2004]. Soil sampled from the objects limed after second, third and fourth swath, showed significantly lower activity of the discussed enzyme in comparison to the soil sampled from the objects that were not limed, as confirmed by the study of Koper *et al*. [2004]. Simultaneously there was no effect of liming on the discussed feature in the soil sampled in the first period. In soils where organic material was used, significantly higher activity of acid phosphatase than in soils sampled from control objects was confirmed; simultaneously the effect of straw was more stimulating than effect of brown coal.

Table 5 presents the activity of alkaline phosphatase, ranging from 0.39 to 0.50 mmol PNP kg^{-1} h^{-1}, which was not dependent on the date of sampling. The effect of increasing amounts of nickel in soil on the discussed feature was analogous to the enzymes discussed before. It was also shown that the soil sampled from limed objects, after swath I, II and IV, had significantly higher alkaline phosphatase activity relative to the not limed soil. Both organic materials – straw and brown coal, used in the pot experiment, stimulated alkaline phosphatase activity in the analysed soil.

The statistical analysis revealed significant correlations between studied traits in the analysed soil (Tab. 6), which is confirmed by high values of correlation coefficients.

In the summary of the conducted study it should be stated that all the factors considered in the experiment, *i.e.* varied amount of nickel in the soil, liming and organic materials: straw and brown coal, significantly modified the activity of urease, dehydrogenases, acid and alkaline phosphatase in the soil sampled after successive swaths of orchard grass. Introduction of 75 mg Ni kg^{-1} soil into the soil resulted in a significant increase in the activity of the enzymes, whereas

Table 4. Acid phosphatase activity in soil (mmol PNP kg^{-1} h^{-1})

Liming		0 Ca					Liming to according 1 Hh					Means
Fertilization	Swaths	Doses of nickel (mg kg^{-1} soil)				Means	Doses of nickel (mg kg^{-1} soil)				Means	
		0	75	150	225		0	75	150	225		
Without organic fertilisation	I	0.71	0.75	0.60	0.50	0.64	0.63	0.70	0.62	0.56	0.63	0.63
	II	0.77	0.79	0.66	0.56	0.69	0.70	0.73	0.61	0.60	0.66	0.67
	III	0.70	0.73	0.60	0.57	0.65	0.57	0.69	0.60	0.60	0.61	0.63
	IV	0.61	0.67	0.74	0.52	0.63	0.57	0.61	0.58	0.55	0.58	0.60
Means		0.70	0.73	0.65	0.54	0.65	0.62	0.68	0.60	0.58	0.62	0.63
Straw	I	0.80	0.81	0.74	0.65	0.75	0.75	0.77	0.73	0.67	0.73	0.74
	II	0.82	0.84	0.75	0.70	0.78	0.81	0.80	0.73	0.68	0.75	0.77
	III	0.79	0.82	0.74	0.59	0.73	0.71	0.75	0.76	0.61	0.71	0.72
	IV	0.75	0.79	0.73	0.63	0.72	0.72	0.73	0.69	0.64	0.70	0.71
Means		0.79	0.81	0.74	0.64	0.75	0.75	0.76	0.73	0.65	0.72	0.74
Brown coal	I	0.73	0.80	0.69	0.62	0.71	0.67	0.74	0.65	0.64	0.67	0.69
	II	0.78	0.81	0.73	0.70	0.75	0.71	0.75	0.70	0.69	0.71	0.73
	III	0.70	0.80	0.73	0.66	0.72	0.71	0.78	0.71	0.67	0.72	0.72
	IV	0.76	0.77	0.66	0.61	0.70	0.69	0.71	0.69	0.63	0.68	0.69
Means		0.74	0.80	0.70	0.64	0.72	0.69	0.74	0.69	0.66	0.69	0.71
Mean in experiment		0.74	0.78	0.70	0.61	0.71	0.69	0.73	0.67	0.62	0.68	0.69

	Swath I	Swath II	Swath III	Swath IV
$LSD_{0.05}$ for:				
doses of nickel	0.043	0.033	0.022	0.036
liming	n.i.	0.017	0.012	0.019
organic materials	0.034	0.026	0.018	0.028

Table 5. Alkaline phosphatase activity in soil (mmol PNP kg^{-1} h^{-1})

Liming		0 Ca					Liming to according 1 Hh					Means
Fertilisation	Swaths	Doses of nickel (mg kg^{-1} soil)				Means	Doses of nickel (mg kg^{-1} soil)				Means	
		0	75	150	225		0	75	150	225		
Without organic fertilisation	I	0.44	0.45	0.34	0.34	0.39	0.46	0.48	0.9	0.36	0.42	0.41
	II	0.39	0.43	0.35	0.36	0.38	0.42	0.48	0.38	0.38	0.41	0.40
	III	0.35	0.46	0.41	0.37	0.40	0.43	0.49	0.42	0.40	0.43	0.42
	IV	0.38	0.43	0.39	0.30	0.37	0.43	0.47	0.41	0.34	0.41	0.39
Means		0.39	0.44	0.37	0.34	0.39	0.43	0.48	0.40	0.37	0.42	0.40
Straw	I	0.42	0.53	0.42	0.38	0.044	0.55	0.52	0.45	0.41	0.48	0.46
	II	0.47	0.52	0.40	0.37	0.44	0.54	0.54	0.44	0.41	0.48	0.46
	III	0.52	0.59	0.43	0.41	0.49	0.55	0.61	0.47	0.43	0.51	0.50
	IV	0.48	0.50	0.40	0.37	0.44	0.47	0.55	0.42	0.42	0.46	0.45
Means		0.47	0.53	0.41	0.38	0.45	0.53	0.55	0.44	0.42	0.48	0.47
Brown coal	I	0.41	0.50	0.42	0.37	0.42	0.50	0.53	0.43	0.42	0.47	0.44
	II	0.43	0.52	0.41	0.37	0.43	0.51	0.53	0.44	0.40	0.47	0.45
	III	0.47	0.49	0.41	0.45	0.45	0.50	0.52	0.45	0.44	0.48	0.46
	IV	0.44	0.46	0.40	0.40	0.42	0.46	0.51	0.43	0.42	0.45	0.44
Means		0.44	0.49	0.41	0.40	0.43	0.49	0.52	0.44	0.42	0.47	0.45
Mean in experiment		0.43	0.49	0.40	0.37	0.42	0.48	0.52	0.43	0.40	0.46	0.44

	Swath I	Swath II	Swath III	Swath IV
$LSD_{0.05}$ for:				
doses of nickel	0.044	0.043	0.065	0.045
liming	0.023	0.023	n.i.	0.024
organic materials	0.035	0.034	0.051	0.036

Table 6. Correlation coefficients between soil parameters

Parameters	Urease	Acid phosphatase	Alkaline phosphatase	Dehydrogenase
Swath I				
Urease	1			
Acid phosphatase	0.863**	1		
Alkaline phosphatase	0.714**	0.735**	1	
Dehydrogenase	0.771**	0.733**	0.715**	1
Swath II				
Urease	1			
Acid phosphatase	0.877**	1		
Alkaline phosphatase	0.767**	0.703**	1	
Dehydrogenase	0.926**	0.776**	0.738**	1
Swath III				
Urease	1			
Acid phosphatase	0.689**	1		
Alkaline phosphatase	0.716**	0.669**	1	
Dehydrogenase	0.762**	0.624**	0.763**	1
Swath IV				
Urease	1			
Acid phosphatase	0.740**	1		
Alkaline phosphatase	0.815**	0.667**	1	
Dehydrogenase	0.746**	0.440*	0.779**	1

* p = 0.05
** p = 0.01

higher doses – of 150 and 225 mg kg^{-1} Ni soil caused a significant decrease in their activity. Nickel in a dose of 75 mg Ni kg^{-1} soil was found to be a biocatalyst of enzyme activity, whereas at higher doses – inhibitor of enzyme activity, which is consistent with both previously conducted studies [Kalembasa and Kuziemska 2008, 2010, Kuziemska 2012] and the results obtained by other authors [Wyszkowska and Wyszkowski 2004].

Liming ambiguously modified examined features, causing, *inter alia*, the reduction of acid phosphatase activity and stimulating the activity of alkaline phosphatase. Both organic materials caused a significant increase in the urease and alkaline phosphatase activity, whereas their effect on the activity of two other analyzed enzymes varied. Straw stimulated the activity of dehydrogenases and acid phosphatase while brown coal caused a slight decrease in their activity. Both liming and organic substances – straw and brown coal were limiting the negative effect of larger amounts of nickel in the soil on activity of analyzed enzymes.

CONCLUSIONS

1. Application of nickel at a dose of 75 mg Ni kg^{-1} soil resulted in a significant increase in the enzymatic activity of the soil, while higher doses resulted in its significant decrease.
2. Liming stimulated the activity of alkaline phosphatase, simultaneously causing reduction of the activity of urease and acid phosphatase in the analysed soil.
3. Straw caused an increase of urease, dehydrogenase, acid and alkaline phosphatase activity in the soil.
4. Brown coal stimulated urease and alkaline phosphatase activity and decreased dehydrogenases acid phosphatase activity in the soil.
5. The negative effect of larger amounts of nickel in the soil on its enzymatic activity was limited by liming and organic material use.

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AKTYWNOŚĆ ENZYMATYCZNA GLEB ZANIECZYSZCZONYCH NIKLEM

Streszczenie. Badaniami objęto glebę po trzyletnim doświadczeniu wazonowym, które przeprowadzono w latach 2009–2011 w obiekcie UPH w Siedlcach, w trzech powtórzeniach, w układzie całkowicie losowym. W eksperymencie uwzględniono następujące czynniki: 1 – ilość Ni w glebie (0, 75, 150 i 225 mg · kg^{-1} gleby, przez stosowanie wodnego roztworu $NiSO_4 \cdot 7H_2O$); 2 – wapnowanie (0 i Ca wg 1 Hh, w formie $CaCO_3$); 3 – odpadowe materiały organiczne (słoma żytnia w dawce 4 t·ha^{-1} i węgiel brunatny w dawce 40 t·ha^{-1}). W każdym roku doświadczenia rośliną

testową była kupkówka pospolita, której zebrano po 4 pokosy. W glebie pobranej po każdym odroście (pokosie) trawy w trzecim roku badań oznaczono aktywność ureazy, fosfatazy kwaśnej i zasadowej oraz dehydrogenaz. Wykazano, że Ni w dawce 75 mg · kg^{-1} gleby aktywuje badane enzymy, natomiast dawki większe powodują ich statystycznie udowodnioną dezaktywację. Najmniejszą aktywność wszystkich analizowanych enzymów stwierdzono w glebie, do której wprowadzono 225 mg Ni · kg^{-1} gleby. Zastosowane wapnowanie powodowało zmniejszenie aktywności ureazy i fosfatazy kwaśnej i zwiększenie aktywności fosfatazy zasadowej, nie różnicując aktywności dehydrogenaz. Wpływ zastosowanych odpadowych materiałów organicznych na aktywność enzymatyczną gleby był zróżnicowany, ale w większości wykazano ich działanie aktywujące. Zarówno wapnowanie, jak i słoma oraz węgiel brunatny niwelowały negatywny wpływ większych dawek niklu na aktywność badanych enzymów.

Słowa kluczowe: aktywność enzymatyczna, nikiel, wapnowanie, słoma, węgiel brunatny