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SEASONAL CHANGES OF SELENIUM AND SELECTED OXIDOREDUCTASES IN SOIL UNDER DIFFERENT FERTILIZATION AND CROP ROTATION

SEZONOWE ZMIANY ZAWARTOŚCI SELENU I AKTYWNOŚCI WYBRANYCH OKSYDOREDUKTAZ W GLEBIE O ZRÓŻNICOWANYM NAWOŻENIU I ZMIANOWANIU

Abstract: The objective of the study was to evaluate effects of different doses of FYM and nitrogen on the total selenium content in soil from different crop rotation systems. The aim of the study was to determine the changes of some oxidoreductases activity and Se concentration in soil in relation to applied doses of fertilizers over vegetation period. The experiment was carried out with the crop rotation systems – depleting and enriching in organic matter. The soil was fertilized with manure under potato in the doses of 0, 20, 40, 60 and 80 Mg/ha and with nitrogen in the doses of 0, 40, 80 and 120 kgN · ha^{-1} under winter wheat. The content of total selenium in the investigated soil was in the range of 0.092 to 0.264 mg · kg^{-1}. From the comparison of the results reported in literature one can observe that the studied soil was poor in selenium. Over the investigated period manuring resulted in an increase of total selenium content in soil and for that reason the FYM application can be recommended as a source of selenium in Se-deficient soils. Fertilization with manure resulted in an increase of dehydrogenases and catalase activities in soil with increasing doses of FYM. The selenium content, as well as DHA and CAT activities demonstrated clear seasonal variations. The present studies indicated a significant relationship between activity of soil enzymes, and the organic matter content, affecting the selenium status in soil and plants.

Keywords: selenium, oxidoreductases, soil, farmyard manure, nitrogen

Selenium is an essential trace element for human and animal metabolism. Its antioxidative properties, comparable to vitamin E, are widely known [1]. However, when it is absorbed in higher concentration, it can be harmful and catalyse the oxidation of thiols and simultaneously generate superoxide [2, 3]. Many authors [4–6] have indicated a strong influence of Se on the activities of oxidoreductase enzymes, such as

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catalase, glutathione peroxidase and superoxide dismutase. The literature provides abundant information on the role Se plays in animals. However, there have been relatively few reports on the contribution of Se to biochemical processes in soil and plants [3]. According to Wyszkowska and Wyszkowski [7] soil enzymes can serve as a tool to determine biochemical soil properties by taking part and playing an important role in chemical changes of carbon, nitrogen, phosphorus and sulphur compounds. For this purpose, activity of dehydrogenases is most commonly assayed, as it is usually positively correlated with the volume of yields, which in turn may indicate, however indirectly, that the activity of those enzymes is related to soil fertility. Dehydrogenases are enzymes which catalyse the removal of hydrogen atom from different metabolites [8]. Active dehydrogenases are considered to exist in the soil as an integral part of intact cells. They conduct a board range of oxidative activities that are responsible for degradation of soil organic matter [9]. Soil dehydrogenase activity can reflect changes in the respiratory activity of a given population size in response to changes in the soil environment. Catalase is an iron porphyrin enzyme which catalyses very rapid decomposition of hydrogen peroxide to water and oxygen [8]. The enzyme is widely present in nature, which accounts for its diverse activities in soil. Catalase activity alongside with the dehydrogenase activity is used to give information on the microbial activities in soil. The objective of the study was to evaluate effects of different doses of FYM (*Farmyard Manure*) and nitrogen on the total selenium content in soil from different crop rotation systems. The aim of the study was to determine the changes of some oxidoreductases activity and Se concentration in soil in relation to applied doses of fertilizers over vegetation period.

Materials and methods

Soil samples were collected from the long-term static experiment established at the Agricultural Experimental Station at Grabow carried out since 1980 by the Department of Plant Nutrition of the Institute of Soil Science and Cultivation in Pulawy. The experiment was conducted applying the following crop rotation systems: "depleting in organic matter" (potato – winter wheat – spring barley – maize) and "enriching in organic matter" (potato – winter wheat + intercrop – spring barley + undersown and red clover + grasses) (factor I), designed in a split-plot with four replications (sub-plots). Organic fertilizer in a form of cattle manure (FYM) was applied under potato in the doses of 0, 20, 40, 60 and 80 Mg · ha^{-1} (factor II) and nitrogen at the doses of 0, 40, 80 and 120 kgN · ha^{-1} was used under winter wheat and spring barley and 0, 30, 60, 90 kgN · ha^{-1} under potato and maize (factor III). Soil samples were collected in the 22nd year of the experiment, in March, May and July 2002, from the 0–20 cm layer under winter wheat. Soil samples were air-dried and sieved through a 2 mm screen. The total selenium content was determined by the method of Watkinson [10] using a Hitachi F-2000 spectrofluorometer. Soil samples were microwave digested with concentrated nitric(V) and perchloric(VII) acids. The different forms of selenium in the samples were reduced by boiling with 10 % HCl. The selenium was complexed with 2,3-*diamino-naphtalene* (DAN) to the fluorescent compound, which was extracted with cyclohexane

and read on the spectrofluorometer at excitation and emission wavelengths of $\lambda = 376$ and 519 nm, respectively. The analytical procedures provided satisfactory values for the standard reference material CRM024-050 from the *Resource Technology Corporation* (RTC); determined value was 0.558 mg Se · kg^{-1} (certified value – 0.540 mg · kg^{-1}). The certified reference material was included in each batch of samples for quality control. *Dehydrogenases activity* (DHA) was assayed applying the method by Casida et al [11]. Soil DHA activity was estimated by reducing 2,3,5-*triphenyltetrazolium* chloride. Soil sample was mixed with $CaCO_3$ and 2,3,5-triphenyltetrazolium chloride (TTC) and incubated for 24 h at 37 ^oC. Dehydrogenase converts TTC to 2,3,5-*triphenyl-formazan* (TPF). The TPF formed was extracted with acetone, the extracts were filtered and absorption was measured at $\lambda = 485$ nm spectrophotometrically. The enzyme activities were expressed as mg *triphenyl tetrazolium formazan* (TPF) · g^{-1} · 24 h^{-1}. *Catalase activity* (CAT) was measured using the method by Johnson and Temple [12]. Soil was incubated with *hydrogen peroxide* H_2O_2 for 20 min at 20 ^oC. The remaining H_2O_2, not broken-down by catalase, was treated with potassium permanganate exposed to H_2SO_4. To eliminate a probable overestimation of enzyme activity due to chemical reduction of H_2O_2 added, a correction for autoclaved soil (0.1 MPa, 120 ^oC, 30 min) was made. The results were expressed in mg H_2O_2 consumed · g^{-1} · min^{-1}. The soil samples were analysed for granulometric composition according to *Bouyoucos-Casagrande* method, organic carbon by wet oxidation with potassium dichromate, total nitrogen following by Kjeldahl method and pH in distilled water and 1 M KCl potentiometrically.

Three-way analysis of variance (ANOVA) was used to identify significant differences ($p < 0.05$) between Se concentrations and enzymes activity in soil under study. Data analysis was carried out using Statistica 8.0 for Windows Stat.Soft. Inc.

Results and discussion

The general properties and total selenium content of the soil under study are given in Table 1. The soil, according to the FAO classification, was classified as Haplic Luvisols and demonstrated the texture of loamy sand and sandy loam; pH values measured in H_2O of soil were in the acidic and slightly acidic range 5.2–6.9. The application of manure resulted in the highest contents of organic carbon and total nitrogen in soil, especially from the plots treated with FYM at the doses of 60 Mg · ha^{-1} and 80 Mg · ha^{-1}. Total selenium content in the soil samples ranged from 0.092 mg · kg^{-1} to 0.264 mg · kg^{-1} (Table 2). Such low levels of selenium in soils indicated that plants growing on these soils are deficient in this microelement. According to Kabata-Pendias [1], the mean total selenium content in the soils worldwide is estimated as 0.44 mg · kg^{-1}, while its background contents in various soil groups range from 0.05 mg · kg^{-1} to 1.5 mg · kg^{-1}. Over the investigated period the selenium content increased with increasing doses of FYM, but nitrogen treatment affected the content of this microelement in the soil in unclear way. In soil sampled in May total selenium content increased with increasing doses of nitrogen, but in July nitrogen fertilization decreased Se concentration in soil. Analysis of variance indicated that in May and July the Se content in soil was higher from plots, where crop rotation enriching in organic matter

Table 1

General properties of soil under study

FYM doses [Mg · ha^{-1}] (factor II)	N doses [kg · ha^{-1}] (factor III)	Crop rotation (factor I)											
		A "depleting in organic matter"						B "enriching in organic matter"					
		Soil particle size fraction [%]		pH in		C_{org} [g · kg^{-1}]	N_{tot} [g · kg^{-1}]	Soil particle size fraction [%]		pH in		C_{org} [g · kg^{-1}]	N_{tot} [g · kg^{-1}]
		< 0.02 [mm]	< 0.002 [mm]	H_2O	KCl			< 0.02 [mm]	< 0.002 [mm]	H_2O	KCl		
0	0	15	5	6.8	5.7	7.62	0.826	18	6	5.8	5.1	7.87	0.889
	40	16	5	6.8	5.8	7.82	0.837	17	6	5.2	5.1	8.36	0.966
	80	14	4	6.8	5.8	8.47	0.854	19	8	6.1	5.1	8.44	0.924
	120	15	5	6.7	5.7	7.41	0.861	17	7	5.9	4.8	8.27	0.966
20	0	17	6	6.8	5.8	7.53	0.823	14	5	6.3	5.3	8.84	0.980
	40	15	4	6.5	5.7	7.30	0.893	16	8	6.4	5.2	8.52	0.956
	80	13	2	6.5	5.6	8.54	0.861	15	6	6.3	5.2	8.70	0.956
	120	12	4	6.5	5.4	8.49	0.875	18	7	6.2	5.1	9.30	0.956
40	0	13	5	6.3	5.6	8.40	0.896	19	8	6.3	5.1	9.49	0.991
	40	15	4	6.6	5.5	9.04	0.931	17	6	6.3	5.2	9.25	1.012
	80	16	4	6.6	5.6	8.13	0.886	13	5	6.2	5.1	10.44	0.942
	120	16	4	6.6	5.5	8.18	0.935	19	6	6.0	4.9	10.26	0.987
60	0	20	5	6.7	6.0	8.65	0.952	16	5	6.4	5.4	10.36	0.931
	40	16	7	6.4	5.8	8.19	0.952	16	6	6.5	5.4	10.19	0.970
	80	16	6	6.7	5.8	8.29	0.977	19	7	6.4	5.3	10.10	0.956
	120	16	6	6.7	5.9	8.39	0.991	20	6	6.4	5.3	9.76	0.921

Table 1 contd.

FYM doses [Mg · ha^{-1}] (factor II)	N doses [kg · ha^{-1}] (factor III)	Crop rotation (factor I)											
		A "depleting in organic matter"						B "enriching in organic matter"					
		Soil particle size fraction [%]		pH in		C_{org} [g · kg^{-1}]	N_{tot} [g · kg^{-1}]	Soil particle size fraction [%]		pH in		C_{org} [g · kg^{-1}]	N_{tot} [g · kg^{-1}]
		< 0.02 [mm]	< 0.002 [mm]	H_2O	KCl			< 0.02 [mm]	< 0.002 [mm]	H_2O	KCl		
80	0	17	7	6.9	5.9	8.18	1.029	15	4	6.4	5.5	10.44	0.959
	40	16	5	6.9	5.7	8.13	0.998	16	6	6.4	5.4	10.11	0.966
	80	15	4	6.7	5.9	8.11	1.015	15	5	6.2	5.3	10.31	0.980
	120	18	7	6.8	5.9	8.75	1.029	14	5	6.2	5.1	10.39	1.005

Table 2

Total selenium content in the investigated soil [mg · kg^{-1}]

FYM doses [Mg · ha^{-1}] (factor II)	N doses [kg · ha^{-1}] (factor III)	Crop rotation (factor I)					
		A "depleting in organic matter"			B "enriching in organic matter"		
		March	May	July	March	May	July
0	0	0.098	0.098	0.100	0.118	0.098	0.103
	40	0.110	0.092	0.101	0.100	0.098	0.098
	80	0.104	0.108	0.104	0.119	0.098	0.115
	120	0.104	0.096	0.095	0.101	0.102	0.108
20	0	0.135	0.172	0.176	0.152	0.171	0.119
	40	0.130	0.170	0.161	0.164	0.172	0.147
	80	0.135	0.175	0.154	0.150	0.167	0.170
	120	0.135	0.164	0.161	0.147	0.172	0.160
40	0	0.166	0.192	0.144	0.196	0.163	0.160
	40	0.172	0.143	0.174	0.177	0.166	0.159
	80	0.175	0.205	0.177	0.203	0.183	0.167
	120	0.188	0.196	0.167	0.207	0.203	0.171
60	0	0.191	0.183	0.192	0.210	0.197	0.173
	40	0.194	0.193	0.159	0.205	0.224	0.162
	80	0.191	0.197	0.196	0.203	0.163	0.165
	120	0.199	0.184	0.202	0.185	0.153	0.158
80	0	0.246	0.199	0.236	0.234	0.227	0.183
	40	0.244	0.190	0.191	0.232	0.186	0.206
	80	0.229	0.200	0.206	0.234	0.176	0.192
	120	0.229	0.190	0.189	0.231	0.173	0.197
Mean		0.169	0.167	0.164	0.178	0.165	0.156
Date of sampling		March		May		July	
Mean for crop rotation (factor I)							
A		0.169		0.167		0.164	
B		0.177		0.165		0.156	
Mean for FYM doses (factor II)							
0		0.105		0.099		0.102	
20		0.143		0.170		0.156	
40		0.185		0.181		0.166	
60		0.197		0.187		0.176	
80		0.236		0.193		0.200	
Mean for N doses (factor III)							
0		0.173		0.170		0.159	
40		0.173		0.170		0.155	
80		0.174		0.166		0.164	
120		0.173		0.158		0.161	
$LSD_{0.05}$		I – 0.002 II – 0.005 III – n.s.		I – n.s. II – 0.007 III – 0.006		I – 0.003 II – 0.007 III – 0.006	

n.s. – non significant.

was applied. Statistical analysis demonstrated a significant dependence between total selenium content and organic carbon and total nitrogen content in soil and silt and clay fractions content (Table 5), what coincides with our earlier findings [13, 14] and those reported by other authors [15, 16]. As it is shown in Fig. 1 the highest amounts of total Se content in soil under study were obtained in March, and during vegetation period its content decreased in both variants of crop rotation.

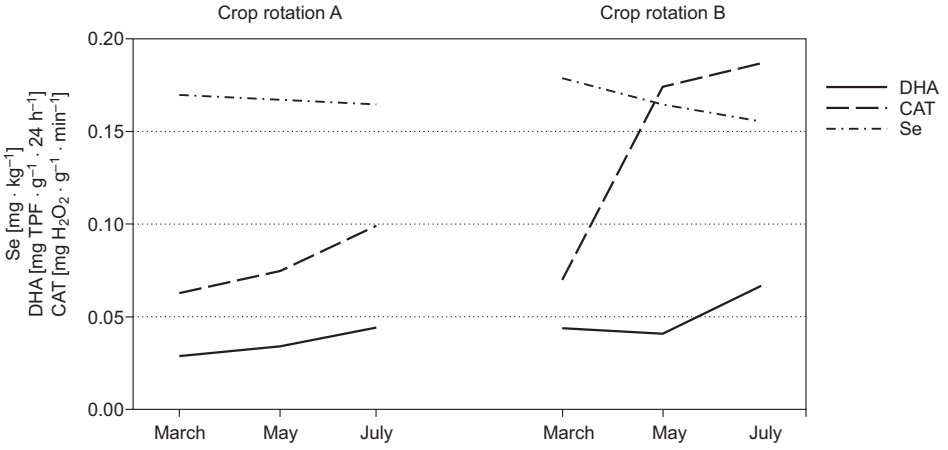

Fig. 1. Seasonal changes of selenium and enzymatic activity in soil under study

The effect of the FYM and nitrogen doses on dehydrogenases activity in soil is presented in Table 3. The organic fertilization applied significantly differentiated the activity of dehydrogenases in soil. FYM application at the doses of 60 and 80 Mg · ha^{-1} significantly increased the enzymatic activity about 47 % (mean for date of sampling), as compared with the treatment without manure. Nitrogen fertilization at the doses of 40 and 80 kg · ha^{-1} increased DHA activity from 4 to 14 % in comparison with soil without N. We found significantly higher amounts of DHA activity in soil from variant B – *"enriching in organic matter"*. Catalase activity in soil under study is presented in Table 4. Crop rotation significantly differentiated CAT activity in soil. During vegetation period higher amounts of CAT activity were obtained in soil from variant B of crop rotation (enriching in organic matter). Manure application strongly stimulated soil catalase activity with increasing doses, but nitrogen fertilization affected the enzymatic activity in unclear way. Generally, the application of nitrogen at the highest dose resulted the highest amounts of CAT activity in soil. As described by Spychaj-Fabisiak and Smolinski [17] nitrogen fertilization stimulated an increase of soil dehydrogenases activity. They concluded that the level of DHA activity in soil increased with quantity of microorganisms and the rate of their metabolism, which allowed them for turn to account the reserve of organic carbon. Koper and Piotrowska [18] noted the increase of catalase activity under mineral fertilization, but Frankenberger and Dick [19] reported that long-term mineral fertilization applying in high doses proved to inhibition of enzymatic reactions.

Table 3

Dehydrogenases (DHA) activity in the soil [mg TPF · g^{-1} · 24 h^{-1}]

FYM doses [Mg · ha^{-1}] (factor II)	N doses [kg · ha^{-1}] (factor III)	Crop rotation (factor I)					
		A "depleting in organic matter"			B "enriching in organic matter"		
		March	May	July	March	May	July
0	0	0.028	0.015	0.037	0.025	0.038	0.047
	40	0.029	0.023	0.038	0.032	0.037	0.053
	80	0.027	0.026	0.039	0.032	0.038	0.067
	120	0.026	0.031	0.038	0.027	0.023	0.060
20	0	0.031	0.035	0.032	0.031	0.027	0.063
	40	0.029	0.028	0.042	0.031	0.030	0.056
	80	0.026	0.029	0.043	0.033	0.045	0.069
	120	0.027	0.028	0.041	0.033	0.027	0.069
40	0	0.027	0.037	0.042	0.052	0.038	0.073
	40	0.028	0.030	0.041	0.041	0.037	0.079
	80	0.027	0.030	0.047	0.047	0.040	0.056
	120	0.027	0.036	0.051	0.049	0.038	0.074
60	0	0.025	0.043	0.056	0.065	0.034	0.061
	40	0.033	0.048	0.061	0.062	0.042	0.072
	80	0.035	0.040	0.047	0.062	0.036	0.082
	120	0.033	0.041	0.053	0.050	0.045	0.059
80	0	0.034	0.037	0.042	0.043	0.046	0.077
	40	0.038	0.039	0.041	0.055	0.089	0.066
	80	0.040	0.038	0.042	0.054	0.067	0.065
	120	0.034	0.038	0.047	0.048	0.064	0.066
Mean		0.030	0.034	0.044	0.044	0.042	0.066
Date of sampling		March		May		July	
Mean for crop rotation (factor I)							
A		0.030		0.033		0.044	
B		0.043		0.042		0.065	
Mean for FYM doses (factor II)							
0		0.028		0.029		0.047	
20		0.030		0.031		0.052	
40		0.037		0.036		0.058	
60		0.045		0.040		0.061	
80		0.043		0.052		0.056	
Mean for N doses (factor III)							
0		0.036		0.035		0.053	
40		0.038		0.040		0.055	
80		0.038		0.039		0.055	
120		0.035		0.036		0.056	
$LSD_{0.05}$		I – 0.001 II – 0.001 III – 0.001		I – 0.001 II – 0.001 III – 0.001		I – 0.001 II – 0.001 III – 0.001	

Table 4

Catalase (CAT) activity in soil under study [mg $H_2O_2 \cdot g^{-1} \cdot min^{-1}$]

FYM doses [Mg · ha^{-1}] (factor II)	N doses [kg · ha^{-1}] (factor III)	Crop rotation (factor I)					
		A "depleting in organic matter"			B "enriching in organic matter"		
		March	May	July	March	May	July
0	0	0.062	0.072	0.115	0.058	0.155	0.183
	40	0.058	0.068	0.106	0.068	0.117	0.191
	80	0.053	0.075	0.051	0.077	0.124	0.175
	120	0.068	0.081	0.109	0.068	0.149	0.191
20	0	0.070	0.081	0.064	0.077	0.157	0.170
	40	0.064	0.070	0.072	0.066	0.189	0.187
	80	0.053	0.066	0.066	0.070	0.191	0.191
	120	0.058	0.072	0.072	0.077	0.181	0.189
40	0	0.066	0.062	0.075	0.058	0.187	0.185
	40	0.062	0.072	0.077	0.066	0.183	0.183
	80	0.060	0.081	0.072	0.070	0.164	0.175
	120	0.060	0.064	0.153	0.077	0.170	0.170
60	0	0.068	0.064	0.077	0.077	0.189	0.195
	40	0.066	0.081	0.077	0.075	0.194	0.179
	80	0.053	0.079	0.079	0.081	0.191	0.195
	120	0.066	0.077	0.125	0.077	0.189	0.193
80	0	0.070	0.079	0.170	0.081	0.196	0.198
	40	0.072	0.068	0.175	0.079	0.175	0.193
	80	0.075	0.079	0.068	0.077	0.191	0.187
	120	0.064	0.079	0.175	0.077	0.189	0.195
Mean		0.063	0.074	0.099	0.073	0.174	0.186
Date of sampling		March		May		July	
Mean for crop rotation (factor I)							
A		0.063		0.073		0.099	
B		0.073		0.174		0.186	
Mean for FYM doses (factor II)							
0		0.064		0.105		0.140	
20		0.067		0.126		0.126	
40		0.065		0.123		0.136	
60		0.070		0.133		0.140	
80		0.074		0.132		0.170	
Mean for N doses (factor III)							
0		0.069		0.124		0.143	
40		0.068		0.122		0.144	
80		0.067		0.124		0.126	
120		0.069		0.125		0.157	
$LSD_{0.05}$		I – 0.002 II – 0.004 III – n.s.		I – 0.002 II – 0.004 III – 0.003		I – 0.006 III – 0.014 III – 0.012	

In soil under study the enzymatic activity demonstrated clear seasonal variations and considerable fluctuations depending on availability of substrate in crop rotation (Fig. 1). A highly significant dependence was found between enzymatic activity and total selenium, total nitrogen and organic carbon content in soil (Table 5).

Table 5

Simple correlation coefficients (r) between selenium content and enzymatic activity and soil properties

Examined properties	Fraction < 0.002	pH_{H_2O}	pH_{KCl}	C_{org}	N_{tot}	Se_{tot}	DHA	CAT
Fraction < 0.02	0.64*	–0.22*	–0.25*	0.29*	0.30*	0.25*	0.22*	0.21*
Fraction < 0.002		0.00	0.14	0.39*	0.40*	0.25*	0.22*	0.30*
pH_{H_2O}			–0.03	–0.04	–0.07	– 0.11	–0.04	0.05
pH_{KCl}				0.22*	0.21*	0.18	0.11	0.20*
C_{org}					0.88*	0.62*	0.62*	0.62*
N_{tot}						0.53*	0.55*	0.56*
Se_{tot}							0.59*	0.45*
DHA								0.63*

* r significant at $\alpha = 0.05$.

In general, management practices that increase inputs of organic residue, plant or animal manures, increase biological activity [20]. According to Samuel [21] addition of farmyard manure, usually increases microbial biomass and soil enzyme activities 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 fertilizers, 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 fertilizer can increase the plant biomass production which in turn increases the amount of residue returned to the soil and stimulates biological activity [22].

Conclusions

The content of total selenium in the investigated soil was in the range (0.092; 0.264) $mg \cdot kg^{-1}$. From the comparison of the results reported in literature one can observe that the studied soil was poor in selenium. Over the investigated period manuring resulted in an increase of total selenium content in soil and for that reason the FYM application can be recommended as a source of selenium in Se-deficient soils. Fertilization with manure resulted in an increase of dehydrogenases and catalase activities in soil with increasing doses of FYM. The selenium content, as well as DHA and CAT activities demonstrated clear seasonal variations. The present studies indicated a significant relationship between activity of soil enzymes, and the organic matter content, affecting the selenium status in soil and plants.

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SEZONOWE ZMIANY ZAWARTOŚCI SELENU I AKTYWNOŚCI WYBRANYCH OKSYDOREDUKTAZ W GLEBIE O ZRÓŻNICOWANYM NAWOŻENIU I ZMIANOWANIU

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Abstrakt: Celem pracy było określenie zmian zawartości selenu ogółem oraz aktywności wybranych enzymów niezbędnych w przemianach oksydoredukcyjnych w glebie w warunkach zróżnicowanego nawożenia i zmianowania. Próbki glebowe pobrano z obiektów, na których uprawiano pszenicę ozimą, trzykrotnie w 2002 roku z doświadczenia prowadzonego przez IUNG w Puławach na terenie RZD Grabów nad Wisłą, z wariantu zubożającego i wzbogacającego glebę w substancję organiczną. Nawożenie obornikiem zastosowano (jednorazowo w trakcie rotacji) pod ziemniaki w dawkach 0, 20, 40, 60, 80 Mg · ha^{-1}, natomiast azot w ilości 0, 40, 80 i 120 kgN · ha^{-1}. Wykazano, że nawożenie obornikiem w całym okresie badawczym istotnie wpływało na koncentrację selenu ogółem w glebie, która wzrastała wraz z jego dawką, niezależnie od terminu pobierania próbek glebowych i rodzaju zmianowania. Nie wykazano natomiast jednoznacznego wpływu azotu w tym zakresie. Zawartość tego pierwiastka oraz aktywność katalazy i dehydrogenaz w glebie podlegała stałym wahaniom i wykazywała zmienność sezonową. Nawożenie obornikiem wyraźnie stymulowało aktywność dehydrogenazową i katalazową gleby. Stwierdzono ścisłą zależność między aktywnością enzymatyczną gleby a zawartością w niej selenu ogółem. Uzyskane z obliczeń statystycznych wartości współczynników korelacji wykazały istotne zależności między aktywnością badanych enzymów glebowych a zawartością węgla organicznego i zawartością azotu ogółem.

Słowa kluczowe: selen, oksydoreduktazy, gleba, obornik, azot