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SOIL ACID PHOSPHATASE, CATALASE AND RHODANASE ACTIVITIES AS AFFECTED BY DIFFERENT SYSTEMS OF PLANT CULTIVATION

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INTRODUCTION

Modern agriculture is aimed at high specialization, which results in reduction of the number of cultivated plant species. Therefore frequency of a given plant cultivation increases and simple crop rotations or even monocultures are used [Płoszyńska 1988].

Long-term experiments [Blecharczyk, Grzebisz 1991; Gawrońska et al. 1979] have shown that different plant species respond unfavourably to monoculture cultivation. This reaction is modified by factors such as climate, soil type and fertilization. The negative influence of plant cultivation in the monoculture on soil fertility is a consequence of high homogeneity of organic matter introduced to soil and the development of specific soil microorganisms, that produce only specific enzymes [Zawiślak et al. 1988]. Microorganisms are an important source of soil enzymes. Total microbiological activity is considered a good index of soil fertility [Gianfreda, Bollag 1996].

Enzymatic activity is in part affected by the presence and character of plant species. Plant roots together with microorganisms enhance increased concentration of soil enzymes. Plants cultivated in monoculture exert unfavourable influence on soil fertility. This results from the plant unique way of absorbing nutrients and is associated with secretion of only specific enzyme groups by plants in monoculture cultivation and causes a decrease in enzymatic activity.

The objectives of this investigation were:

- to assay enzymatic activity of soil under monoculture in comparison with traditional crop rotation,
- to determine the changes of catalase, acid phosphatase and rhodanase activities of soil in different phases of plant vegetation.

MATERIALS AND METHODS

Soil samples were taken from long-term cultivation experiment carried out in the Experiment Station in Mochetek near Bydgoszcz (middle-north Poland). The experiment was initiated in 1973 by the Department of Soil Science and Plant Cultivation, University of Technology and Agriculture in Bydgoszcz on a lessivé soil with granulometric composition of fine loamy sand. It is a static experiment with different plant cultivation systems (crop rotation and monoculture).

Mineral fertilization (NPK) rates used in both plant systems were in agreement with plants requirement. Full mineral fertilization (NPK), both in traditional and monoculture systems, was applied in the following rates (in kg/ha):

Plant	Before sowing			Top-dressing		Total
	N	P ₂ O ₅	K ₂ O	I	II	
Sugar beet	90	120	220	30	–	460
Field pea	–	120	180	–	–	300
Spring barley	50	120	200	30	–	400
Winter wheat	30	120	200	60	30	440

Farmyard manure was used every 6 years in the rate of 30 t/ha on the plots with sugar beet in crop rotation and every 3 years in monoculture. Mineral fertilizers were used in the following forms: ammonium nitrate (34%), granulated superphosphate (46%), potassium salt (50%). No liming was used.

Soil samples were taken from the Ap horizon in May, July and September 1994 from two depths: 5–15 cm, 20–27 cm under four plants.

In the sampling period the weather conditions were as follows:

	May	July	September	
Average month air temp. [°C]	17.7	16.7	11.7	
Average month sum of rainfall [mm]	18.7	71.1	95.3	
Average month soil temp. [°C]				
Depth [cm]:	5	16.5	17.5	12.6
	10	15.4	16.8	12.3
	20	14.2	16.4	12.7

Soil enzyme activity was determined using the following methods:

- catalase [E.C. 1.11.1.6.]: gasometrically according to Zwiaginew [1980], with 5% H₂O₂ as a substrate;
- rhodanase [E.C. 2.8.1.1.]: colorimetrically as described by Tabatabai and Singh [1976], using thiosulphate and cyanide as substrates;
- acid phosphatase [E.C. 3.1.3.2.]: colorimetrically by the Tabatabai and Bremner [1969] method, using p-nitrophenylophosphate as a substrate.

Physico-chemical soil properties were determined as follows:

- granulometric composition by the Cassagrande method as modified by Pró-szyński,
- pH in H₂O and KCl electrometrically; the ratio soil : solution was 1: 2,5,
- C_{org.} mineralization were done by the Tiurin's method.

- N_{tot} was assayed in Büchi apparatus.

For determination of the relationship between the investigated parameters the variance and correlation analysis with Tuckey test were used.

RESULTS AND DISCUSSION

The granulometric composition (Table 1) showed that almost all of the investigated soil samples belonged to fine loamy sand (fls). Only three soil samples taken from the depth of 20–27 cm from the plots with sugar beet, spring barley and winter wheat had higher silt and clay fraction content than that found for the same fraction of fine loamy sand. These samples were fine sandy loam.

The pH in KCl values ranged 6.7–6.9 while those in H₂O ranged 7.2–7.7. The highest pH in H₂O values were obtained for soil samples taken in September and the lowest in July. The highest pH_{KCl} values were in soil samples from crop rotation taken in July and for monoculture in September (Table 2). Lack of differences in soil reaction between monoculture objects and the ones under crop rotation could have been caused by more frequent application of manure on the plots with sugar beet cultivated in monoculture.

The average C_{org} (Table 3) content of investigated soil was 0.49% in soil samples from the depth of 5–15 cm from crop rotation (Table 2). The average C_{org} content of soil samples from monoculture was 0.47%. C_{org} content of soil samples taken from the horizon 20–27 cm was 0.34% from monoculture as well as from crop rotation. More frequent fertilization with farmyard manure under sugar beet

TABLE 1. Granulometric composition of investigated soil

Plant	Depth of sampling [cm]	Percentage of fraction of diameter [mm]				Texture
		1–0.1	0.1–0.02	0.02–0.002	<0.002	
Crop rotation						
Sugar beet	5–15	65	20	10	5	fls
	20–27	62	19	10	9	fsl
Field pea	5–15	67	22	8	3	fls
	20–27	68	18	9	5	fls
Spring barley	5–15	70	15	11	4	fls
	20–27	64	19	9	8	sl
Winter wheat	5–10	67	19	8	6	fls
	20–27	63	21	9	7	fls
Monoculture						
Sugar beet	5–15	67	21	7	5	fls
	20–27	70	18	6	6	fls
Field pea	5–15	70	20	8	2	fls
	20–27	73	16	9	2	fls
Spring barley	5–15	67	19	8	6	fls
	20–27	67	19	7	7	fls
Winter wheat	5–15	66	20	8	6	fls
	20–27	68	19	7	6	fls

TABLE 2. pH of investigated soil

Plant	Depth of sampling [cm]	pH in H ₂ O			pH in KCl		
		May	July	Sep.	May	July	Sept.
Crop rotation							
Sugar beet	5-15	7.2	7.2	7.5	6.9	6.9	6.8
	20-27	7.4	7.2	7.4	6.9	6.8	6.8
Field pea	5-15	7.3	7.2	7.3	6.5	6.8	6.8
	20-27	7.2	7.2	7.4	6.8	6.9	6.8
Spring barley	5-15	7.2	7.2	7.3	6.6	6.8	6.8
	20-27	7.3	7.2	7.5	6.8	6.9	6.8
Winter wheat	5-15	7.2	7.2	7.4	6.8	6.8	6.8
	20-27	7.3	7.2	7.4	6.9	6.8	6.9
Monoculture							
Sugar beet	5-15	7.2	7.2	7.5	6.8	6.8	6.8
	20-27	7.3	7.2	7.5	6.8	6.8	6.9
Field pea	5-15	7.6	7.2	7.3	6.8	6.8	6.9
	20-27	7.3	7.2	7.3	6.8	6.7	6.8
Spring barley	5-15	7.6	7.3	7.5	6.7	6.7	6.9
	20-27	7.3	7.3	7.3	6.9	6.9	6.9
Winter wheat	5-15	7.3	7.3	7.7	6.7	6.7	6.8
	20-27	7.3	7.2	7.5	6.8	6.7	6.9

monoculture conditions could possibly result in a diminishing of plant monoculture effects on the cummulation and quality of soil organic matter, as compared with the crop rotation cultivation. The highest C_{org.} content (0.58%) was in soil samples taken in May from field pea in crop rotation.

This soil had the highest N_{tot.} content (112.0 mg%), too (Table 3). The highest N_{tot.} content was usually found in soil sampled in July, whereas the lowest N_{tot.} content in soils sampled in September (Table 3).

The statistical analysis indicated differences in the activity level of the investigated enzymes in relation to cultivation system, date and depth of sampling and the kind of plant under cultivation.

The results in this paper for enzyme activities of the soil with monoculture and crop rotation confirmed earlier findings [Cieřla et al. 1977].

The increase of enzymatic activity in soil samples from monoculture in comparison with crop rotation was observed (Tables 4 and 5). Usually, the plants cultivated in monoculture caused higher changes of quality and number of soil microorganisms: an increase of the number of some groups and decrease the others. This process influences on the number of enzymes and their level of activity in the soil.

The highest catalase activity was observed in soil samples taken in May from all cultivated plants (Fig. 1a). The activity ranged 1.9-3.5 ml O₂ · g⁻¹ · min⁻¹. In soil samples taken in July and September a considerable decrease of catalase activity was noticed. This decrease reached about 50% in relation to soil samples taken in May. The catalase activity was significantly higher for soil samples under sugar beet and field pea in the crop rotation on the average (1.7 ml O₂ · g⁻¹ · min⁻¹),

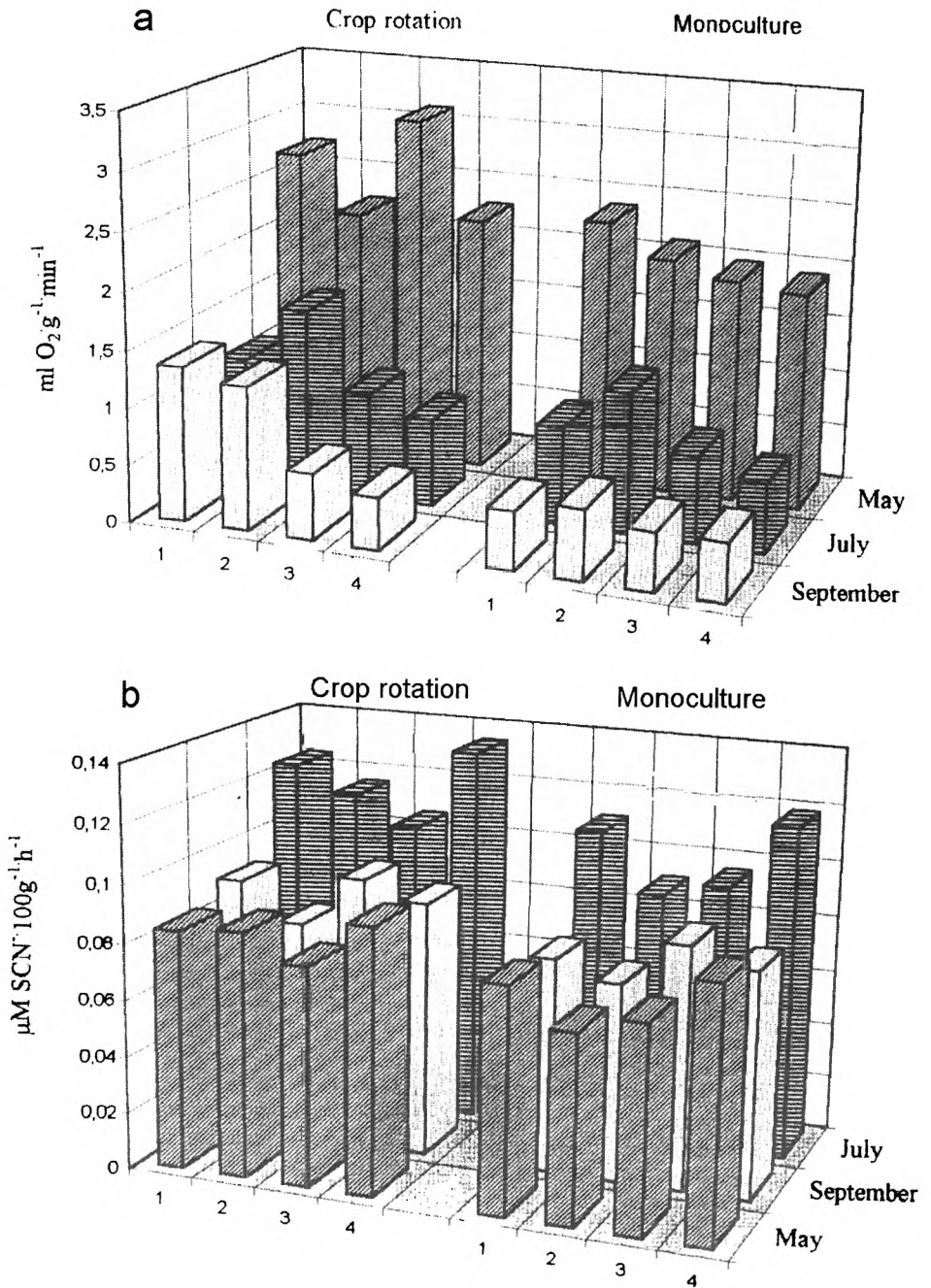


FIGURE 1. Catalase – a and rhodanase – b activity as dependence on cultivated plants, kind of cultivation and date of sampling: 1 – sugar beet, 2 – field pea, 3 – spring barley, 4 – winter wheat

TABLE 3. Organic carbon and total nitrogen content

Plant	Depth of sampling [cm]	C _{org.} [%]			N _{tot.} [mg %]		
		May	July	Septem.	May	July	Septem.
Crop rotation							
Sugar beet	5–15	0.41±0.03	0.49±0.04	0.46±0.05	98.0±3.0	80.4±5.4	79.3±3.5
	20–27	0.32±0.01	0.33±0.02	0.36±0.03	78.4±2.5	69.1±4.8	56.9±3.0
Field pea	5–15	0.56±0.04	0.47±0.03	0.48±0.04	112.0±4.0	98.0±3.5	77.5±2.5
	20–27	0.32±0.02	0.34±0.02	0.37±0.03	86.3±3.5	95.2±3.0	62.3±2.0
Spring barley	5–15	0.49±0.03	0.55±0.03	0.52±0.04	92.4±2.5	101.8±2.0	86.8±2.6
	20–27	0.31±0.01	0.37±0.03	0.34±0.03	67.2±2.5	89.6±2.0	60.7±2.4
Winter wheat	5–15	0.51±0.04	0.48±0.04	0.49±0.03	100.8±2.0	100.9±2.0	70.0±2.4
	20–27	0.33±0.01	0.32±0.02	0.38±0.03	85.9±2.5	71.9±2.5	54.5±3.5
Monoculture							
Sugar beet	5–15	0.49±0.04	0.46±0.04	0.46±0.05	99.1±3.0	72.8±3.5	59.7±2.6
	20–27	0.31±0.03	0.32±0.03	0.39±0.03	56.0±3.0	78.4±3.0	52.9±3.0
Field pea	5–15	0.50±0.04	0.49±0.05	0.46±0.02	67.2±2.5	86.9±4.5	64.4±3.5
	20–27	0.38±0.03	0.36±0.03	0.31±0.03	56.4±2.6	76.6±3.5	54.1±3.6
Spring barley	5–15	0.42±0.04	0.49±0.04	0.49±0.04	80.3±2.5	91.5±3.0	58.8±4.5
	20–27	0.39±0.02	0.37±0.02	0.33±0.03	67.2±3.0	71.9±3.2	55.5±5.6
Winter wheat	5–15	0.46±0.03	0.49±0.03	0.49±0.04	79.3±2.4	75.6±3.0	77.6±3.5
	20–27	0.30±0.04	0.31±0.03	0.37±0.01	74.1±2.6	76.5±3.5	70.8±4.6

while this activity in soil samples under winter wheat and spring barley cultivations was usually higher in soil with monoculture than in the crop rotation (Tables 4 and 5). Catalase activity was positively correlated with the organic matter content ($r = 0.97$ by $p = 0.05$). This is in agreement with the findings of Turski et al. [1985].

For both kinds of plant cultivation, rhodanase activity ($0.08\text{--}0.12 \mu\text{M SCN}^- \cdot 100 \text{ g}^{-1} \cdot \text{h}^{-1}$) has not showed significant differences. Szajdak [1996] obtained lower values ($110\text{--}970 \text{ nM SCN}^- \cdot \text{g}^{-1} \cdot \text{h}^{-1}$) of rhodanase activity of soil with rye cultivation in monoculture and crop rotation. In the soil with rye monoculture cultivation he observed 2.5 times higher rhodanase activity in comparison with soil from crop rotation. The rhodanase activity was the highest in July ($0.10\text{--}0.14 \mu\text{M SCN}^- \cdot 100 \text{ g}^{-1} \cdot \text{h}^{-1}$) (Tables 4 and 5) in soil samples taken from all plants. These results correspond with the data reported by Szajdak [1996], who received the highest increase (to $952 \text{ nM SCN}^- \cdot \text{g}^{-1} \cdot \text{h}^{-1}$) in July in the beginning of rye blooming. Lower levels of soil rhodanase activity: $120\text{--}875 \text{ nM SCN}^- \cdot \text{g}^{-1} \cdot \text{h}^{-1}$ and $30\text{--}130 \text{ nM SCN}^- \cdot \text{g}^{-1} \cdot \text{h}^{-1}$ were obtained by Tabatabai and Singh [1976] and Lawrence et al. [1988], respectively. The correlation analysis showed that rhodanase activity was positively correlated with C_{org.} content ($r = 0.87$). Similar correlations for these parameters were found by Freney et al. [1971].

We registered the highest phosphatase activity in soil samples taken in Summer (Fig. 2). We observed differences in phosphatase activity in relation to plant species. The average phosphatase activity in soil samples for spring barley was $25.3 \mu\text{g PNP} \cdot \text{g}^{-1} \cdot \text{h}^{-1}$ whereas for winter wheat was $30.8 \mu\text{g PNP} \cdot \text{g}^{-1} \cdot \text{h}^{-1}$ (Table 5). These results are in discrepancy with the data of Ross et al. [1984], who observed lower acid phosphatase activity.

In our investigations phosphatase activity in soil samples from crop rotation

TABLE 4. Enzymatic activity (catalase [$\text{ml O}_2 \cdot \text{g}^{-1} \cdot \text{min}^{-1}$] rhodanase [$\mu\text{M SCN} \cdot 100 \text{g}^{-1} \cdot \text{h}^{-1}$], acid phosphatase [$\mu\text{g PNP} \cdot \text{g}^{-1} \cdot \text{h}^{-1}$] of soil under sugar beet and field pea as dependent on kind of cultivation, date and depth of sampling

Objects		Sugar beet			Field pea		
		catalase	rhodanase	acid phosphatase	catalase	rhodanase	acid phosphatase
Kind of cultivation	Crop rotation	1.72	0.10	27.0	1.68	0.09	24.2
	Mono-culture	1.23	0.09	17.8	1.31	0.08	21.6
Date of sampling (for both kind of cultivation)	May	2.54	0.08	21.9	2.15	0.08	24.7
	July	0.97	0.12	27.5	1.39	0.10	27.3
	Sept.	0.92	0.09	17.8	0.95	0.08	16.8
Depth of sampling [cm] (for both kind of cultivation)	5–15	1.52	0.12	28.3	1.72	0.11	31.0
	20–27	1.44	0.07	16.5	1.37	0.07	14.8
Mean		1.48	0.1	22.4	1.49	0.09	22.9
NIR _{0.05}							
Kind of cultivation (I)		0.043	0.005	2.35	0.162	0.009	2.989
Date of sampling (II)		0.107	0.004	1.66	0.083	0.003	2.368
Depth of sampling (III)		0.107	0.004	1.99	0.085	0.002	0.856
Interactions	I × II	***	**	***	***	***	***
	I × III	***	**	***	***	***	N.I.
	II × III	***	***	***	***	***	***

** $p < 0.01$, *** $p < 0.001$, N.I. – not significant.

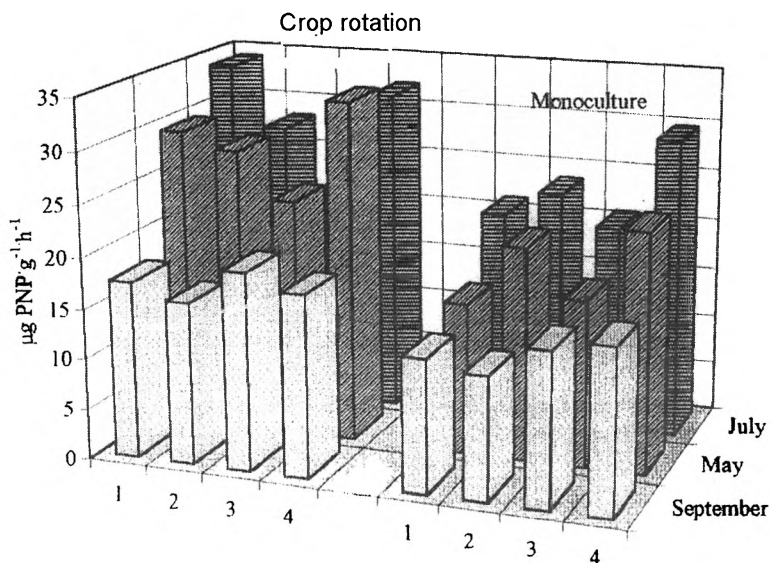


FIGURE 2. Acid phosphatase activity as dependence on cultivated plants, kind of cultivation and date of sampling: 1 – sugar beet, 2 – field pea, 3 – spring barley, 4 – winter wheat

TABLE 5. Enzymatic activity (catalase [$\text{ml O}_2 \cdot \text{g}^{-1} \cdot \text{min}^{-1}$], rhodanase [$\mu\text{M SCN} \cdot 100 \text{g}^{-1} \cdot \text{h}^{-1}$], acid phosphatase [$\mu\text{g PNP} \cdot \text{g}^{-1} \cdot \text{h}^{-1}$] of soil under spring barley and winter wheat as dependent on kind of cultivation, date and depth of sampling

Objects		Sugar beet			Field pea		
		catalase	rhodanase	acid phosphatase	catalase	rhodanase	acid phosphatase
Kind of cultivation	Crop rotation	1.52	0.09	23.1	1.18	0.11	27.7
	Monoculture	1.28	0.09	18.7	1.44	0.11	23.7
Date of sampling (for both kind of cultivation)	May	2.54	0.08	19.2	2.53	0.09	28.4
	July	1.01	0.11	25.3	0.88	0.15	30.8
	Sept.	0.66	0.09	18.3	0.52	0.09	18.0
Depth of sampling [cm] (for both kind of cultivation)	5–15	1.43	0.11	27.5	1.37	0.14	32.1
	20–27	1.37	0.07	14.3	1.26	0.08	19.3
Mean		1.4	0.09	20.9	1.31	0.11	25.7
NIR _{0.05}							
Kind of cultivation (I)		0.077	0.010	2.99	0.16	0.002	1.89
Date of sampling (II)		0.103	0.004	2.15	0.122	0.003	1.29
Depth of sampling (III)		0.103	0.003	1.03	0.088	0.003	1.15
Interactions	I × II	***	**	*	**	***	***
	I × III	N.I.	N.I.	**	***	**	**
	II × III	*	***	***	**	***	***

** $p < 0.01$, *** $p < 0.001$, N.I. – not significant.

and monoculture ranged 23.1–27.0 $\mu\text{g PNP} \cdot \text{g}^{-1} \cdot \text{h}^{-1}$ and 17.8–23.8 $\mu\text{g PNP} \cdot \text{g}^{-1} \cdot \text{h}^{-1}$, respectively. Acid phosphatase activity was higher in soil samples taken from spring barley with crop rotation than from field pea. Similar results were noticed by Xu and Johnson [1995] for acid phosphatase activity in the soil under these plant species. It is well known that acid phosphatase activity is a product of plant roots [Juma, Tabatabai 1988]. Spring barley produced 5 times more roots than field pea in the vegetation period [Heeraman, Juma 1993]. This was reflected as higher phosphatase activity in the soil samples taken under this plant. However, it should be admitted that the authors did not consider a higher dynamics of decomposition during the legume root in comparison with the cereal roots process, especially under the conditions imposed with crop rotation.

The correlation analysis showed a high positive relation between phosphatase activity and C_{org} content ($r = 0.98$) as well as catalase activity and C_{org} content ($r = 0.97$) in soil samples taken in Autumn. Also Januszek [1990] found a positive correlation between phosphatase activity and the C_{org} content ($r = 0.92$).

We did not find any correlation between the grain yield and activities of the enzymes investigated. Enzymatic activity was lower in the soil with monoculture in comparison with crop rotation. Grain yields were significantly lower in the monoculture cultivation of the plant (Table 6). It seems to be that the lower yield of plants cultivated under monoculture does not result from chemical changes but from the biological cycle of the soil.

TABLE 6. Yield of plants cultivated in crop rotation and monoculture [t/ha]

Kind of cultivation	Sugar beet	Field pea	Spring barley	Winter wheat
Crop rotation	50.5	1.39	2.91	2.96
Monoculture	40.9	0.15	1.90	1.88

CONCLUSIONS

1. Enzymatic activity of soil under crop rotation was usually higher than in soil samples taken from monoculture. A negative effect of monoculture on biological soil properties was found, despite more intense manure fertilization. A decrease in enzymatic activity was observed in the plant yields with monoculture cultivation in comparison with crop rotation.
2. Higher enzymatic activity was noticed in soil samples taken from the depth of 5–15 cm in comparison with soil samples from the depth of 20–27 cm. Rhodanase and acid phosphatase activities of soil samples taken for all plants in all terms were the lowest at the depth of 20–27 cm.
3. The highest catalase activity was in soil samples taken in Spring in the monoculture and crop rotation plots, whereas rhodanase and acid phosphatase activities were the highest in soil samples taken in July for both systems of plant cultivation.
4. Analysis of variation demonstrated significant interactions between enzymatic activities, plant species, system of cultivation and date of soil sampling. Correlation analysis showed significant correlations between catalase, acid phosphatase and rhodanase activities and C_{org} content in investigated soil.

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WPŁYW RÓŻNEGO SYSTEMU UPRAWY ROŚLIN NA AKTYWNOŚĆ GLEBOWEJ FOSFATAZY KWAŚNEJ, KATALAZY I RODANAZY

Katedra Gleboznawstwa i Biochemii Akademii Techniczno-Rolniczej
w Bydgoszczy

STRESZCZENIE

Badano wpływ roślin (burak cukrowy, peluszka, jęczmień jary, pszenica ozi-
ma) uprawianych w zmianowaniu i w monokulturze na aktywność enzymatyczną
gleby płowej. Próbkę glebowe pobierano w 21 roku prowadzenia doświadczenia
w 1994 r. zlokalizowanego w RZD w Mochelku koło Bydgoszczy. Pobierano je
z dwóch głębokości poziomu Ap gleby (5–15 cm i 20–27 cm) w maju, lipcu i we
wrześniu w różnych fazach rozwojowych roślin. Największą aktywność kwaśnej
fosfatazy, katalazy i rodanazy odnotowano w próbkach gleby pobranych z poletek
ze zmianowaniem upraw. Stwierdzono ujemne oddziaływanie monokultury na
biologiczne właściwości gleby, mimo większych dawek obornika. Większą
aktywność enzymów odnotowano w próbkach glebowych pobranych z głębokości
5–15 cm niż w próbkach pobranych z głębokości 20–27 cm. Katalaza najaktyw-
niejsza była w próbkach glebowych pobranych wiosną, natomiast aktywność
rodanazy i fosfatazy kwaśnej była największa w próbkach pobranych w lipcu.
Otrzymano wysokie współczynniki korelacji między aktywnością katalazy, kwaś-
nej fosfatazy i rodanazy a zawartością C_{org} w glebach.

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