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EVALUATION OF THE INFLUENCE OF ORGANO-MINERAL FERTILIZER ON THE UPTAKE OF ZINC, CADMIUM AND LEAD AND ON THE BUCKWHEAT CROP

The influence of organo-mineral fertilizer, which was produced on the basis of brown coal, on chemical constitution and on the cropping of buckwheat was established. This research is the next stage of the five-year vase experiments carried out on the effectiveness of this fertilizer in blocking zinc, cadmium and lead in soil.

Based on the analysis of the content of the aforementioned metals in buckwheat straw and grain, it can be concluded that the fertilizer used once in the doses of 100 Mg/ha and 150 Mg/ha reduced by even 50% the uptake of zinc and lead by buckwheat in comparison to uncultivated soil. The results for lead were worse – the uptake approached 20%. Moreover, the fertilizer had a beneficial influence on cropping and on the content of magnesium, phosphate and potassium in plants.

1. INTRODUCTION

The soils of the Częstochowa region accumulate such heavy metals as cadmium zinc and lead in higher concentrations than their average concentrations in the surface soils of arable land in Poland. The greatest threat to plant production is cadmium because of its relatively high concentration in soils (0.46 mg/kg) and a considerable area (over 9% of all arable lands) of II° or of higher degrees of pollution. There is also a potential danger of including metals into food chain because of the mechanical composition of soils and their acid reaction. This has been proven by the results of research on plants coming from this region [1]–[4]. Many authors emphasize that migration of metals from soil environment to the plants depends, among others, on a proper fertilization of soils. The enrichment of soils of low adsorption abilities with humus compounds and keeping up the neutral reaction at the same time may limit the fitoadsorption of metals in an effective way. Organic matter may form simple compounds or chelate complex compounds with heavy metals. They prevent the metals from displacement and immobilize the metals in soil [9]–[11].

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A great amount of organic matter is characteristic of organo-mineral fertilizers which are produced on the basis of brown coal. The specific quality of these preparations is the possibility of adjusting their composition to the properties of the fertilized soil [12, [13].

A very essential problem is the time of the impact of these fertilizers on the limitation of metal migration. There is no exhaustive research in this subject. In the paper, there has been presented the the influence of organo-mineral fertilizer produced from brown coal on the chemical constitution and cropping of buckwheat. This research is the next stage of the experiments that have been continued for five years on the effect of a single soil fertilizer, called Rekulter, on the cropping and chemical composition of plants, taking into consideration particularly its influence on the fitoadsorption of Zn, Cd and Pb.

2. MATERIALS AND METHODS

2.1. CHARACTERISTICS OF SOIL USED IN THE VASE EXPERIMENT

The soil has been taken from the field sown with grass, in Dyrdy town, commune Woźniki Śląskie. The grain composition analysis has shown that because of the fluming parts content this soil should be rated as light soil. The soil was characterized by very low potassium content and medium magnesium content. It contained higher amount of lead (I°) and was slightly polluted with zinc and cadmium (II°). The content of nickel, copper and manganese was on a level of natural content for light soils (table 1).

Table 1

Basic physicochemical properties of soil

pH_{KCl}	pH_{H_2O}	C_{org}	K	Ca	Mg	Zn	Cd	Ni	Cu	Pb
		%	The content of available nutriens (mg/kg d.m)			Total content of heavy metals (mg/kg d.m)				
5.0	5.8	0.87	29.8	997.0	32.2	174.0	1.66	8.4	14.5	62.7

Soil samples were taken from the surface soil according to the BN-78/9180-02 norm.

2.2. THE AGRICULTURAL CHARACTERISTICS OF BROWN COAL AND OF THE ORGANO-MINERAL FERTILIZER CALLED REKULTER

Brown coal, which was used as a fertilizer for the experiments and simultaneously as a basic component of organo-mineral fertilizer, came from KWB Konin. It belonged to soft forms of brown coals, the so-called smudge coals. The coal used in the

experiment contained 30% of water and its pH in 1 M KCl was 5.5. It was used in the disintegrated form and its diameters were smaller than 3.0 mm.

The organo-mineral fertilizer Rekulter was produced from brown coal being enriched with macro- and microcomponents necessary for promoting the growth of plants. The composition of fertilizer which was used in the experiment is presented in table 2, and its pH in 1 M KCl was 7.0.

Table 2

The composition of organo-mineral fertilizer used in the experiments

Component name	Component mass (kg)
Brown coal	920
Single superphosphate $Ca(H_2PO_4)_2$	11
Urea $(NH_2)_2CO$	4
Potassium salt K_2SO_4	4
Dolomite	60
Supersorbent	1
Overall	1000

2.3. THE VASE EXPERIMENT

The vase experiment was conducted between 1998 and 2002 in the plant house of the Experimental Science Department of Soil Environment, Main School of Farming, in Skierniewice. The aim of the experiment was, first of all, to examine the influence of organo-mineral fertilizer on the adsorption of cadmium, zinc and lead by the chosen plants. The following kinds of fertilization were applied:

- organo-mineral fertilizer called Rekulter used in three doses: 50, 100 and 150 Mg/ha,
- brown coal in the dose of 92 t/ha, which is an equivalent of brown coal content within the Rekulter dose of 100 Mg/ha,
- mineral fertilization (single superphosphate, urea, potassium salt, dolomite, supersorbent), which is an equivalent of these fertilizers in the Rekulter dose of 100 Mg/ha.

These different combinations of fertilizers enabled us to establish whether this kind of fertilization could reduce the adsorption of heavy metals by plants (table 3).

In 2002, the buckwheat was cultivated in vases. The plants were sown directly to vases, watered by distilled water (up to 60% of maximum capillary water capacity). The plants were cultivated from August to September.

The analyses of soils and plants were carried out by means of the methods commonly used in soil science and agricultural chemistry.

Table 3

Scheme of the vase experiment

Combination*	The kind and the dose of fertilizer (g/vase)
0	Control – without fertilization
1R	Rekulter 92
2R	Rekulter 184
3R	Rekulter 276
W	Brown coal 170
N	NPK: urea, 0.7; potassium salt, 0.7; single superphosphate, 2.0; dolomite 10.5; supersorbent, 0.2

* Each of the combination was in four repetitions.

3. THE RESULTS OF EXPERIMENTS

3.1. THE INFLUENCE OF DIVERSIFIED FERTILIZATION ON CROPS

The plants fertilized by Rekulter in the doses of 100 Mg/ha and 150 Mg/ha grew more vigorously than plants fertilized by other combinations of fertilizers (table 4).

Table 4

Buckwheat crop

Combination	Buckwheat straw		Buckwheat grain
	g.m., g/vase	d.m., g/vase	d.m., g/vase
0	101.8	28.0	8.5
1R	101.9	29.0	9.2
2R	108.2	30.2	9.7
3R	109.6	30.5	9.8
W	107.5	29.3	8.7
N	108.0	29.4	8.8

The values given in the table are the averages of four repetitions.
g.m. – green matter, d.m. – dry matter.

While putting the combinations into series, there were obtained:
Buckwheat straw – 3R>2R>N>W>1R>0.
Buckwheat grain – 3R>2R>1R>N>W>0.

The Rekulter in the dose of 3R enriched best the soil with nutrients. What is more, the Rekulter deacidified the soil to a great extent, thus making the nutrients available for plants. Their growth was the consequence of improving the chemical properties of soil and its structure and the influence of organic matter of brown coal.

3.2. THE INFLUENCE OF DIVERSIFIED FERTILIZATION ON CHEMICAL CONSTITUTION OF PLANTS

3.2.1. THE CONTENT OF PHOSPHORUS, MAGNESIUM, CALCIUM AND POTASSIUM IN PLANTS

The content of macro- and microcomponents in cultivated plants affects their nutritive values. While analysing the content of magnesium, potassium and phosphorus in buckwheat straw and buckwheat grain, it was observed that the fertilization by the Rekulter had the most beneficial influence on the content of these elements in plants (table 5).

Table 5

The content of phosphorus, magnesium, calcium and potassium in plants, % in dry matter

The kind of fertilization	Buckwheat straw				Buckwheat grain			
	P	Mg	Ca	K	P	Mg	Ca	K
0	0.030	0.11	0.83	1.35	0.204	0.11	0.08	0.67
1R	0.037	0.17	0.86	1.67	0.234	0.11	0.08	0.68
2R	0.045	0.22	0.80	1.67	0.272	0.11	0.07	0.68
3R	0.045	0.24	0.84	1.85	0.270	0.12	0.08	0.68
W	0.041	0.18	0.83	1.62	0.217	0.11	0.07	0.60
N	0.037	0.19	0.81	1.54	0.208	0.09	0.08	0.58

The values given in the table are the averages of four repetitions.

The highest dose of fertilizer caused an increase in the content of magnesium in buckwheat straw by even 100% in comparison to the control combination. There was not observed, however, a significant increase in the content of this element in buckwheat grain. No significant changes were observed in the content of calcium in buckwheat straw and buckwheat grain under the influence of diversified fertilization, although the Rekulter enriched the soil with calcium.

3.2.2. THE CONTENT OF ZINC, CADMIUM AND LEAD IN PLANTS

The content of zinc, cadmium and lead in buckwheat straw and buckwheat grain was examined. The soil used in the experiment was weakly polluted by zinc and cadmium and contained higher concentration of lead. In the buckwheat straw, the content of all above mentioned metals was several times higher than in the buckwheat grain. A diversified fertilization had impact on the changes in the concentrations of metals in plants (table 6).

Zinc – fertilization by the Rekulter in the doses of 2R and 3R limited significantly zinc concentrations in straw which were respectively by 29% and of 41% lower in comparison with the control combination (table 6). For the grain there was obtained a respective reduction of 45% and of 51%.

Table 6

The content of zinc, cadmium and lead in plants, mg/kg of dry matter

The kind of fertilization	Buckwheat straw			Buckwheat grain		
	Zn	Cd	Pb	Zn	Cd	Pb
0	140.1	5.62	8.33	45.6	0.70	2.83
1R	134.5*	5.00**	7.93**	32.2**	0.70^{ns}	2.80**
2R	98.9**	3.14***	7.43**	24.9**	0.64**	2.33**
3R	82.6***	2.88***	7.43***	22.3***	0.61**	2.40***
W	125.5*	5.01*	7.60**	25.9**	0.73*	2.33***
N	125.9*	5.20*	7.63*	26.4**	0.73*	2.53**

* For $p < 0.05$.
** For $p < 0.01$.
*** For $p < 0.001$.
^{ns} The result uniportant statistically.
NIR – the comparison of particular combinations of fertilizers with the control.

Fertilization by brown coal decreased the zinc content in straw by about 11%, and in grain by 44%. While presenting the examined combinations of fertilization according to zinc content in buckwheat straw and buckwheat grain, we obtained the following series:

3R<2R<W<N<1R<0 for straw.
3R<2R<W<N<1R<0 for grain.

Cadmium – organo-mineral fertilization by the Rekulter had the most effective influence on the reduction of adsorption of cadmium by buckwheat. It should be emphasized that this effect would be much higher for straw in comparison to buckwheat grain (table 6).

While using the Rekulter in the dose of 3R, the reduction of cadmium content in straw and grain reached 49% and 15%, respectively. The dose of 2R decreased the metal content in straw by 44% and in grain by 9% in comparison to the control. The other kinds of fertilization did not have any significant influence on the change of cadmium content in plants. While presenting the examined combinations of fertilization according to cadmium content in buckwheat straw and grain, we obtained:

3R<2R<1R<W<N<O for straw.
3R<2R<1R=O<W+N for grain.

Lead – as in the case of zinc and cadmium, the highest reduction of lead content in buckwheat was obtained as a result of organo-mineral fertilization by the Rekulter in the doses of 2R and 3R (table 6). The lead content in straw decreased by 11%, and in grain by 18%. In the case of grain, fertilization by brown coal was responsible for similar effects.

While presenting the examined combinations of fertilization according to lead content in buckwheat straw and buckwheat grain, we obtained:

3R = 2R<2R,W<N<1R<O for straw.
2R = W<3R<N<1R<O for grain.

3.3. THE FACTORS INFLUENCING METAL BIOACCUMULATION IN BUCKWHEAT

The indices of bioaccumulation were used in order to evaluate the changes in the mobility of zinc, cadmium and lead in soil due to diversified fertilization [1]–[3]. The values of indices were calculated as the ratio of a given metal content in a plant to a total content of this metal in soil [14].

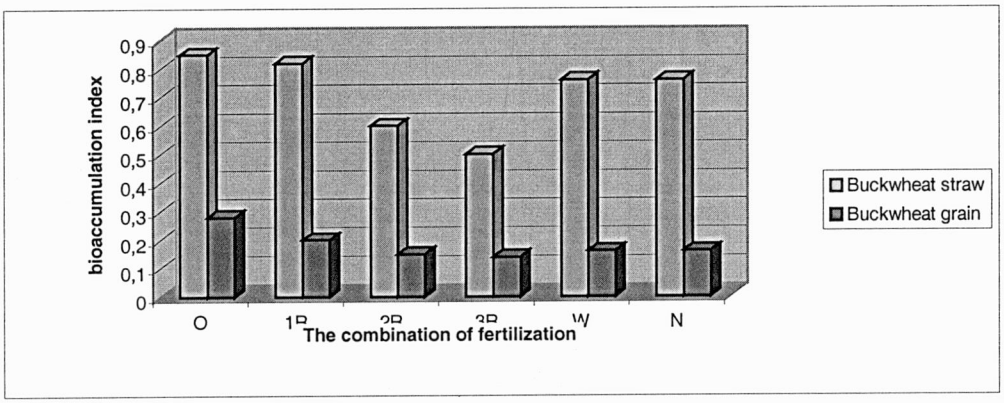

Fig. 1. The influence of fertilization on the value of bioaccumulation coefficient of zinc in buckwheat straw and buckwheat grain

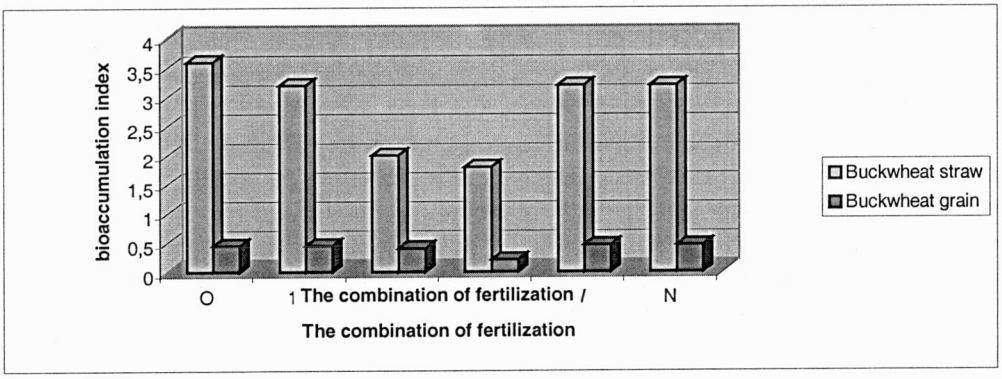

Fig. 2. The influence of fertilization on the value of bioaccumulation coefficients of cadmium in buckwheat straw and buckwheat grain

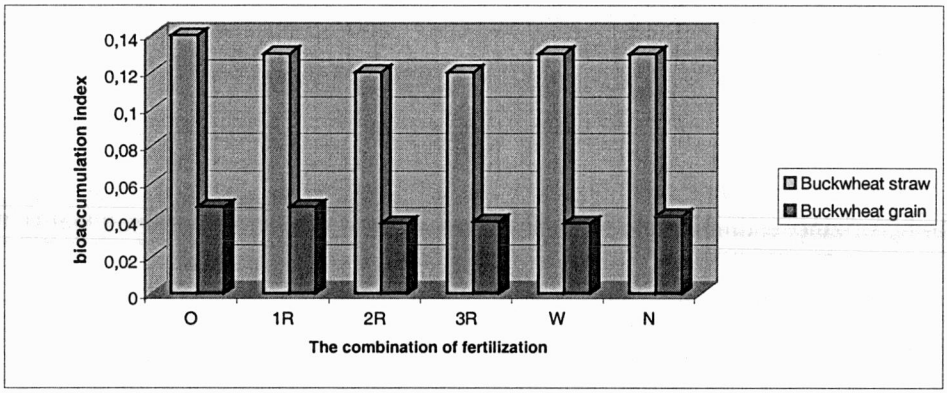

Fig. 3. The influence of fertilization on the value of bioaccumulation coefficients of lead in buckwheat straw and buckwheat grain

While comparing the values of bioaccumulation coefficients, it is found that cadmium and zinc are accumulated by plants in higher concentrations than lead. Fertilization by the Rekulter at the doses of 3R and 2R decreased significantly bioaccumulation of cadmium and zinc, and to a smaller extent lead bioaccumulation.

4. CONCLUSIONS

1. The best effects of reduction in the uptake of cadmium, zinc and lead by buckwheat, of among various combinations of fertilization, were due to use of the Rekulter in the dose of 100 or 150 Mg/ha. Moreover, the Rekulter had a beneficial influence on the plant cropping and on the content of magnesium, potassium and phosphate in plants.

2. Fertilization by the Rekulter increased the zinc content in buckwheat straw and buckwheat grain by 40–50%, cadmium content in straw by 50%, in grain by 15%, and lead content in straw and in grain by 10–20%.

3. The values of bioaccumulation coefficients of zinc, cadmium and lead were several times higher for straw in comparison to these values for grain.

4. While considering the changes in cropping and the changes in heavy metals content in plants, which were caused by the Rekulter, it can be claimed that the fertilizer is still active after five years of its usage and it is likely that the period of its influence on plants will be longer.

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OCENA ODDZIAŁYWANIA NAWOZU ORGANICZNO-MINERALNEGO NA POBIERANIE CYNKU, KADMU I OŁOWIU ORAZ PLONOWANIE GRYKI

Badano wpływ nawozu organiczno-mineralnego na bazie węgla brunatnego na skład chemiczny oraz plonowanie gryki. Badania te są kolejnym etapem kontynuowanych od pięciu lat doświadczeń wazonowych nad skutecznością działania tego nawozu, głównie pod kątem blokowania cynku, kadmu i ołowiu w glebie.

Na podstawie analizy zmian w zawartości tych metali w ziarnie i słomie gryki można stwierdzić, że jednorazowo zastosowany nawóz w dawkach 100 Mg/ha i 150 Mg/ha ogranicza pobieranie cynku i kadmu przez grykę nawet do 50% w porównaniu z glebą nienawożoną. Efekty dla ołowiu są gorsze – do 20%. Ponadto nawóz wpływa korzystnie na plonowanie oraz zawartość magnezu, fosforu i potasu w roślinach.