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THE IMPACT OF MANURE, MUNICIPAL SEWAGE SLUDGE AND COMPOST PREPARED FROM MUNICIPAL SEWAGE SLUDGE ON CROP YIELD AND CONTENT OF Mn, Zn, Cu, Ni, Pb, Cd IN SPRING RAPE AND SPRING TRITICALE

Anna Iżewska

Chair of Environmental Chemistry
Western Pomeranian University of Technology

Abstract

The aim of the research was to estimate the impact of manure, municipal sewage sludge and compost prepared from municipal sewage sludge on crop yield and content of microelements (Mn, Zn, Cu, Ni) as well as Pb, and Cd in spring rape and spring triticale and also to specify the bioaccumulation indexes of microelements in test plants.

A pot experiment was set up in the Vegetation Hall of the University of Agriculture in Szczecin 2006. Manure, raw sewage sludge and compost prepared from sewage sludge with the GWDA method were used. The pot experiment was set up with the split plot method in three repetitions. Objects of the first factor were types of fertilizers (manure, municipal sewage sludge and compost prepared from sewage sludge) and objects of the second factor were the doses of individual fertilizers introduced to soil in conversion to the amount of incorporated nitrogen (85 and 170 kg $N \cdot ha^{-1}$ i.e. 0.26 and 0.52 g N per pot).

The results indicate that the best yields of spring rape seeds and spring triticale grains were obtained from the object fertilized with a double dose of sewage sludge. Fertilization with manure, sewage sludge and compost prepared from sewage sludge increased the content of microelements as well as Pb and Cd in seeds and grains of the test plants. These contents did not exceed permissible values for industrial plants. The calculated bioaccumulation indexes of microelements indicate that spring rape and spring triticale were accumulating moderate amounts of manganese and zinc.

Key words: manure, sewage sludge, compost prepared from sewage sludge, spring rape, spring triticale, bioaccumulation indexes.

dr inż. Anna Iżewska, Chair of Environmental Chemistry, Western Pomeranian University of Technology, ul. Słowackiego 17, 71-434 Szczecin, Poland, phone (091) 449 6337; e-mail: anna.izewska@zut.edu.pl

WPŁYW OBORNIKA, KOMUNALNEGO OSADU ŚCIEKOWEGO I KOMPOSTU Z NIEGO WYPRODUKOWANEGO NA WIELKOŚĆ PLONU I ZAWARTOŚĆ MIKROSKŁADNIKÓW Mn, Zn, Cu, Ni ORAZ Pb I Cd W RZEPAKU JARYM I PSZENŻYCIE JARYM

Abstrakt

Celem badań było określenie wpływu nawożenia gleb obornikiem, komunalnym osadem ściekowym i kompostem z niego wyprodukowanym na wielkość plonu i zawartość mikroskładników (Mn, Zn, Cu, Ni) oraz Pb i Cd. w rzepaku jarym i pszenżycie jarym oraz określenie wskaźników bioakumulacji tych pierwiastków w roślinach uprawianych.

W 2006 r. założono doświadczenie wazonowe na terenie hali wegetacyjnej AR w Szczecinie. Do badań użyto obornik, surowy osad ściekowy i wyprodukowany metodą GWDA kompost z osadów ściekowych.

Doświadczenie wazonowe założono metodą split plot w trzech powtórzeniach. Obiektami pierwszego czynnika były rodzaje nawozów (obornik, komunalny osad ściekowy, kompost z osadu ściekowego), a obiektami II czynnika – dawka poszczególnych nawozów wprowadzana do gleby w przeliczeniu na ilość wniesionego azotu (85 i 170 kg $N \cdot ha^{-1}$, tj. 0,26 i 0,52 g N na wazon). Uzyskane wyniki badań wskazują, że największy plon nasion rzepaku jarego i ziarna pszenżyta jarego zebrano z obiektów nawożonych podwojoną dawką osadu ściekowego. Nawożenie osadem ściekowym oraz kompostem spowodowało zwiększenie zawartości mikroskładników oraz Pb i Cd w nasionach oraz ziarnie roślin testowych. Zawartości te jednak nie przekroczyły dopuszczalnych wartości dla roślin przemysłowych. Obliczone wskaźniki bioakumulacji wskazują, że rzepak jary i pszenżyto jare w stopniu średnim akumulowały mangan i cynk.

Słowa kluczowe: obornik, osad ściekowy, kompost z osadu ściekowego, rzepak jary, pszenżyto jare, wskaźniki bioakumulacji.

INTRODUCTION

The amount of sewage sludge produced in Poland has been increasing in recent years.. In 2006 1,064.7 thousand ton d.m. of sewage sludge was produced, including 501.3 thousand ton d.m. of municipal sewage sludge.

Sewage sludge can be used for fertilization of plants if it is submitted to stabilization and hygienization processes. One of the stabilization processes is composting with organic materials. Composts from sewage sludge, like raw sewage sludge, are a rich source of organic substance and components. However, sewage sludge and composts produced from sewage sludge can be loaded with excessive amounts of heavy metals. Therefore, it is important to find the way of managing and utilizing sludge that will not threaten natural environment. One of the methods is phytoremediation, i.e. using the ability of plants to take up and accumulate polluted substances or to biodegrade them.

The aim of the research was to estimate the impact of manure, municipal sewage sludge and compost prepared from municipal sewage sludge on crop yield and content of microelements (Mn, Zn, Cu, Ni) as well as Pb and Cd in spring rape and spring triticale and also to specify the bioaccumulation indexes of microelements in the test plants.

MATERIAL AND METHODS

A pot experiment was set up in the Vegetation Hall of the University of Agriculture in Szczecin in 2006. Kick-Brauckmann's pots holding 9 dm^3 were filled with 9 kg of soil each. Manure, raw sewage sludge and compost prepared from sewage sludge with the GWDA method were tested. The chemical composition of the manure, raw sewage sludge and compost was presented in the earlier research (IŻEWSKA 2007).

In the experiment soil from the Agricultural Experimental Station in Lipnik belong to the University of Agriculture in Szczecin was used. It was taken from the level of Ap and represented the grain size distribution of clay slight dusty sand. Soil reaction was acid (pH in 1mol $KCl \cdot dm^{-3}$ – 5.13) and the content of available phosphorus, potassium and magnesium was average. The pot experiment was set up with the split plot method in three replications. The objects of the first factor were types of fertilizers (manure, municipal sewage sludge and compost prepared from sewage sludge) and the objects of the second factor were the doses of individual fertilizers to the soil in conversion to the amount of incorporated nitrogen (85 and 170 kg $N \cdot ha^{-1}$ i.e. 0.26 and 0.52 g N per pot). The objects with sole fertilization NPK received 0.18 g nitrogen per pot as the first dose and 0.36 g nitrogen as the second dose. In all the objects 0.12 g P per pot and 0.26 g K per pot were added. In the second year of the experiment, mineral fertilization was performed, including 0.30 g N per pot, 0.24 g P per pot and 0.72 g K per pot.

The test plant in the first year of the experiment was spring rape cv. Licosmos; in the second year it was spring triticale cv. Dalgety. Determination of microelements as well as Pb and Cd was accomplished with the AAS method after previous wet mineralization of the samples of plant material in a mixture of nitric acid (V) and perchloric acid (VII).

The bioaccumulation indexes were calculated as a ratio of the content of a given element in the plant to its content in the organic fertilizer (KABATA-PENDIAS et al. 1993). four-degree scale of the accumulation of heavy metals was obtained (MICHAŁOWSKI, GOŁAŚ, 2001).

RESULTS AND DISCUSSION

The study showed that fertilization of soil of manure, raw sewage sludge and compost prepared from sewage sludge at both fertilization levels had significant influence on the volume of yield of spring rape seeds (Table 1). An average yield of spring rape seeds was 11.6 g per pot, about 69.31% higher than the yield which was gathered from the control variant (Table 1).

Table 1

Seed yield of spring rape and grain yield of spring triticale (g from pot)

Specification	Spring rape			Spring triticale		
	dose I	dose II	mean	dose I	dose II	mean
Manure	10.07	11.32	10.70	20.00	23.60	21.80
Sewage sludge	12.32	15.20	13.76	22.50	28.00	25.30
Compost	10.89	11.63	11.26	24.40	20.80	22.60
NPK	11.68	10.16	10.92	25.50	23.40	24.50
Mean	11.68	12.08	11.66	23.10	24.00	23.60
Control	3.56			14.50		

$LSD_{0.01}$ for rape seeds I factor 1.88; II factor 0.99; IxII 1.96
$LSD_{0.01}$ for triticale grains I factor n.s; II factor n.s; IxII 5.19

The maximum yield of spring rape seeds was gathered from the objects with raw sewage sludge. It was considerably higher than the yield obtained from the remaining fertilization variants. The impact of manure, compost and NPK on yield did not differmuch. An average yield of seeds of spring rape after the first dose of fertilizer was 11.68 g per pot and was significantly lower than after the double dose.

Mineral fertilization as well introduction of manure, sewage sludge and compost from sewage sludge had non-significant influence on yield of spring triticale grain. The yield gathered from the control object was 14.50 g per pot, being about 9.1 g lower than the average yield obtained from the soils which were fertilized by any of the analyzed fertilizers. In the second year of the experiment, the maximum yield was likewise obtained after fertilization of soil with sewage sludge (25.30 g per pot) and the lowest yield occurred after application of manure (21.80 g from a pot). The best effect in terms of yield of spring triticale grain was obtained in the object where the higher dose of sewage sludge was used (28.00 g per pot). The grain yield from this object was significantly higher than the yield obtained from the soils, which were fertilized with manure and the double dose of compost.

Regarding the influence of fertilization on the content of Mn, Cu, Zn Ni as well as Pb and Cd, it was demonstrated that for both spring rape seeds (Table 2) and triticale grains (Table 3) the yields from fertilized objects were higher than from the control variant.

Sewage sludge used to fertilize spring rape caused increased content of zinc, copper, nickel and lead in seeds, but the increase was statistically proven only for nickel. As the dose of the fertilizer rose, the content of microelements as well as Pb and Cd in seeds of spring rape increased.

The experimental factors: the type of fertilizers (manure, sewage sludge, compost from sewage sludge) and the increasing doses, did not significantly

Table 2

Content of microelements as well as Pb and Cd in seeds of spring rape ($mg \cdot kg^{-1}$ d.m.)

Specification	Mn			Zn			Cu			Ni			Pb			Cd		
	1*	2*	$\overline{x}$	1*	2*	$\overline{x}$	1*	2*	$\overline{x}$	1*	2*	$\overline{x}$	1*	2*	$\overline{x}$	1*	2*	$\overline{x}$
Manure	53.3	51.5	52.4	28.1	27.7	27.9	3.62	3.95	3.78	2.72	3.09	2.90	4.29	4.25	4.27	0.142	0.188	0.165
Sewage sludge	49.5	49.8	49.6	35.7	48.1	41.9	3.82	4.38	4.10	3.86	3.99	3.76	4.70	4.66	4.68	0.132	0.128	0.130
Compost	56.8	41.3	49.0	31.4	32.2	31.8	2.78	4.18	3.48	2.86	2.58	2.72	3.33	4.31	3.82	0.198	0.230	0.214
NPK	45.6	55.0	50.3	28.6	37.8	33.2	4.22	4.15	4.18	3.63	3.94	3.78	5.08	5.26	5.17	0.162	0.198	0.180
Mean	51.3	49.4	50.3	30.9	36.5	33.7	3.61	4.16	3.89	3.27	3.32	3.29	4.35	4.62	4.48	0.159	0.186	0.172
Control		43.7			24.1			3.60			2.27			3.26			0.123	
$LSD_{0.01}$																		
I factor		n.s.			n.s.			n.s.			1.58			2.12			n.s.	
II factor		n.s.			n.s.			n.s.			n.s.			n.s.			n.s.	
IxII		n.s.			n.s.			n.s.			n.s.			n.s.			n.s.	

1*dose I;
2*dose II

Table 3

Content of microelements as well as Pb and Cd in grains of spring triticale ($mg \cdot kg^{-1}$d.m.)

Specification	Mn			Zn			Cu			Ni			Pb			Cd		
	1*	2*	$\overline{x}$	1*	2*	$\overline{x}$	1*	2*	$\overline{x}$	1*	2*	$\overline{x}$	1*	2*	$\overline{x}$	1*	2*	$\overline{x}$
Manure	46.38	53.67	50.03	32.4	37.9	35.2	4.69	5.16	4.93	0.194	0.243	0.219	0.46	0.42	0.44	0.102	0.100	0.101
Sewage sludge	53.67	67.94	60.81	34.6	41.1	37.9	5.95	5.34	5.65	0.244	0.236	0.240	0.55	0.41	0.48	0.104	0.092	0.098
Compost	55.89	73.30	64.60	38.6	37.8	38.2	5.09	6.37	5.73	0.155	0.258	0.207	0.35	0.56	0.46	0.107	0,122	0.115
NPK	76.11	75.74	75.93	35.2	32.4	33.8	6.40	5.12	5.76	0.227	0.258	0.256	0.51	0.52	0.52	0.112	0.107	0.109
Mean	58.01	67.66	62.84	35.2	37.3	36.3	5.53	5.50	5.52	0.218	0.256	0.231	0.47	0.48	0.48	0.106	0.105	0.106
Control	42.24			28.7			4.99			0.114			0.47			0.087		
$LSD_{0.01}$																		
I factor	n.s.			n.s.			n.s.			n.s.			n.s.			n.s.		
II factor	n.s.			n.s.			n.s.			n.s.			n.s.			n.s.		
IxII	n.s.			n.s.			n.s.			n.s.			n.s.			n.s.		

1*dose I;
2*dose II

Table 4

Average bioaccumulation indexes of microelements as well as Pb and Cd in seeds of spring rape and in grains of spring triticale

Specification	Mn		Zn		Cu		Ni		Pb		Cd	
	rape	triticale	rape	triticale	rape	triticale	rape	triticale	rape	triticale	rape	triticale
Manure	0.600	0.573	0.252	0.318	0.150	0.198	0.268	0.020	0.178	0.018	0.157	0.096
Sewage sludge	0.127	0.155	0.104	0.095	0.028	0.039	0.114	0.007	0.080	0.008	0.032	0.025
Compost	0.108	0.143	0.099	0.119	0.033	0.055	0.124	0.010	0.055	0.007	0.044	0.024
Mean	0.278	0.290	0.152	0.178	0.070	0.097	0.169	0.012	0.104	0.011	0.078	0.048

influence the content of microelements or Pd and Cd in grain of spring triticale (Table 3). The soil used for the experiment was acid in reaction (pH_{KCl} 5,13), which raised the availability of heavy metals in the soil (KABATA-PENDIAS, PENDIAS 1999). In the author's own research, despite the double dose of the fertilizers, the content of microelements in spring rape seeds and spring triticale grain increased marginally and did not deviate from the values which are given for these species in the literature (KABATA-PENDIAS et al. 1993). According to BARAN et al. (1996), FLIS-BUJAK et al. (1996), BARAN et al. (1998), Gorlach and Gambuś (1999) organic substance added to soil caused increasing sorption capacity of soil. As a result, the amounts of available forms of these elements were enlarged. The impact of organic substance raised complexing properties of soil and caused formation of metal-organic bonds, which reduced assimilation of the microelements.

The analysis of the average bioaccumulation factors of microelements as well as Pb and Cd in rape seeds and triticale grain (Table 4) showed that only the bioaccumulation index for manganese and zinc was on an average level, likewise the indexes for nickel and lead in spring rape seeds. The remaining indexes were on a low level. Similar dependences were given by FILIPEK-MAZUR et al. 2002, MICHAŁOWSKI and Gołaś 2001.

CONCLUSIONS

1. The best effects in respect to the yield of spring rape seeds of and spring triticale grain were received from the object with the double dose of sewage sludge.

2. Fertilization with sewage sludge and sewage sludge compost increased the content of microelements as well as Pb and Cd in seeds and grains of the test plants. The content of the heavy metals did not exceed permissible values for industrial plants.

3. The computed bioaccumulation indexes showed that spring rape and spring triticale accumulated manganese and zinc to an average degree.

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