J. Elem. s. 431–440 DOI: 10.5601/jelem.2012.17.3.06

EFFECT OF THE GWDA COMPOST AND PRP SOL FERTILISATION ON THE TOTAL CONTENT OF NICKEL, MANGANESE AND LEAD AND THEIR SOLUBLE FORMS IN SOIL

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Abstract

A field experiment was carried out at the Agricultural Experimental Station in Lipnik near Stargard Szczeciński in 2008-2009. It was set up on soil classified as soil quality class IVa and good rye complex (5). In the study, the GWDA compost produced at the Municipal Sewage Treatment Plant in Stargard Szczeciński was used. This compost was characterised by neutral reaction (pH_{H_2O} 7.15). The total content of heavy metals, which limits its possible use as fertiliser, did not exceed the standards given in the Regulation of the Minister of Agriculture and Rural Development (Official Journal of Law No. 119, item 765 of 2008). Compost doses were determined based on the total nitrogen content. It was assumed that 100 kg N ha^{-1} was added to soil with the 1st dose, 200 kg N with the 2nd dose, and 300 kg N with the 3rd dose. The experiment was carried out in two series: with and without addition of the active substance PRP SOL. In autumn 2007, respective compost doses were introduced into soil on established plots according to the experimental design. The active substance PRP SOL was applied at a 150 kg ha^{-1} dose before sowing or seeding test plants. The whole experimental area was fertilised with multicomponent fertiliser Polifoska 6 in a 200 kg ha^{-1} dose in 2008 and 2009. Due to a small content of nitrogen in Polifoska 6 (6% N), top-dressing nitrogen fertilisation was applied in the form of urea (46% N) at a 100 kg N ha^{-1} dose. The test plants were winter wheat cultivar Korweta in 2008 and spring rape cultivar Bosman in 2009.

The results indicate that the total average manganese, lead and nickel content in soil increased by 15.1%, 5.0% and 3.0%, respectively, under organic fertilisation with and without the active substance compared to the initial content. In the course of time, manganese, nickel and lead content decreased to a different extent. This resulted from these microelements being taken up by the cultivated crop or their leaching outside the rhizo-

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sphere. With respect to the soil abundance, it can be stated that it is characterised by medium abundance in manganese soluble forms.

Key words: municipal sewage sludge, compost, active substance PRP SOL, soil, nickel, manganese, lead.

WPŁYW NAWOŻENIA KOMPOSTEM GWDA I PRP SOL NA ZAWARTOŚĆ OGÓLNĄ ORAZ FORM ROZPUSZCZALNYCH NIKLU, MANGANU I OŁOWIU W GLEBIE

Abstrakt

Doświadczenie polowe przeprowadzono w Rolniczej Stacji Doświadczalnej w Lipniku k. Stargardu Szczecińskiego w latach 2008-2009, na glebie zaliczanej do klasy bonitacyjnej IV_a, kompleksu przydatności rolniczej żytniego dobrego (5). Do badań użyto kompostu GWDA wyprodukowanego w Komunalnej Oczyszczalni Ścieków w Stargardzie Szczecińskim. Kompost ten miał odczyn obojętny (pH_{H_2O} 7,15). Zawartość ogólna metali ciężkich, która limituje możliwość wykorzystania go do celów nawozowych, nie przekraczała norm podanych w Rozporządzeniu Ministra Rolnictwa i Rozwoju Wsi (Dz.U. 08.119.765). Dawki kompostu ustalono na podstawie zawartości azotu ogólnego. Przyjęto, że z I dawką wniesiono 100 kg N, z II – 200 kg N, a z III – 300 kg N ha^{-1}. Doświadczenie prowadzono w dwóch seriach: bez dodatku i z dodatkiem substancji czynnej PRP Sol. Jesienią 2007 r. zgodnie ze schematem badań na wyznaczonych poletkach wprowadzono do gleby odpowiednie dawki kompostu. Substancję czynną PRP Sol w dawce 150 kg ha^{-1} stosowano przed siewem lub sadzeniem roślin testowych.

Całą powierzchnię doświadczenia w 2008 i 2009 r. nawożono Polifoską 6 w dawce 200 kg ha^{-1}. Ze względu na niewielką zawartość azotu w Polifosce 6 (6% N), zastosowano pogłównie nawożenie tym pierwiastkiem w formie mocznika (46% N) w dawce 100 kg N ha^{-1}. Roślinami testowymi były w 2008 r. pszenica ozima odmiany Korweta, a 2009 rzepak jary odmiany Bosman.

Wykazano, że średnia zawartość form ogólnych manganu, ołowiu i niklu w glebie pod wpływem nawożenia organicznego bez dodatku i z dodatkiem substancji czynnej PRP Sol zwiększyła się odpowiednio o 15,1%, 5,0% i 3,0% w porównaniu z zawartością wyjściową. W miarę upływu czasu zawartość manganu, niklu i ołowiu zmniejszała się w różnym stopniu. Było to wynikiem pobrania tych mikroskładników przez uprawiane rośliny, a także wypłukania ich poza strefę korzeniową roślin. Oceniając zasobność analizowanej gleby można stwierdzić, że zasobność formy rozpuszczalnej manganu jest średnia.

Słowa kluczowe: komunalny osad ściekowy, kompost, substancja PRP Sol, gleba, nikiel, mangan, ołów.

INTRODUCTION

The livestock populations in Poland have been diminished drastically over the last years. Consequently, the production of natural fertilisers has declined as well. At the same time, prices of mineral fertilisers have risen very high, while prices paid for manufactured farm produce have increased only a little. This has reduced amounts of organic matter introduced to soils and the supply of nutrients for plants. New and less expensive sources

of organic matter and nutrients for plants have been searched for. Different organic and mixed organic and mineral waste and substances have been tested in order to determine their effect on soil fertility indices, crop yield volume and quality as well as the environmental impact.

In the present experiment, attention has been paid to the use of compost produced from municipal sewage sludge originating from the Municipal Sewage Treatment Plant in Stargard Szczeciński. Many authors, including Bowszys et al. (2009), Jakubus (2006), Jasiewicz et al. (2007), Grzywnowicz (2007), Krzywy et al. (2007), Wieczorek and Gambuś (2006), Wołoszyk et al. (2009), suggest that composts produced with addition of sewage sludge may be a rich source of organic matter for soils and nutrients for plants. However, such composts may contain excessive concentrations of heavy metals, which have a toxic effect on plants, animals and humans. Therefore, municipal sewage sludge, prior to its introduction into soil, should contain permissible amounts of heavy metals specified in the *Regulation of the Minister of Agriculture and Rural Development* (Official Journal Of Law No 119, item 765 of 2008).

Trials conducted in France have demonstrated that PRP SOL mineral solution pellet contains 30% CaO, 8% MgO, 3.5% Na and 3-5% premixes, together with which 48 microelements are introduced into soil (e.g. manganese, lead, iron, boron and molybdenum). The content of PRP SOL components contributes to the improvement of soil physical properties, inducing the conversion of hardly assimilable forms of phosphorus, potassium and magnesium into compounds which can be available to plants; it also enhances soil enzymatic activity and enriches it with microelements necessary for the development of plants (Krzywy-gawrońska 2009).

Nickel, manganese and lead belong to chemical elements whose quantities in sewage sludge differ greatly depending on its origin (Kalembasa et al. 2008). On the other hand, large quantities of organic matter found in this waste and soil liming eliminate the toxicity of the above chemical elements after their application into soil (Bowszys et. al. 2005, Schufer, Seifert 2006). Some chemical elements, including manganese, lead and nickel, are essential in precisely determined doses for the normal growth and development of plants. Excessive quantities of these chemical elements in fertilisers and then in soil lead to their excessive uptake by plants, and decrease crop yields and yield quality.

The present study aimed at determination of the effect of fertilisation with increasing doses of organic fertiliser with and without addition of the active substance PRP SOL on the total content of nickel, manganese and lead and their forms soluble in 1 mol dm^{-3} HCl in soil during a two-year study period.

MATERIAL AND METHODS

A field experiment was set up and carried out at the Agricultural Experimental Station in Lipnik. It was established on brown, incomplete soil developed from light loamy silty sand with a medium-deep underlying layer of light loam. The soil belongs to soil quality class IVa and good rye complex. Fields of the Agricultural Experimental Station in Lipnik lie on brown, acid, complete (soil quality class V) and incomplete (soil quality classes IVa and IVb) soils. The examinations of the topmost soil (0-25 cm) show that its reaction was close to neutral (pH_{KCl} 6.65). The abundance of assimilable phosphorus forms in soil was high (78.2 mg kg^{-1}d.m.), whereas that of potassium and magnesium (113.9 and 38.6 mg kg^{-1}d.m., respectively) was medium (Table 1).

Table 1

Some iindices of soil fertility in the 0-25 cm layer of the experimental field

Total content (g kg^{-1} d.m. soil)						C_{org} (g kg^{-1})	Assimilable forms (mg kg^{-1} d.m. soil)			
N	P	K	Ca	Mg	S		P	K	Mg	$S\text{-}SO_4$
0.64	1.10	2.41	2.18	0.60	0.12	7.55	78.2	113.9	38.6	9.26

The GDWA compost from municipal sewage sludge used in our examinations was produced at the Municipal Sewage Treatment Plant in Stargard Szczeciński. This compost was characterised by neutral reaction (pH_{H_2O} 7.15) and contained more nitrogen (28.6 g kg^{-1}d.m.) and phosphorus (12.0 g kg^{-1}d.m.) when compared to potassium (6.70 g kg^{-1}d.m.). The total content of heavy metals, which restrains its use for fertilisation purposes, did not exceed standards given in the Regulation of the Minister of Agriculture and Rural Development (*Regulation*... 2008) – see Table 2.

In our field experiment, two factors were taken into account: factor A – increasing doses of compost, and factor B – increasing doses of compost + PRP SOL. The control consisted of plots without fertilisation (control I) and with addition of the active substances PRP SOL (control II). In the experi-

Table 2

Chemical composition of the GWDA compost used in the field experiment at the Agricultural Experimental Station in Lipnik

pH_{H_2O}	N	C	P	K	Mg	Ca	Hg	Mn	Ni	Pb	Cr
	content (g kg^{-1} d. m.)						content (g kg^{-1}d.m.)				
7.15	28.6	246	12.0	6.70	2.22	4.80	0.025	170	3.55	45.3	14.7

mental design, three doses of compost produced from municipal sewage sludge were applied, so as to supply 100, 200 and 300 kg N ha^{-1}. The tested plants were winter wheat cultivar Korweta in 2008 and spring rape cultivar Bosman in 2009.

In autumn 2007, respective doses of compost produced by the GWDA method were introduced into soil on established plots according to the experimental design. In March 2008 and 2009, the whole experimental area was fertilised with the complex fertiliser Polifoska 6 at a 200 kg ha^{-1} dose. Due to the low content of nitrogen in Polifoska 6 (6% N), top-dressing nitrogen fertilisation was applied in the form of urea (46% N) at a dose of 100 kg N ha^{-1}. The total dose of nitrogen under spring rape and winter wheat was divided into two equal parts, applied in two time periods (in spring – 50% of the dose before sowing spring rape and 50% before inter-row closing, while for winter wheat 50% at the beginning of the vegetative growth and 50% at the stem elongation stage). PRP SOL was introduced into soil at a 150 kg N ha^{-1} dose before sowing the test plants. In autumn 2008 and in 2009, the same measures were carried out in the field experiment.

Total manganese, nickel and lead were determined by the method of atomic absorption spectrometry using a Perkin Elmer AAS 300 spectrophotometer. Stock solution was obtained following wet mineralisation of soil material according to the Polish standards PN–ISO 11466 and PN-ISO 11047. The content of soluble manganese, nickel and lead forms was determined with the method commonly used at Chemical and Agricultural Stations. These determinations were made in 1 mol dm^{-3} HCl under a fume cupboard with the AAS method for fertilisation consulting purposes. The results were processed with the analysis of variance using a Statistica 8.0 computer software package. Tukey's test at the significance level $\alpha \leq 0.05$ was used to check significance of differences.

RESULTS AND DISCUSSION

The results obtained in this study are presented in Tables 3, 4 and 5. Mean total manganese, nickel and lead contents in soil following the application of increasing doses of compost without and with addition of active substance PRP SOL are compared in Table 3. In control objects (control I without compost and control II with PRP SOL), total manganese, nickel and lead contents in soil decreased when compared to the initial data (Table 3). This phenomenon is induced by uptake of the examined microelements by test plants during the experiment.

The total content of manganese, nickel and lead and their 1 mol dm^{-3} HCl soluble forms in soil was higher in 2008 than in 2009, which was due to partial leaching of these chemical elements deep into the soil profile and

Table 3

Effect of increasing doses of compost without and with addition of PRP SOL on total manganese, lead and nickel contents in soil; data are given (mg kg^{-1} d.m.)

Fertilisation treatments	Years	Mn	Pb	Ni
		(mg kg^{-1} d.m.)		
Initial content	2008	321	15.2	6.45
Control	2008	315	15.4	6.55
	2009	310	14.9	6.50
Mean		312	15.1	6.52
Control with PRP SOL	2008	322	15.2	6.30
	2009	318	15.0	6.40
Mean		320	15.1	6.35
1st dose of compost without PRP SOL	2008	368	15.7	6.62
	2009	357	15.5	6.50
2nd dose of compost without PRP SOL	2008	375	16.1	6.67
	2009	362	15.9	6.58
3rd dose of compost without PRP SOL	2008	382	16.3	6.71
	2009	370	16.1	6.66
Mean for doses without PRP SOL		369	15.9	6.62
1st dose of compost with PRP SOL	2008	376	15.9	6.68
	2009	363	15.7	6.55
2nd dose of compost with PRP SOL	2008	382	16.3	6.72
	2009	368	16.1	6.62
3rd dose of compost with PRP SOL	2008	394	16.5	6.83
	2009	381	16.3	6.72
Mean for doses with PRP SOL		387	16.1	6.68
$LSD_{0.05}$		6.436	0.176	0.102
A - compost doses		3.251	0.089	ns
B - PRP SOL effect AxB		ns	ns	ns

their uptake by the test plants as well as the reaction of the soil. During the experiment, the pH_{KCl} value increased as affected by organic fertilisation with and without PRP SOL addition. Higher soil reaction induces a decrease occurred in the total content of manganese, nickel and other heavy metals and the content of their soluble forms in 1 mol dm^{-3} HCl. Such a phenomenon occurred in the field experiment. ANDRZEJEWSKI and DERĘGOWSKA (1986) report a decrease in the content of heavy metals in soil fertilised with raw or composted sewage sludge. On the other hand, MERCIK and KUBIAK (1995) state that formation of chelate complexes with trace elements, including heavy metals, induces soil detoxication, which may decrease their availability for plants (Tables 3 and 4). The increasing doses of organic fertiliser (compost) as a rule caused an increase in the total content of cad-

Table 4

Effect of increasing doses of compost with and without addition of PRP SOL on the content of 1 mol dm^{-3} HCl-soluble manganese, lead and nickel forms in soil; data are given (mg kg^{-1} d.m.)

Fertilisation treatments	Years	Mn	Pb	Ni
		(mg kg^{-1} d.m.)		
Initial content	2008	246	9.20	3.35
Control	2008	277	10.1	3.58
	2009	265	10.0	3.51
Mean		271	10.0	3.54
Control with PRP SOL	2008	282	10.6	3.53
	2009	270	10.5	3.49
Mean		276	10.5	3.51
1st dose of compost without PRP SOL	2008	291	11.2	3.72
	2009	280	10.9	3.65
2nd dose of compost without PRP SOL	2008	302	11.5	3.78
	2009	295	11.0	3.70
3rd dose of compost without PRP SOL	2008	310	11.7	3.84
	2009	320	11.1	3.75
Mean for doses without PRP SOL		299.7	11.2	3.74
1st dose of compost with PRP SOL	2008	302	11.3	3.82
	2009	290	10.9	3.76
2nd dose of compost with PRP SOL	2008	319	11.6	3.88
	2009	310	11.1	3.82
3rd dose of compost with PRP SOL	2008	338	11.8	3.94
	2009	329	11.3	3.83
Mean for doses with PRP SOL		314.7	11.3	3.84
$LSD_{0.05}$		12.5	0.316	0.0385
A - compost doses		6.18	0.160	0.018
B - PRP SOL effect AxB		ns	ns	0.050

mium, copper and zinc and their soluble forms in soil. This is related to the introduction of compost with sewage sludge – which was the main source of the analysed chemical elements – into soil. PRP SOL in the control treatment and in treatments with increasing compost doses contributed to a higher total content of manganese, nickel and lead and their soluble forms in soil.

The highest manganese, nickel and lead concentrations were characteristic of the soil fertilised with a triple dose of compost with PRP SOL addition (Table 3). The largest mean increase in the total manganese, nickel and lead content, by 24.2%, 8.60% and 3.91% respectively versus the control, during this two-year experiment (2008-2009) was found in the treatments fertilised with a triple dose of compost with PRP SOL (Table 3). On the

other hand, the smallest mean increase in manganese, lead and nickel (by 16.2%, 3.31% and 0.61%, respectively) was found in the treatments fertilised with a single compost dose (Table 3).

Differences in the effect of the increasing compost doses significantly affected the accumulation of manganese, lead and nickel contents in soil. Significant differences in the manganese and lead content were found in the treatments fertilised with increasing doses of compost and PRP SOL, whereas differences in the nickel content under the same fertilisation were non-significant. The results show that fertilisation may be a source of manganese, nickel and lead in soil for cultivated plants.

The concentration of chemical elements analysed in soil was within natural content limits and considerably lower when compared to the total content of examined chemical elements given by the State Research Institute of Soil Science and Plant Cultivation (1995).

Most of the soluble manganese, lead and nickel forms was contained in the soil fertilised with a triple dose of compost with a PRP SOL addition. The biggest decrease in the manganese content between 2008 and 2009 (by 3.97%) was found in the treatment fertilised with a single dose of compost with PRP SOL; in the lead (3.54%) and nickel content (1.57%) – in the treatment fertilised with a triple dose of compost.

The biggest mean increase in the content of manganese, lead and nickel soluble forms (by 16.1%, 13.0% and 8.47%, respectively) was obtained in the treatments fertilised with increasing doses of compost with PRP SOL addition when compared to the control (Table 4).

Differences in the effect of the fertilisation variants on the content of soluble manganese, nickel and lead forms in soil were significant. Introduction of increasing doses of compost with and without addition of PRP SOL had a significant effect of the content of soluble forms of chemical elements analysed in soil. On the other hand, CZEKAŁA (2004) shows that sewage sludge or composts made from sewage sludge or composted sewage sludge applied in different doses did not significantly affect the content of soluble manganese in soil. When evaluating the abundance of the examined soil in 1 mol dm^{-3} HCl soluble forms, it can be stated that the manganese content was moderate.

The average percentage of manganese, nickel and lead forms soluble in 1 mol dm^{-3} HCl in their total content in the soil differed slightly between the fertilisation treatments (Table 5). Out of the analysed chemical elements, the highest percentage of their soluble forms in the total content was found for manganese (86.0%) in the treatment fertilised with a triple dose of compost with PRP SOL, while the lowest one was determined for nickel (56.1%) in the treatments fertilised with a single dose of compost without addition of PRP SOL. Based on the average percentage of soluble forms of these chemical elements in their total contents after two years, heavy metals can be arranged in the following decreasing value order: Mn > Pb > Ni. Similar results were obtained by IŻEWSKA et. al. (2009).

Table 5

Mean percentage of 1 mol dm^{-3} HCl-soluble forms of microelements in their total soil content after the harvest of the test plants according to applied fertilisation (%)

Fertilisation objects	Mn	Pb	Ni
1st dose of compost without PRP SOL	78.7	70.8	56.1
2nd dose of compost without PRP SOL	81.0	70.3	56.4
3rd dose of compost without PRP SOL	83.8	70.4	56.8
Mean	81.2	70.5	56.4
1st dose of compost with PRP SOL	81.1	70.2	57.3
2nd dose of compost with PRP SOL	83.8	70.1	57.7
3rd dose of compost with PRP SOL	86.0	70.4	57.3
Mean	83.6	70.2	57.4

CONCLUSIONS

1. The biggest average increase in the total manganese, lead and nickel content during this two-year study was found in the treatments fertilised with a triple dose of compost with PRP SOL when compared to the control.

2. The direct effect of increasing compost doses on the total content of manganese, lead and nickel and their 1 mol dm^{-3} HCl soluble forms in soil was higher than the residual effect of fertilisation.

3. The biggest average increase in the content of soluble manganese, lead and nickel forms was obtained in the treatments fertilised with increasing doses of compost with PRP SOL when compared to the control.

4. The applied organic fertilisation with and without addition of PRP SOL induced an increase in the total content of manganese, lead and nickel and their soluble forms in the first year of our study. Organic fertilisation did not induce excessive concentrations of the examined chemical elements, irrespective of the size of a compost dose.

5. The highest percentage of soluble forms in total content was found for manganese (86.0%) in the treatment fertilised with a triple dose of compost with PRP SOL addition, while the lowest one was observed for nickel (56.1%) in the treatment fertilised with a single dose of compost without addition of PRP SOL.

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