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CONTENT AND REMOVAL OF Cu AND Zn WITH HARVESTED CROPS GROWN ON SOIL FERTILIZED WITH COMPOSTED MUNICIPAL SEWAGE SLUDGE

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Abstract

The purpose of the study has been to determine the direct and residual effect of farmyard manure and composts made from sewage sludge on the content and uptake of copper and zinc by crops growing in a four-field crop rotation system. In 2004-2007, a field experiment was established on proper grey-brown podzolic soil, originating from light boulder clay, rich in P, moderately abundant in K and low in Mg, whose reaction was pH = 5.04. The experiment involved a four-field crop rotation cycle with the following crops: potato, spring barley, winter oilseed rape and winter wheat. The design of the experiment, set up according to the random block method, consisted of 8 object (2 x 4): 1) FYM, 2) composted sewage sludge, 3) compost (sewage sludge + straw), 4) dried and granulated sewage sludge. The composts and farmyard manure were applied once in the rotation system (under potato) at a rate of 10 t d.m. ha^{-1} or twice, each time 5 t d.m. ha^{-1} (under potato and under winter oilseed rape). In the objects fertilized with organic fertilizers and manure, nitrogen was balanced to 150 $kg \cdot ha^{-1}$ (under potato) and to 120 $kg \cdot ha^{-1}$ (under oilseed rape) depending on their total content of nitrogen. Spring barley and winter wheat received only mineral fertilizers. Before the experiment was set up, samples of soil, manure and composts had been collected for determination of Cu and Zn in 1 mol HCl dm^{-3} by atomic absorption spectrophotometry.

The content of zinc and copper in the crops was modified by the form of sewage sludge and sewage sludge composts to a greater extent than by the way these fertilizers were applied in the crop rotation system. Soil fertilization with dried and granulated sewage sludge or composted sludge increased the content of copper and its removal with harvested potato and winter rape, but the analogous values were higher when the cereals were grown on FYM fertilized soil. The strongest influence on the content and removal of zinc

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was exerted by soil fertilization with dried and granulated sewage sludge. The index of copper and zinc uptake was to a greater degree conditioned by the species of a crop than by the type of fertilizers or their application method. Municipal sewage sludge and sewage sludge composts can be used as a substitute of manure in farms which do not keep farm animals.

Key words: copper, zinc, crops, sewage sludge, composted municipal sewage sludge.

ZAWARTOŚĆ I WYNOS Cu I Zn Z PLONEM ROŚLIN UPRAWIANYCH NA GLEBIE UŻYŹNIANEJ KOMPOSTAMI Z KOMUNALNYCH OSADÓW ŚCIEKOWYCH

Abstrakt

Celem badań było określenie bezpośredniego i następczego wpływu obornika oraz kompostów z osadów ściekowych na zawartość oraz pobranie miedzi i cynku przez rośliny uprawiane w czteropolowym zmianowaniu. W latach 2004-2007 na glebie płowej typowej, wytworzonej z gliny lekkiej zwałowej, o wysokiej zawartości przyswajalnego P, średniej K, niskiej Mg i pH=5,04, przeprowadzono doświadczenie z czteropolowym płodozmianem: ziemniak, jęczmień jary, rzepak ozimy, pszenica ozima. Schemat doświadczenia założonego metodą losowanych bloków obejmował 8 obiektów (2x4): 1) obornik, 2) osad ściekowy kompostowany, 3) kompost (osad ściekowy+słoma), 4) osad ściekowy suszony i granulowany. Komposty i obornik zastosowano 1 raz w zmianowaniu (pod ziemniak) w dawce 10 t s.m.·ha^{-1} lub 2 razy po 5 t s.m.·ha^{-1} (pod ziemniak i rzepak ozimy). Na obiektach z nawozami organicznymi i obornikiem azot został zbilansowany do 150 kg·ha^{-1} (pod ziemniak) i do 120 kg·ha^{-1} (pod rzepak), w zależności od zawartości w nich N-ogółem. Pod jęczmień jary i pszenicę ozimą stosowano tylko nawożenie mineralne. Przed założeniem doświadczenia pobrano do analizy próbki gleby, obornika i kompostów, i oznaczono w nich zawartość Cu, Zn w 1 mol HCl·dm^{-3} metodą ASA.

Zawartość cynku i miedzi w roślinach uprawnych była w większym stopniu modyfikowana formą osadów ściekowych i kompostów produkowanych z ich udziałem, niż sposobem stosowania w zmianowaniu. Użyźnianie gleby osadem ściekowym suszonym i granulowanym lub tylko kompostowanym zwiększało zawartość i wynos miedzi z plonem ziemniaka i rzepaku ozimego, a wartości te były wyższe, gdy rośliny zbożowe uprawiano na obiektach nawożonych obornikiem. Największy wpływ na zawartość i wynos cynku z plonem roślin miało nawożenie gleby osadem ściekowym suszonym i granulowanym. Indeks zbioru miedzi i cynku w większym stopniu zależał od gatunku rośliny niż od rodzaju i sposobu użyźniania gleby. Komunalne osady ściekowe, zwłaszcza komposty z ich udziałem, mogą być stosowane jako substytut obornika w gospodarstwach bezinwentarzowych.

Słowa kluczowe: miedź, cynk, rośliny uprawne, osady ściekowe, kompostowane komunalne osady ściekowe.

INTRODUCTION

The current conditions in agriculture stimulate the importance of micronutrients, which can be easily depleted due to the dramatically lower FYM fertilization, especially at farms which do not keep farm animals. A possible alternative to farmyard manure is the application of sewage sludge, which consists mostly of organic substance, which in turn lends it-

self readily to composting (KLASA et al. 2007, MAZUR 1996, SIUTA 1996). Good quality compost can be applied in crop production at rates and frequencies analogous to those of FYM fertilization (ANDRUSZCZAK et al. 1988, HRYŃCZUK et al. 2000, KACZOR et al. 2006).

The objective of this study has been to determine the direct and residual effect of FYM and sewage sludge composts on the content of copper and zinc as well as their uptake by crops grown in a four-field crop rotation system.

MATERIAL AND METHODS

A field experiment was conducted at the Experimental Station in Bałcyny near Ostróda from 2004 to 2007. The experiment was established on proper grey-brown podzolic soil, originating from light boulder clay, which was highly abundant in available P, moderately abundant in K and poor in Mg. The soil reaction was pH 5.04 in 1 mol KCl dm^{-3}. The experimental crops were grown in the following four-field crop rotation system: potato, cv. Jssia, spring barley, cv. Justyna, winter oilseed rape, cv. Californium and winter wheat, cv. Zyta. The experiment was set up according to a random block design and comprised eight objects (2 x 4): 1) farmyard manure (FYM), 2) composted sewage sludge, 3) compost (sewage sludge + straw at a ratio of 1:0.5), 4) dried and granulated sewage sludge. The sewage sludge for the tests came from two wastewater treatment plants: one in Ostróda (object 2) and the other one in Iława (objects 3 and 4). The composts and FYM were applied once in the whole crop rotation system (under potato) at a rate of 10 t d.m. ha^{-1} or twice (under potato and winter rape) at a rate of 5 t d.m. ha^{-1} each time. In the objects fertilized with organic fertilizers or manure, nitrogen was balanced to 150 kg·ha^{-1} (under potato in 2004) and to 120 kg·ha^{-1} (under winter oilseed rape in 2005), depending on the total content of nitrogen. Spring barley (N– 90, P– 26 and K– 100 kg·ha^{-1}) as well as winter wheat (N– 120, P– 26 and K 100 kg·ha^{-1}) received only mineral fertilization. The concentration of micronutrients in the composts was presented in another paper (BOWSZYS et al. 2009).

Before the experiment was established, samples of soil, manure and composts had been taken to determine the content of Cu and Zn in 1 mol HCl dm^{-3} using atomic absorption spectrometry with an aid of an AA-6800 Shimadzu device (Table 1).

The plant material, sampled during the technological maturity phase, was first mineralized in a mixture of nitrogen (V) and chloric (VII) acids and then assayed for the content of Cu and Zn. The determination of the elements was conducted on an AA-Schimadzu apparatus by atomic absorption spectrophotometry.

The results (from replications) underwent analysis of variance, testing the significance of differences at p=0.05.

RESULTS AND DISCUSSION

Some authors claim that the uptake of copper and zinc by plants from sewage sludge as well as the distribution and accumulation of these elements in particular plant organs can be conditioned by certain differences between botanic families and species of plants (BORKOWSKA et al. 1996, BAVACQUA et al. 1993, MISHRA et al. 1995). The response of the four crops to the organic fertilizers tested in this experiment was to a greater extent dependent on the species and organs of plants as well as on the type of a fertilizer applied than on the actual fertilization method (Tables 2, 3).

The highest content of copper (5.04 mg kg^{-1} d.m.) was found in potato tubers grown in soil fertilized with dried and granulated sewage sludge (Table 2). Potato plants cultivated on the other objects were characterised by similar levels of copper (on average 4.60 mg·kg^{-1} d.m.). By adding a second rate of sewage sludge under winter oilseed rape (the series 2 × 5 t d.m. ha^{-1}), elevated concentration of copper in rape seeds was obtained. The average increase, depending on the form of sewage sludge used, was around 7%. In turn, the content of copper in rape straw collected from all the objects was approximately the same, reaching on average 1.47 mg·kg^{-1} d.m.

No significant residual effect of the tested organic fertilizers (sewage sludge) has been found on the content of copper in the cereal plants tested. The grain of spring barley and winter wheat fertilized with FYM appeared to be richer in copper (5.52 and 3.72 mg·kg^{-1} d.m., respectively). The straw of these two cereal plants sampled from any of the objects had a similar concentration of this micronutrient, on average 1.72 and 1.20 mg·kg^{-1} d.m., respectively.

The direct influence of the bio-waste fertilizers on the content of zinc in potato tubers was significantly varied mainly due to the rate of a fertilizer applied (Table 3). In the objects which received 10 t d.m. ha^{-1} in a single dose, the concentration of zinc in potato tubers was on average 13% higher than in the objects which received two doses of fertilizers, 5 t d.m. ha^{-1} each. Moreover, MAĆKOWIAK et al. (1999) demonstrated that tubers of potato fertilized with sewage sludge composts accumulated less zinc than the ones receiving mineral fertilizers.

The way the manure and composts were introduced to soil in the crop rotation system did not play a significant role in the accumulation of zinc in oilseed rape seeds, with an average level of this element being 39.49 (the series 10 t d.m. ha^{-1}) and 40.63 mg Zn ka^{-1} d.m. (the series 2 x 5 t d.m. ha^{-1}). Fertilization of soil with dried sewage sludge or composted sludge alone

raised the content of zinc in spring barley grain by 7% and in winter wheat grain by 27%, as compared to the objects treated with FYM.

WOŁOSZYK et al. (2004) found out that the direct effect of composts consisted of increasing the content of copper and zinc in oilseed rape seeds, whereas the residual effect of these fertilizers modified the content of zinc more profoundly than that of copper in wheat grain and straw. Also HRUŃCZUK et al. (2000) noticed more Cu and Zn in grain of wheat fertilized with sewage sludge than that nourished with farmyard manure, although the differences were not statistically proven.

The removal of copper and zinc with harvested crops depended mainly on the type of a fertilizer applied (Figures 1, 2). The highest copper removal with potato (on average 61.5 $g \cdot ha^{-1}$) and oilseed rape (on average 31.6 $g \cdot ha^{-1}$) yields occurred when dried or composted sewage sludge had been applied in a single dose of 10 t d.m. ha^{-1}. The cereal crops, in contrast, took up most of copper in the objects fertilized with FYM, irrespective of the way it had been introduced to soil (single or split dose). The respective values were 56.9 and 39.6 $g \cdot ha^{-1}$. Potato as well as the cereals took up most zinc from the soil which had received 10 t d.m. ha^{-1} of dried and granulated sewage sludge, whereas oilseed rape accumulated most zinc when fertilized with an analogous dose of composted sewage sludge. Studies reported by other researchers seem to confirm that sewage sludge stimulates the uptake of copper and zinc by plants (KACZOR et al. 2006, HANEKLAUS et al. 1999).

The index of copper uptake depended on a plant species (81-82% for cereals and *ca* 64% for oilseed rape) and, to some extent, on the type of a fertilizer used (Figure 1). For spring barley and winter wheat, the index was higher when FYM had been used (*ca* 83%). The sewage sludge composts slightly depressed the contribution of grain to the total accumulation of copper. As regards winter oilseed rape, the highest Cu uptake index was obtained when composted sewage sludge (with or without straw) had been introduce to soil, especially in the series consisting of two doses of 5 t d.m. fertilizer per ha.

The grain of the two cereal plants accumulated on average from 79% (wheat) to 88% (barley) of zinc, whereas rape seed gathered about 75% of this element (Figure 2). As for the cereals, the sewage sludge composts only slightly increased the contribution of grain to retaining zinc, while for oilseed rape the highest value of the uptake index was attained when dried and granulated sewage sludge had been used.

The total removal of copper and zinc in the four-field crop rotation system is shown in Figure 3. The crops growing on the objects fertilized with FYM or dried and granulated sewage sludge took up, respectively, 161 and 164 g $Cu \cdot ha^{-1}$. Soil fertilization with composted sewage sludge (with or without straw) made it possible to keep the uptake of this micronutrient at an average level of 153-155 $g \cdot ha^{-1}$. When the composts were applied twice dur-

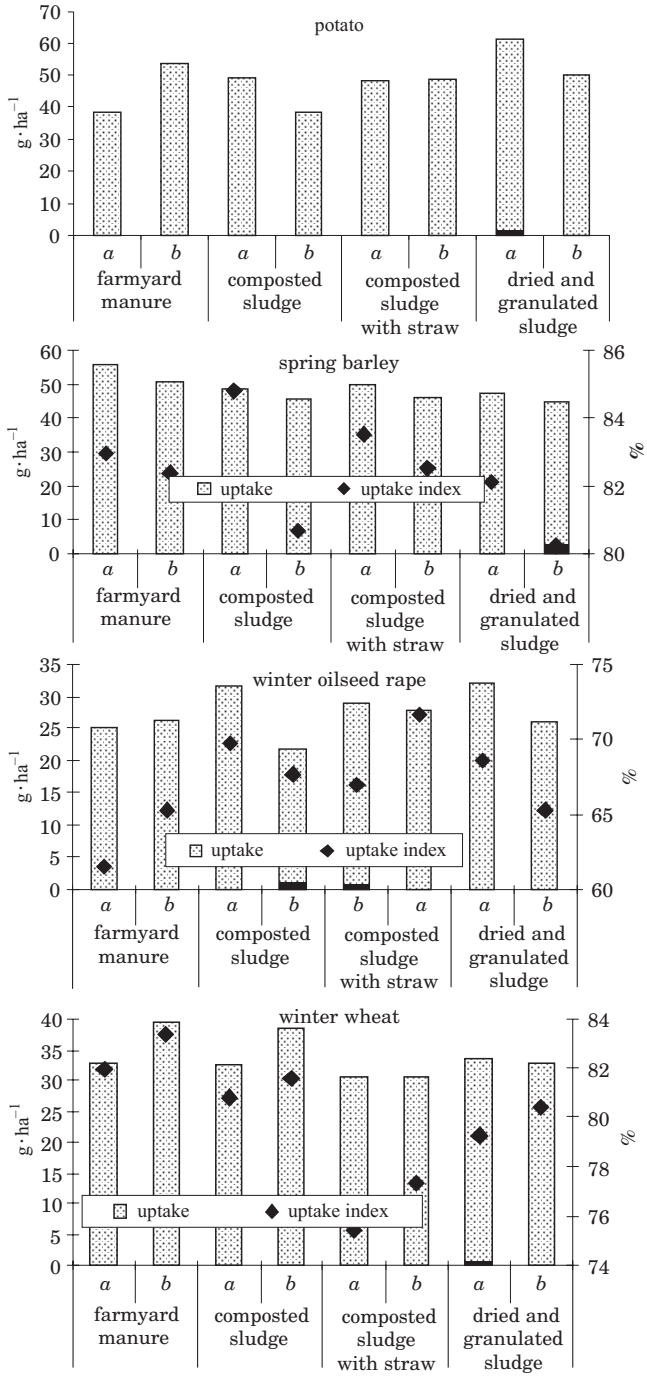

Fig. 1. Copper removal and uptake index (*a, b* – explained under Table 2)

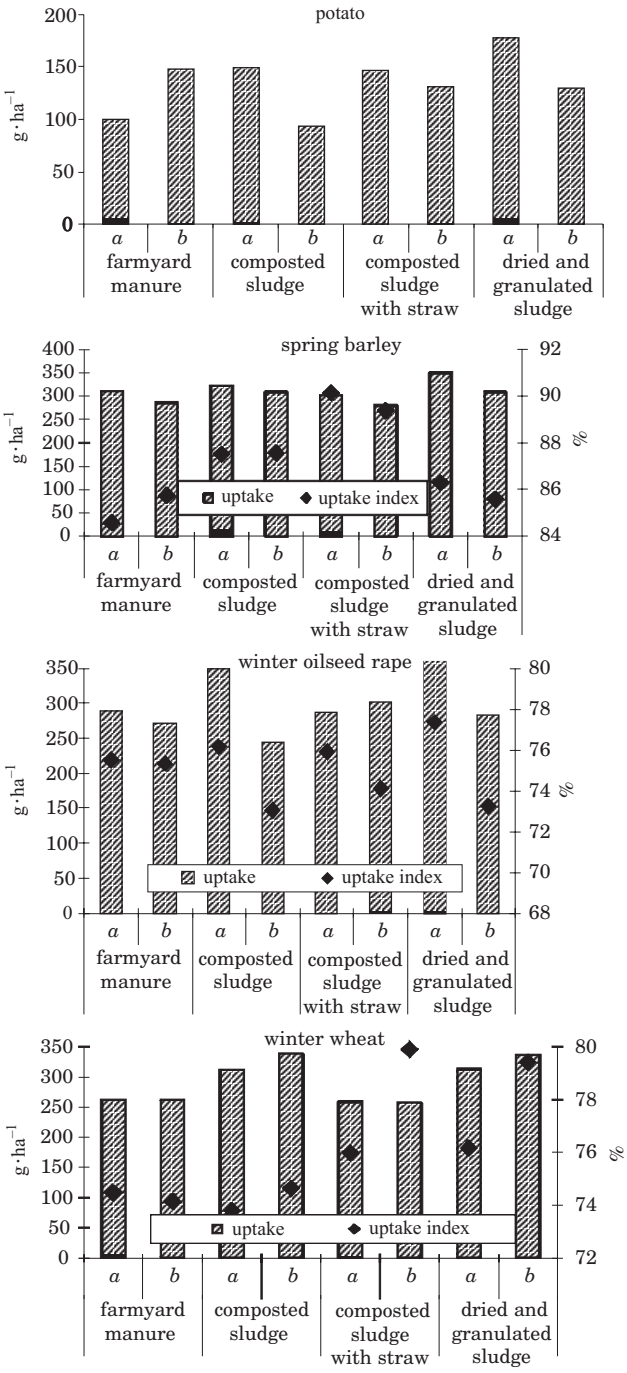

Fig. 2. Zinc removal and uptake index (*a, b* – explained under Table 2)

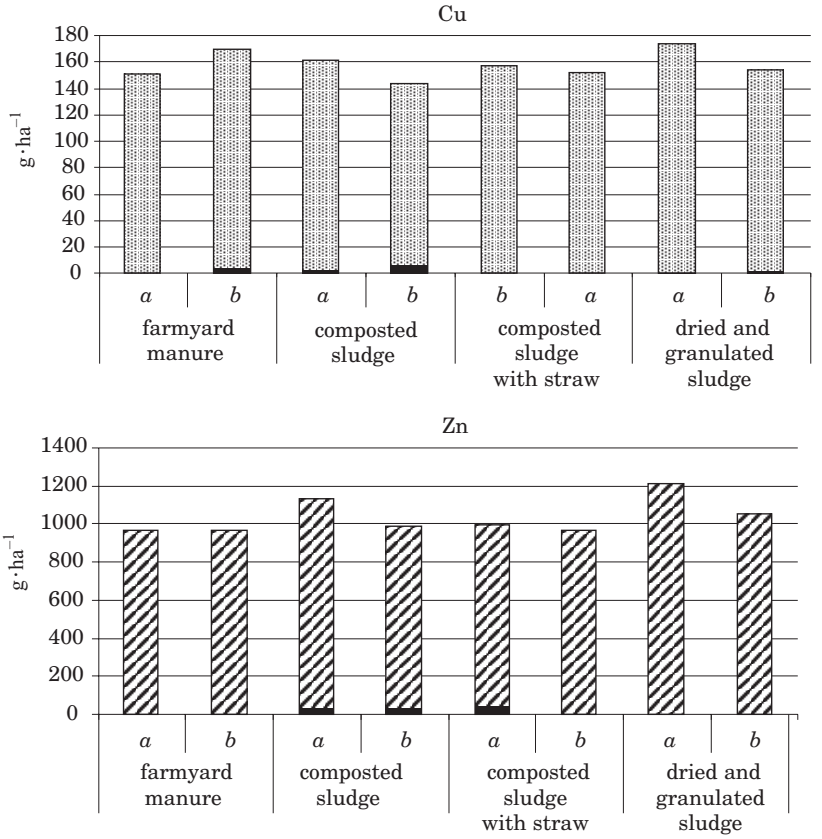

Fig. 3. Total removal of copper and zinc in the crop rotation cycle
(*a, b* – explained under Table 2)

ing the crop rotation cycle (series 2 × 5 t d.m. ha^{-1}), the uptake of Cu was raised only slightly. The highest total uptake of zinc was found following the application of sewage sludge fertilizers – dried and composted sewage sludge (respectively, 1135 and 1060 $g \cdot ha^{-1}$). Plants growing on the objects fertilized with sewage sludge composted with straw took up similar amounts of zinc as those fertilized with FYM.

CONCLUSIONS

1. The content of copper and zinc in crops was more strongly modified by the form of sewage sludge and sewage sludge composts than by the way these fertilizers were introduced to soil.

2. Fertilization of soil with dried and granulated sewage sludge or composted sewage sludge alone increased the content and uptake of copper by potato and winter oilseed rape yields; as for the cereal crops, the analogous values were higher when the plants were fertilized with farmyard manure.

3. The content of zinc and its uptake by the crops was most strongly affected by fertilization with dried and granulated sewage sludge.

4. The index of copper and zinc removal depended on the species of a plant rather than the type of a fertilizer and the application method.

5. Municipal sewage sludge, and sewage sludge composts in particular, can be used as a substitute of FYM in farms which do not keep farm animals.

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