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INFLUENCE OF LIMING AND ORGANIC FERTILIZATION ON YIELD AND CONTENT OF SELECTED HEAVY METALS IN THE BIOMASS OF ORCHARD GRASS

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Abstract: In pot experiment the influence of liming and differentiated organic fertilization on the yield of biomass of orchard grass as well as on the amount of Cu, Zn, Cd and Pb harvested with the biomass were investigated. In the scheme of experiment the following objects were investigated: 1) without liming, 2) with liming in which $CaCO_3$ was applied in the dose equal to 1 unit of hydrolitic acidity. Waste activated sludge, broiler litter and brown coal were used as organic fertilizers and applied in the dose 2 g C $\cdot$ kg^{-1} of soil. In the vegetation period 4 cuts of tested plants were harvested. The biomass of tested plant was air dried and ashed by dry combustion in the furnace at 450 ^{o}C. The ash was dissolved in 10 % HCl and in the obtained solution the contents of lead and manganese were determined by ICP-AES method. The highest yield of biomass (sum of 4 cuts) and the amount of determined heavy metals were harvested from the objects fertilized with waste activated sludge and the lowest ones when brown coal was applied.

Keywords: liming, organic fertilization, orchard grass, heavy metals

Not only macronutrients, organic compounds, but also trace elements contents recognition is important at evaluating the quality of plant-origin products. Excessive content of trace elements in plants is a potential threat for health and life of humans and animals [1–3]. Lower rates of natural and organic fertilizers applied recently forces to search for other sources organic matter and nutrients for plants, but some of them may cause the increase of heavy metals content in soils and plants [4, 5]. Therefore, applying sewage sludge and other waste substances for fertilization purposes requires continuous control for toxic components [6]. The problem is regulated by corresponded legal acts [7–9].

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The present study was aimed at evaluating the influence of liming and varied organic fertilization on yields and contents of selected heavy metals at orchard grass.

Material and methods

The pot experiment in completely randomized pattern was conducted in greenhouse of University of Podlasie, Siedlce in 2004. It included two factors: I – liming, and II – varied organic fertilization. The soil for experiment was collected from plough 0–20 cm layer of Podzol of strong loamy sand granulometric composition characterizing by the following properties: organic carbon 7.9 g $\cdot$ kg^{-1}, total nitrogen 0.98 g $\cdot$ kg^{-1}, available phosphorus 69 mg $\cdot$ kg^{-1}, available potassium 75 mg $\cdot$ kg^{-1}, while pH in 1 mol $\cdot$ dm^{-3} KCl was 5.6. Metals contents amounted to: 23.0 mg Zn, 3.13 mg Cu, 6.60 mg Pb and 0.5 mg Cd $\cdot$ kg^{-1} soil.

The soil material of 10 kg amount was put into the pots of 15 dm^3 capacity. The moisture content was maintained at the level of 60 % of field water capacity during the vegetation period. Objects with liming (in a form of $CaCO_3$ at the rate calculated according to 1 Hh of soil material) or without liming were included within the experiment scheme. Following fertilization using organic material was applied: sewage sludge from purification plant in Siedlce, broiler chickens droppings and brown coal from Brown Coal Mine in Turow (Table 1).

Table 1

Chemical composition of organic materials used in pot experiment

Component	Organic materials		
	Sludge from Siedlce	Broilers droppings	Brown coal
	[g $\cdot$ kg^{-1} d.m.]		
C	371	399.1	541
N	60.5	16.8	4.0
P	31.17	23.6	0.11
K	4.28	20.0	0.84
Ca	39.6	39.2	5.18
Mg	8.42	6.96	2.33
	[mg $\cdot$ kg^{-1} d.m.]		
Zn	1276.8	295.6	17.16
Cd	1.99	15.2	0.07
Pb	50.5	5.00	3.71
Cu	137.7	54.1	10.12
Dry matter [g $\cdot$ kg^{-1}]	180	400	850

All wastes were applied at the introductory dose of 2 g C $\cdot$ kg^{-1} of soil material (about 7 Mg $\cdot$ ha^{-1}). The orchard grass was the test plant. Four cuts of tested grass were harvested during its vegetation period. For four years and for every orchard grass contents of Zn, Cu, Pb and Cu in each cut of test plant were determined by means of ICP-AES technique after dry digestion in muffle furnace at 450 ^{o}C and subsequent ash grinding and dissolution in 10 % HCl [10]. Achieved results were statistically processes by means of variance analysis according to F-Fisher-Snedecor's test applying F.R. Anal var. 4.1 software (acc. to Franciszek Rudnicki), while $LSD_{0.05}$ values were calculated on a base of Tukey test.

Results and discussion

Liming and organic fertilization significantly differentiated the yields of orchard grass dry matter (Table 2), which may be attributed to the chemical composition of applied waste materials (Table 1).

Table 2

The yield [$g \cdot pot^{-1}$] of orchard grass

Organic fertilization \ Number of cut	Liming										Mean
	No liming					Liming acc. to 1 Hh					
	I	II	III	IV	Sum	I	II	III	IV	Sum	
Without organic fertilization	3.6	2.1	4.4	0.9	11.0	7.4	1.8	4.4	0.9	14.5	3.2
Waste activated sludge from Siedlce	18.4	7.9	9.1	1.8	37.2	21.6	8.2	9.3	1.8	40.9	9.8
Poultry litter	14.8	4.6	5.9	1.4	26.7	14.8	7.3	8.3	1.4	31.8	7.3
Brown coal	2.5	1.7	4.3	1.1	9.6	6.6	3.1	5.1	0.5	15.3	3.1
Mean	9.8	4.1	5.9	1.3	21.1	12.6	5.1	6.8	1.1	25.6	5.9

$LSD_{0.05}$:	1st cut	2nd cut	3rd cut	4th cut	Sum
for liming	2.578	0.882	0.969	n.s.	3.227
for organic fertilization	4.920	1.683	1.850	0.544	6.159
for interaction of liming × organic fertilization	n.s.	n.s.	n.s.	n.s.	n.s.
for interaction of organic fertilization × liming	n.s.	n.s.	n.s.	n.s.	n.s.

Explanation for Tables 2, 4, 5 and 6: n.s. – non significant.

Sewage sludge from purification plant in Siedlce was the most abundant in macro- and microelements, which was consistent with earlier studies [11]. Brown coal from Brown Coal Mine in Turow appeared to be the least abundant in macro- and microelements (except from organic carbon), which was confirmed by other authors studies [12].

For the 1st cut, applied liming significantly elevated the dry matter yield of orchard grass in all fertilization objects, except from those where poultry droppings were used. In the case of the 2nd and 3rd cuts, the adverse dependence was observed: liming caused considerable increase of the plant yields only on objects where droppings were applied.

Significantly the highest dry matter yields of all cuts of orchard grass were achieved from objects with sewage sludge from purification plant in Siedlce, while the lowest – where no organic fertilization or brown coal was applied (Table 2). Total yield of orchard grass was significantly differentiated by studied factors. Liming made significant increase of the total yield. Considerably the highest yield of tested plant was found on objects where sludge fertilization was used, whereas the lowest – in objects with brown coal.

Copper amounts in orchard grass yield (Table 3) were significantly differentiated by both studied factors as well as interaction between them, which was confirmed by results of other authors [13].

Table 3

The amount of Cu [mg · pot^{-1}] taken up by the biomass of orchard grass

Organic fertilization \ Number of cut	Liming										Mean
	No liming					Liming acc. to 1 Hh					
	I	II	III	IV	Sum	I	II	III	IV	Sum	
Without organic fertilization	0.03	0.02	0.01	0.01	0.07	0.04	0.02	0.003	0.01	0.07	0.02
Waste activated sludge from Siedlce	0.18	0.06	0.02	0.01	0.27	0.32	0.08	0.02	0.01	0.430	0.09
Poultry litter	0.13	0.01	0.02	0.02	0.18	0.14	0.04	0.02	0.003	0.20	0.05
Brown coal	0.02	0.01	0.01	0.01	0.04	0.03	0.003	0.003	0.001	0.04	0.01
Mean	0.08	0.03	0.02	0.01	0.14	0.13	0.04	0.01	0.006	0.189	0.04

$LSD_{0.05}$:	1st cut	2nd cut	3rd cut	4th cut
for liming	0.030	0.008	0.002	0.004
for organic fertilization	0.057	0.014	0.003	0.007
for interaction of liming × organic fertilization	0.080	0.020	0.004	0.010
for interaction of organic fertilization × liming	0.059	0.015	0.003	0.007

Liming considerably increased the copper content in the 1st cut yield from objects fertilized with sewage sludge from Siedlce. Significantly the highest concentration of the element was recorded in yield of plants grown on sludge from Siedlce, while the lowest on objects with brown coal from Turow. Liming significantly elevated the content of copper in the 2nd cut yield on objects with sewage sludge (as similar as in the first cut) as well as it caused the decrease of the element content at plants harvested from objects with brown coal applied. Liming significantly decreased the copper amounts in the 3rd cut yield of grass cultivated on objects where brown coal was used as well as on those with no organic fertilization was applied. For the 4th cut, discussed factor caused significant decrease of the yield of analyzed microelement harvested along with the plants grown on brown coal objects (as for the 2nd and 3rd cuts) as well as those where poultry droppings were used. In the case of all combined cuts, the highest copper amounts were recorded in plants grown on sewage sludge from purification plant in Siedlce, whereas the lowest on objects where brown coal was applied, which can be explained by chemical composition of organic materials and the amount of copper introduced along with them into the soil (0.742 mg Cu · kg^{-1} of soil with the sludge from Siedlce, while only 0.037 mg Cu · kg^{-1} of soil with brown coal).

Zinc amounts harvested in the orchard grass yields were presented in Table 4. It was significantly differentiated only by organic fertilization. No influence of liming can be elucidated with the short period after calcium fertilizers application. For all cuts, the highest zinc contents were recorded in plants grown on objects with sewage sludge and poultry droppings, while the lowest on objects with brown coal. As similar as for copper, the fact can be accounted for the amounts of the element introduced into the soil along with these materials: 6.22 mg Zn · kg^{-1} of soil with sewage sludge, 1.48 mg Zn · kg^{-1} of soil with poultry droppings, and only 0.063 mg Zn · kg^{-1} of soil with brown coal.

Table 4

The amount of Zn [mg · pot^{-1}] taken up by the biomass of orchard grass

Organic fertilization \ Number of cut	Liming										Mean
	No liming					Liming acc. to 1 Hh					
	I	II	III	IV	Sum	I	II	III	IV	Sum	
Without organic fertilization	0.20	0.11	0.17	0.05	0.53	0.28	0.07	0.13	0.05	0.53	0.013
Waste activated sludge from Siedlce	0.98	0.40	0.32	0.08	1.78	1.11	0.48	0.36	0.09	2.04	0.48
Poultry litter	0.71	0.19	0.21	0.07	1.18	0.64	0.30	0.21	0.05	1.20	0.30
Brown coal	0.13	0.09	0.12	0.06	0.40	0.17	0.09	0.11	0.03	0.40	0.10
Mean	0.51	0.20	0.20	0.006	0.97	0.54	0.24	0.20	0.06	1.40	0.25

$LSD_{0.05}$:	1st cut	2nd cut	3rd cut	4th cut
for liming	n.s.	n.s.	n.s.	n.s.
for organic fertilization	0.235	0.084	0.050	0.028
for interaction of liming × organic fertilization	n.s.	n.s.	n.s.	n.s.
for interaction of organic fertilization × liming	n.s.	n.s.	n.s.	n.s.

The amounts of cadmium harvested with orchard grass yields were significantly differentiated by both studied factors (Table 5) as well as additionally interactions between them in the 2nd and 4th cuts.

Liming elevated the cadmium amounts harvested with the 1st cut yield of plants growing on objects where droppings were used, and in 2nd cut of plants cultivated on objects with droppings plus brown coal and sludge from purification plant in Siedlce. Liming significantly decreased the amount of the element in the 3rd cut of plants grown in objects where no organic fertilization was applied and where brown coal was used; it also caused considerable increase of cadmium content at plants fertilized with sewage sludge and poultry droppings. Liming caused significant decrease of cadmium harvested in the 4th cut along with plants grown on objects with sludge from Siedlce, droppings, and brown coal from Turow. For the 1st, 2nd and 4th cuts, the highest amounts of the metal was found at plants grown on objects with sludge from Siedlce, while for the 3rd cut, with poultry droppings, despite of the fact that its largest quantities were introduced along with the material, amounting 0.076 mg Cd · kg^{-1} of soil.

Tabela 5

The amount of Cd [mg · pot^{-1}] taken up by the biomass of orchard grass

Organic fertilization \ Number of cut	Liming										Mean
	No liming					Liming acc. to 1 Hh					
	I	II	III	IV	Sum	I	II	III	IV	Sum	
Without organic fertilization	0.003	0.001	0.007	0.002	0.018	0.006	0.001	0.005	0.002	0.014	0.004
Waste activated sludge from Siedlce	0.013	0.006	0.007	0.012	0.038	0.015	0.010	0.012	0.003	0.040	0.010
Poultry litter	0.007	0.003	0.009	0.007	0.026	0.012	0.014	0.013	0.005	0.044	0.004
Brown coal	0.001	0.001	0.006	0.003	0.011	0.004	0.006	0.011	0.001	0.022	0.006
Mean	0.006	0.003	0.007	0.006	0.022	0.009	0.008	0.010	0.003	0.030	0.026

$LSD_{0.05}$:	1st cut	2nd cut	3rd cut	4th cut
for liming	0.003	0.001	0.002	0.001
for organic fertilization	0.006	0.002	0.004	0.002
for interaction of liming × organic fertilization	n.s.	0.003	n.s.	0.003
for interaction of organic fertilization × liming	n.s.	0.002	n.s.	0.002

Significantly lowest amounts of the element was harvested in the 1st and 4th cuts with yield of plants cultivated on objects where brown coal was applied; it contained minimum amounts of cadmium – 0.003 mg Cd · kg^{-1} of soil. The lowest quantities of cadmium were found in the 2nd and 3rd cuts of plants from objects where no organic fertilization was used.

Lead amounts harvested along with orchard grass yields (Table 6) in the 1st cut was differentiated both by liming and organic fertilization.

Table 6

The amount of Pb [mg · pot^{-1}] taken up by the biomass of orchard grass

Organic fertilization \ Number of cut	Liming										Mean
	No liming					Liming acc. to 1 Hh					
	I	II	III	IV	Sum	I	II	III	IV	Sum	
Without organic fertilization	0.02	0.04	0.15	0.03	0.24	0.07	0.01	0.09	0.03	0.20	0.06
Waste activated sludge from Siedlce	0.16	0.06	0.29	0.05	0.56	0.18	0.09	0.27	0.05	0.59	0.14
Poultry litter	0.05	0.02	0.18	0.04	0.29	0.12	0.22	0.23	0.03	0.60	0.11
Brown coal	0.002	0.01	0.13	0.02	0.18	0.04	0.01	0.08	0.01	0.14	0.04
Mean	0.06	0.03	0.19	0.04	0.32	0.10	0.08	0.17	0.03	0.38	0.09

$LSD_{0.05}$:	1st cut	2nd cut	3rd cut	4th cut
for liming	0.021	0.018	n.s.	n.s.
for organic fertilization	0.041	0.035	0.040	0.015
for interaction of liming × organic fertilization	n.s.	0.050	0.057	n.s.
for interaction of organic fertilization × liming	n.s.	0.037	0.042	n.s.

Liming caused considerable increase of the lead yield harvested with plants grown on objects with poultry droppings as well as those with no organic fertilization. Amount of lead in 2nd cut yield was considerably differentiated by both experimental factor as well as their interaction. Liming significantly decreased the amount of lead from objects without organic fertilization and it caused considerable increase of studied element on objects with poultry droppings and sewage sludge application. For the 3rd cut, the lead amounts were significantly affected by applied organic nutrition as well as interactions between studied factors, while in the case of 4th cut, only by applied organic fertilization.

The largest lead amounts were found in the 1st, 3rd, and 4th cuts of plants from objects where sewage sludge from Siedlce was applied, which can be attributed with its largest amounts of the metal introduced into the soil along with that material (0.272 mg $Pb \cdot kg^{-1}$ of soil). The lowest levels of lead were harvested with plant yields from objects fertilized with brown coal, which can be explained with its lowest quantities introduced to the soil along with that organic material (only 0.014 mg $Pb \cdot kg^{-1}$ of soil) as well as its alkalizing properties.

It can be supposed that applied liming and organic nutrition significantly differentiated the orchard grass yields as well as copper, zinc, cadmium, and lead amounts harvested along with its yield.

The highest total grass yield was harvested from objects fertilized with sewage sludge, while significantly the lowest from objects with brown coal. The largest amounts of studied metals were found at plants grown on sewage sludge from purification plant in Siedlce, which can be attributed with the fact that the highest levels of copper, zinc, and lead were introduced into the soil along with that material, which was consistent with research of other authors [14]. The lowest quantities of discussed metals were harvested with yields of plants cultivated on objects fertilized with brown coal, along which their minimum amounts were introduced into the soil, and which has the sorption properties in relation to cations – according to numerous studies [10, 15].

The highest average copper and zinc amounts were harvested along with plants of the 1st cut, while lead and cadmium of the 3rd cut, which was consistent with earlier results [17], and which can be explained with the highest yields of both cuts (Table 2).

Conclusions

1. Liming not univocally differentiated the orchard grass yields and harvested amounts of copper, zinc, cadmium and lead.
2. Considerably the highest total yield of the test plant was harvested from objects fertilized with sewage sludge from purification plant in Siedlce, while the lowest from those with brown coal.
3. Significantly the highest amounts of studied metals were harvested with yield of plants grown on objects with sewage sludge, whereas the lowest with brown coal.

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WPŁYW WAPNOWANIA I NAWOŻENIA ORGANICZNEGO NA PLON ORAZ ZAWARTOŚĆ WYBRANYCH METALI W KUPKÓWCE POSPOLITEJ

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Abstrakt: W doświadczeniu wazonowym badano wpływ wapnowania i zróżnicowanego nawożenia organicznego na plon kupkówki pospolitej oraz zebrane z tym plonem ilości Cu, Zn, Cd i Pb. W badaniach uwzględniono obiekty bez stosowania wapnowania i ze stosowaniem $CaCO_3$ w dawce równoważnej 1 Hh gleby. W doświadczeniu zastosowano również nawożenie organiczne (osad ściekowy, kurzeniec od brojlerów, węgiel brunatny) w dawce wprowadzającej do gleby 2 g C · kg^{-1}. W sezonie wegetacyjnym zebrano cztery pokosy uprawianej rośliny, w której po wysuszeniu i zmieleniu oznaczono zawartość omawianych pierwiastków metodą ICP-AES po wcześniejszej mineralizacji "na sucho" w piecu muflowym.

Największy plon sumaryczny oraz najwięcej omawianych metali zebrano z obiektów nawożonych osadem ściekowym, a najmniej z obiektów, w których stosowano węgiel brunatny.

Słowa kluczowe: wapnowanie, nawożenie organiczne, kupkówka pospolita, metale ciężkie