ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 17, No. 4–5 2010

Marcin NIEMIEC[1] and Barbara WIŚNIOWSKA-KIELIAN

EFFECT OF DREDGED BOTTOM SEDIMENT ADDITION TO THE SUBSTRATUM ON THE FODDER VALUE OF PLANT MATERIAL Part 1. MACROELEMENTS CONTENT

WPŁYW DODATKU BAGROWANEGO OSADU DENNEGO DO PODŁOŻA NA WARTOŚĆ PASZOWĄ MATERIAŁU ROŚLINNEGO Cz. 1. ZAWARTOŚĆ MAKROELEMENTÓW

Abstract: Pot experiments were conducted in 2004 and 2005 in which light soil, quartz sand and bottom sediment dredged from the Roznow Reservoir were used as a substratum. The experiments aimed at an assessment of the effect of growing bottom sediment share in the substratum on the quality of cultivated crop biomass. The test plants were maize and horse bean, oat and lupine cultivated after each other in 2004 whereas in 2005 the test plant was barley cultivated in the same substrata. The biomass was assessed on the basis of limit values for good quality fodder based on macroelement (P, K, Ca, Mg and Na) contents.

The results show that biomass of most test plants contained too little macroelements considering their use for fodder. Bottom sediment added to the slightly acid soil only slight changed the contents of magnesium, calcium, potassium and sodium in biomass of all test plants, despite a considerable increase in these elements quantity in the substratum. A considerable increase in calcium and magnesium in the plant biomass was assessed in the substrata with sand. A decline in phosphorus content in biomass of all plants was observed even at the lowest sediment admixture, however it was more pronounced in case of the substrata with soil. Greater sediment supplements did not cause any further limiting of phosphorus uptake by plants. In the second year of the experiment on average higher contents of all macroelements were registered in barley biomass, which improved its feed value.

Bottom sediment supplement to the substratum worsened the quality of all plant biomass because of too low phosphorus content, whereas increasing amounts of calcium and magnesium improved the quality of biomass obtained in the experiments.

Environmental management of the sediment dredged from the Roznow Reservoir may be recommended on light acid soils to improve their physicochemical properties, yielding and plant chemical composition, but simultaneous monitoring of other substances in the biomass is necessary.

Keywords: light soil, quartz sand, bottom sediment, macroelements, P, K, Ca, Mg, Na, content, biomass quality

[1] Department of Agricultural Chemistry, University of Agriculture in Krakow, al. A. Mickiewicza 21, 31–120 Kraków, Poland, phone +48 12 662 4347, fax +48 12 662 4341, email: niemiecm@tlen.pl

Element uptake by plants and their chemical composition is a resultant of many factors, among others cation exchange through cell membranes, processes occurring in the rhizosphere, total contents and the forms in which these elements occur in soil. Soil pH and organic matter contents are the factors to which the most serious influence on element bioavailability is ascribed [1]. A sudden change of soil pH may definitely increase or decrease the amount of bioavailable components [2]. Elements absorbed by plants are included in the biogeochemical cycle. The optimum macroelement content in plants conditions their yielding and covers animal nutritional needs if they are used for feeds. A deficiency or excess of elements may have a negative effect on animals directly or indirectly leading to limited or excessive uptake of other elements.

Bottom sediment from rivers and dam reservoirs reveal chemical properties similar to soils from the catchment area. They usually have neutral or alkaline pH and considerable proportion of silt and clay fractions in their granulometric composition [3, 4]. Technical degradation of dam reservoirs may in future cause enlargement of areas with chronic or periodical water deficits and will compel their reclamation, among other things through dredging [5].

The investigations aimed to determine the effect of growing share of bottom sediment in the substratum on macroelement content in plant biomass and assessment of potential environmental management of this sediment on light acid soils.

Material and methods

The investigations were conducted in the years 2004–2005 in conditions of pot experiments in which light soil and quartz sand with bottom sediment supplement dredged from the Roznow Reservoir were used as a substratum (Table 1).

Table 1

Selected properties of substrata components used in experiments

Component	pH_{KCl}	P	Mg	Ca	Na	K	P	K_2O
		total content [$g \cdot kg^{-1}$]					available forms [$mg \cdot kg^{-1}$]	
Sediment	7.2	0.532	3.833	17.46	0.973	8.632	18.0	96.6
Soil	5.82	0.392	0.564	1.038	0.084	0.556	63.3	256
Sand	6.39	0.072	0.824	0.417	0.091	0.459	4.45	19.2

The experimental design comprised 11 combinations in each series of substrata in three replications. The share of sediment in the substratum was growing from 10 % to 100 %, by 10 % in the subsequent objects. The control treatments were soil and sand without the sediment admixture. In all objects basic fertilization was applied: 1 g N, 0.25 g P and 1.25 g K per pot, thoroughly mixed with the substratum components. Chemically pure NH_4NO_3, KH_2PO_4 and KCl were used for fertilization. In 2004 the test plants were maize (*Zea mays* L.), ‘Prosna’ F1 c.v., and horse bean (*Vicia faba* L.), ‘Nadwislanski’ c.v., as a consecutive plant and oat (*Avena sativa* L.), ‘Chwat’ c.v., and narrow leafed lupine (*Lupinus angustifolius* L.), ‘Sonet’ c.v., as a consecutive plant. In the experiment continued in 2005 on the same substrata, spring barley (*Hordeum vulgare* L.), 'Rambo' c.v., was cultivated as a test plant. After harvest the plants were dried, samples were dry mineralized and after the ash solution in HNO_3 (1:2) P, K, Ca, Mg and Na contents were assessed in the aboveground biomass using ICP-AES method.

Results and discussion

Phosphorus content in plants cultivated in the conducted experiments was diversified, fluctuating from 0.79 to 6.29 g · kg^{-1} (Table 2). Mean content of this element in all plants was 1.87 g P · kg^{-1}. Slightly higher phosphorus content was registered in the plants cultivated in substrata with sand. The largest diversification of P content (RSD %) in biomass of plant grown on substrata with soil was registered for lupine and on substrata with sand for horse bean and the smallest one on both kinds of substrata was founded for oat.

Table 2

Phosphorus contents in biomass of plants

Share of sediment in substratum [%]	Substratum with soil					Substratum with sand				
	maize	oat	horse bean	lupine	barley	maize	oat	horse bean	lupine	barley
	[g P · kg^{-1} d.m.]									
0	3.30	3.57	4.27	4.29	6.29	1.73	1.81	3.71	2.48	2.70
10	0.99	2.08	2.45	1.74	3.75	0.94	1.78	1.56	1.55	3.09
20	1.04	1.70	2.00	1.56	3.24	0.88	2.11	1.44	1.56	3.67
30	1.03	2.02	1.85	1.41	2.84	0.94	2.07	1.59	1.14	3.24
40	0.96	1.76	2.09	1.05	2.87	0.96	2.19	1.73	0.95	3.25
50	0.94	1.73	1.51	0.94	2.52	0.98	2.22	1.85	1.11	2.59
60	0.97	2.38	1.47	1.03	2.35	0.93	2.23	2.28	1.36	2.48
70	0.84	1.94	1.38	1.10	2.19	0.82	1.92	2.92	1.17	2.62
80	0.99	1.59	1.17	1.21	2.12	0.79	2.33	2.05	1.22	2.04
90	0.85	1.68	1.47	0.90	2.21	0.91	2.39	2.25	1.24	2.30
100	0.79	1.71	1.41	1.07	1.87	0.79	1.71	1.41	1.07	1.87
Mean	1.16	2.01	1.92	1.48	2.93	0.97	2.07	2.07	1.35	2.71
SD	0.72	0.57	0.87	0.97	1.24	0.26	0.23	0.71	0.42	0.55
RSD	62.0	28.1	45.3	65.3	42.4	26.9	11.2	34.1	31.1	20.3

Explanation for Tables 2–6: SD – standard deviation, RSD – relative standard deviation [%].

An admixture of bottom sediment constituting 10 % of the substratum mass caused a considerable limiting of phosphorus uptake by all plants. Greater supplements of this component did not lead to any further lowering of this element content in the plant biomass. Optimal phosphorus content in plants for fodder is 3 g · kg^{-1} [6], therefore it may be estimated that the bottom sediment added to the substratum worsened feed value of the plants in the experiment.

The most frequently encountered phosphorus contents in biomass of maize, barley and oats at the flowering stage are: 2.5–4.5; 3–6 and 4–6 g P · kg^{-1} d.m., respectively [7, 8]. Similar phosphorus contents in barley biomass were registered by Bednarek and Lipinski [9]. Micek et al [10] reported 4.2 g P · kg^{-1} d.m. phosphorus content at oat earing stage. Wisniowska-Kielian [11] noted up to 1.9 g P · kg^{-1} in maize biomass cultivated in alkaline soil, harvested before flowering, up to 3.5 g P · kg^{-1} in oat biomass at the earing stage, while on acid soil maize contained up to 2.1 g P and oat up to 2.6 g P · kg^{-1}.

Maize and oat biomass obtained in the experiment contained considerable smaller quantities of phosphorus than reported by the authors mentioned above, however the amounts of this element assessed in barley were comparable. Wyszkowski and Wyszkowska [12] reported the contents approximate to obtained in barley biomass in the presented experiment, ie 2.79 g P · kg^{-1}. Czyz et al [13] found considerably higher phosphorus contents in meadow sward in the former Slups province, while Wisniowska-Kielian [11] and Wisniowska-Kielian and Pazdziorko [14] assessed similar content of this element in meadow sward in the Podkarpackie province and Beskid Zywiecki Mts. Bottom sediment admixture to the substratum in the Authors' own research decreased this element content in test plants to the level observed by other authors. Horse bean from the control treatment on the soil substratum contained greater amount of phosphorus than plants obtained in the pot experiment conducted by Wyszkowska [15], whereas a 20 % admixture of the sediment turned the relationship. Sediment supplements to the substratum lowered phosphorus content in plants causing considerable deficiencies of this element in view of plant development and their use for forage. Already a 10 % supplement of the sediment to the soil caused over three-fold decline in phosphorus content in the aboveground biomass in comparison with the amount observed in the control plants (from 3.30 to 0.99 g P · kg^{-1} d.m.). In conditions of intensive deacidification chemisorption processes occur in soil, in result of which this metal bioavailability decreases radically, as was reported by other authors [16, 17] who observed a significant dependence between soil pH and its contents of bioavailable phosphorus.

Potassium content in all experimental plants fluctuated from 8.73 to 42.5 g K · kg^{-1} (Table 3) and was on average 16.12 g K · kg^{-1}.

No definite differences were assessed in this element contents depending on the kind of substratum. The highest amounts of potassium were assessed in barley biomass, however no differences were observed in this element uptake between the other test plants.

The diversification of K content (RSD %) in plant biomass was not as big as observed in case of P. The largest its changeability in biomass of plant grown on substrata with soil was registered for lupine and on substrata with sand for horse bean and the smallest one on both kinds of substrata was noted for maize.

Potassium contents in plant biomass obtained in the experiment of 2004 were lower than the most commonly encountered values in cereals ranging from 23.4 to 26.6 g K · kg^{-1} d.m. [8], whereas this element contents in barley cultivated in 2005 were higher than reported by these authors and approximate to registered by Wyszkowski [18]. This element content in leaves and stems of horse bean in the pot experiment conducted by Wyszkowska [15] was twice higher than in horse bean in the Authors' own experiment.

Table 3

Potassium contents in biomass of plants

Share of sediment in substratum [%]	Substratum with soil					Substratum with sand				
	maize	oat	horse bean	lupine	barley	maize	oat	horse bean	lupine	barley
	[g K · kg^{-1} d.m.]									
0	10.72	13.75	15.50	13.10	42.50	11.24	12.71	9.43	13.91	25.93
10	13.50	10.89	13.05	15.75	37.96	12.21	12.55	11.78	13.64	30.92
20	13.13	11.04	15.37	12.50	38.16	13.18	12.69	13.66	12.78	37.07
30	12.84	14.31	12.35	11.85	33.75	12.56	12.38	13.24	10.73	33.81
40	12.62	11.05	13.53	10.09	30.58	13.38	14.31	12.96	10.61	32.63
50	12.32	11.16	14.81	10.70	27.56	13.75	10.86	13.39	10.72	29.22
60	11.58	13.94	10.89	8.86	29.95	14.31	12.04	14.32	11.21	26.68
70	12.94	11.13	14.36	9.60	28.56	12.53	10.24	8.73	10.87	28.86
80	12.88	14.00	12.40	9.80	31.21	13.13	12.75	17.22	11.85	30.92
90	12.56	11.11	13.24	8.99	28.01	13.38	13.00	11.75	10.61	28.43
100	12.48	11.83	14.91	8.76	26.91	12.48	11.83	14.91	8.76	26.91
Mean	12.50	12.20	13.67	10.91	32.29	12.92	12.31	12.85	11.43	30.12
SD	0.77	1.45	1.46	2.19	5.16	0.83	1.08	2.40	1.51	3.38
RSD	6.1	11.9	10.6	20.0	16.0	6.5	8.8	18.7	13.2	11.2

Czapla and Nowak [19] registered similarly high contents of this element in oat biomass after application of potassium treatment. In the experiment conducted by Benedycka and Nowak [20] potassium content in horse bean aboveground parts was considerably higher (ca 50 g K · kg^{-1} d.m.) than in the horse bean from the presented experiment. These amounts greatly exceeded the optimum value in feeds, ie 17 g K · kg^{-1} [6], whereas the quantities of this element noted by Wyszkowska [15] in leaves and stems of horse bean were by half lower than in the research of the above-mentioned authors, still they were much higher than in the presented investigations. In their research Wyszkowska and Wyszkowski did not find any differences in potassium content in barley biomass, which accumulated 20.77 g K · kg^{-1} [12] or oat which had 20.63 g K · kg^{-1}. Considerably bigger differences between the species were registered by Wisniowska-Kielian [11] who found between 33 and 35 g K · kg^{-1} in maize biomass and between 50–54 g K · kg^{-1} in oat biomass at the earing stage, irrespective of the soil acidification. Gorlach and Curylo [22] did not notice any influence of growing $CaCO_3$ doses on the content of bioavailable potassium in soil or this cation uptake by plants, whereas Alvares de Oliveira et al [23] noted a high negative correlation between the content of calcium and magnesium in soil and potassium uptake by soyabean.

Calcium content in the test plants was changing to a small degree under the influence of bottom sediment admixture to the substratum. No significant differences were noted, either depending on the kind of substratum. The highest calcium contents were found in horse bean and lupine biomass, whereas the smallest amounts were registered in monocotyledonous plant biomass (Table 4).

Table 4

Calcium contents in biomass of plants

Share of sediment in substratum [%]	Substratum with soil					Substratum with sand				
	maize	oat	horse bean	lupine	barley	maize	oat	horse bean	lupine	barley
	[g Ca · kg^{-1} d.m.]									
0	3.15	5.78	13.10	19.88	7.79	2.37	5.83	9.92	10.35	3.62
10	4.13	7.47	16.01	10.84	8.05	4.49	5.97	14.97	18.51	6.95
20	4.70	6.20	19.43	26.13	8.47	4.36	6.78	17.79	20.28	9.63
30	3.94	5.39	16.76	18.90	6.77	4.24	5.57	18.80	21.24	8.08
40	4.67	4.59	19.84	11.06	6.49	4.96	6.54	18.93	15.97	6.30
50	4.67	4.68	15.43	20.09	4.43	4.90	6.93	20.36	19.72	5.19
60	4.23	5.34	17.71	19.32	5.79	4.50	7.51	15.32	18.64	6.37
70	4.31	5.46	17.45	20.11	4.65	4.35	7.77	14.72	18.15	5.25
80	4.50	5.03	17.60	19.93	5.13	3.88	5.60	12.97	20.54	5.27
90	4.07	3.32	17.51	19.92	4.95	4.23	5.65	12.66	18.37	5.41
100	3.76	5.06	14.76	20.12	5.17	3.76	5.06	14.76	20.12	5.17
Mean	4.19	5.30	16.87	18.75	6.15	4.19	6.29	15.56	18.36	6.11
SD	0.47	1.04	1.97	4.31	1.45	0.70	0.87	3.14	3.03	1.64
RSD	11.1	19.5	11.7	23.0	23.5	16.8	13.9	20.2	16.5	26.9

The diversification of Ca content (RSD %) in plant biomass was similar to observed in case of K. The largest its changeability in biomass of plant grown on both kinds of substrata was found for barley and the smallest one on substrata with soil was registered for maize and on substrata with sand for oat.

A sediment supplement to the substratum caused an increase in this element content in all plants biomass, however more pronounced effect was observed on the substrata containing sand. The optimum calcium content in biomass of plants destined for forage is 6 g Ca · kg^{-1} [6], therefore the sediment admixture to the substratum improved the monocotyledonous quality but worsened the quality of horse bean and lupine. Calcium contents in maize at the pre-flowering stage fluctuated from 3.0 to 7.0 g Ca · kg^{-1} d.m. [7]. In the research conducted by Micek et al [10] calcium content at the earing stage of oat cultivated for green forage was 3.0 g Ca · kg^{-1} d.m. Maize, oat and barley biomass contained amounts of this element approximate to reported by the authors mentioned above.

Wyszkowski [18] obtained lower calcium contents in maize grown in a pot experiment, whereas Wyszkowski and Wyszkowska [12] registered 3.71 Ca · kg^{-1} in barley. Wisnowska-Kielian [11] observed greater contents of calcium in plants: 6.3–10.3 g Ca · kg^{-1} in oat biomass and 4.6–11.5 g Ca · kg^{-1} in maize, depending on the soil acidification. These values approximated those noted in maize biomass in the presented experiment. Lupine and horse bean contained much higher quantities of calcium, which might have resulted from the fact that the dicotyledonous are more abundant in this element (on average 13.1 g Ca · kg^{-1}) than the monocotyledonous (on average 4.9 Ca · kg^{-1}) [6]. Wyszkowska [15] noted similarly high content of this element in horse bean. Calcium contents in the aboveground biomass of lupine and horse bean were similar, whereas they were smaller in barley and maize. Bottom sediment introduced to both kinds of substratum caused an increase in calcium content in all test plant biomass, however the highest accumulation of this element occurred already after the application of the smallest admixtures of the sediment. Gorlach and Curylo [22] noted a high positive correlation between $CaCO_3$ dose applied for the soil deacidification and calcium contents in plants, however the stronger relationship was observed for oat than maize, which may explain the differences obtained in the Authors' own investigations.

All plants cultivated in the experiments contained small amounts of magnesium, on average 1.43 g Mg · kg^{-1}, and the amount fluctuated from 0.69 to 2.22 g Mg · kg^{-1} (Table 5).

Table 5

Magnesium contents in biomass of plants

Share of sediment in substratum [%]	Substratum with soil					Substratum with sand				
	maize	oat	horse bean	lupine	barley	maize	oat	horse bean	lupine	barley
	[g Mg · kg^{-1} d.m.]									
0	1.15	1.03	1.45	1.88	1.46	1.02	0.69	1.12	1.58	0.79
10	1.38	0.97	1.29	1.55	1.18	1.56	0.89	1.20	1.42	1.38
20	1.61	0.97	1.46	1.73	1.35	1.63	0.97	1.41	1.43	1.20
30	1.64	1.06	1.39	1.46	1.46	1.58	0.96	1.42	1.28	1.50
40	1.72	0.95	1.51	1.43	1.42	1.76	1.25	1.73	1.42	1.42
50	1.71	1.05	1.53	1.44	1.39	1.83	1.09	1.94	1.50	1.39
60	1.68	1.07	1.50	1.56	1.64	1.69	1.18	1.85	1.51	1.59
70	1.78	1.18	1.72	1.41	1.35	1.74	1.22	2.22	1.46	1.52
80	1.61	1.05	1.63	1.50	1.54	1.74	1.09	1.67	1.61	1.60
90	1.74	0.92	1.52	1.41	1.68	1.79	1.02	1.81	1.45	1.76
100	1.70	0.95	1.57	1.51	1.49	1.70	0.95	1.57	1.51	1.49
Mean	1.61	1.02	1.51	1.53	1.45	1.64	1.03	1.63	1.47	1.42
SD	0.19	0.08	0.11	0.15	0.14	0.22	0.16	0.33	0.09	0.25
RSD	11.6	7.4	7.6	9.6	9.7	13.6	15.8	20.1	6.1	17.9

No definite differences were observed for this element contents in the monocotyledonous and dicotyledonous plants. An admixture of the sediment to the substratum caused slight increase in this element content in plants growing on the substrata containing sand and a decrease in its uptake on the substrata with soil. Generally the sediment supplement improved the plant quality on the substrata with sand but worsened on the substrata with soil.

The diversification of Mg content (RSD %) in plant biomass was smaller than those registered for K and Ca and in plant grown on substrata with soil than those with sand. The largest its changeability in biomass of plant grown on substrata with soil was observed for maize and the lowest one for oat and on substrata with sand the largest diversification of Mg content was found for horse bean and the smallest one was calculated for lupine.

Magnesium contents in maize biomass before flowering fluctuated most frequently from 2.0 to 6.0 g Mg · kg^{-1} d.m., whereas the analogous values for oat and barley at this stage were 2.1–4.0 g Mg · kg^{-1} d.m. [7]. Plant biomass obtained in the Authors' own experiments revealed lower magnesium content than deterined by the abovementioned authors, and the highest amounts were found for oat. In the research conducted by Wyszkowski and Wyszkowska [12] barley biomass contained 2.11 g Mg · kg^{-1} d.m. and oat biomass [21] 1.23 g Mg · kg^{-1} d.m.

Poulik [24] assessed similar, low magnesium content in oat 1.7 g Mg · kg^{-1}. Mazur and Wisniowska-Kielian [25] observed an opposite response after the application of dolomite to very acid and weakly acid soil. Under these conditions oat and maize contained 2–3 times greater amounts of magnesium (3.9–4.6 g · kg^{-1}).

In pot experiments Wisniowska-Kielian [11] assessed between 3.8–5 g Mg · kg^{-1} in maize biomass and 2.2–3.2 g Mg · kg^{-1} in oat biomass. Under the influence of bottom sediment added to the substratum magnesium content in maize biomass increased to the level approximate to observed in this plant by Wyszkowski [18]. In the Authors' own investigations an increase in magnesium contents in biomass of oat and horse bean was observed only when they were cultivated in substrata with sand, whereas on the substrata with soil their levels did not change. A lack of evident changes in magnesium content in plants, despite its big quantities in the sediment, was most probably the consequence of very high calcium content in the sediment and the competition between these ions. Kuht and Reintam [26] stated that large doses of calcium may considerably lower the content of available magnesium forms in soil. Gorlach and Curylo observed an increase in magnesium contents in maize and oat biomass only after the soil liming with a fertilizer dose equaling 0.5 and 1.0 hydrolytic acidity, whereas higher admixtures of calcium decreased magnesium level in these plants' biomass. Magnesium deficiencies most frequently occur in light and acid soils, therefore a necessity of magnesium fertilization of these soils appears. Application of bottom sediment on light soil may constitute a valuable source of this element. The bottom sediment used for the experiments contained several times more magnesium than the soil and sand (Table 1).

All plants used in the Authors' own investigations assessed in view of their fodder usability were characterized by insufficient magnesium content [6], ie 2 g Mg · kg^{-1} d.m.

Sodium content in the plants was fluctuating considerably under the influence of bottom sediment admixture to the substratum. Its content ranged from 39.63 to 2159 mg Na · kg^{-1} (Table 6).

Average sodium content in all plants was 372 mg · kg^{-1}. The highest contents were registered in horse bean biomass. The Na content (RSD %) in plant biomass was diversified in a larger extend than of K, Ca and Mg content. The largest its changeability in biomass of plant grown on both substrata was noted for horse bean and the smallest one on substrata with soil was observed for barley and on substrata with sand for maize.

Table 6

Sodium contents in biomass of plants

Share of sediment in substratum [%]	Substratum with soil					Substratum with sand				
	maize	oat	horse bean	lupine	barley	maize	oat	horse bean	lupine	barley
	[mg Na · kg^{-1} d.m.]									
0	56.9	180	103	299	430	50.8	262	53	248	304
10	42.9	256	256	373	368	50.6	220	176	191	432
20	54.6	177	334	214	384	42.9	215	303	248	508
30	43.7	200	440	281	328	48.6	199	820	256	549
40	43.0	212	914	342	420	41.1	229	309	240	312
50	57.9	179	1162	469	357	56.4	483	391	375	358
60	50.4	234	1619	259	411	47.6	550	569	377	416
70	39.6	203	1356	404	403	57.1	504	1414	408	664
80	43.6	197	1322	175	394	48.6	316	1214	426	490
90	47.9	224	2159	247	404	65.0	385	958	323	470
100	48.8	299	1161	213	363	48.8	299	1161	213	363
Mean	48.1	215	984	298	387	51.0	333	670	300	442
SD	6.22	37.2	642.6	90.5	30.7	6.73	127.9	466.2	83.7	108.7
RSD	12.9	17.3	65.3	30.4	7.9	13.3	38.4	69.6	27.8	24.6

Wozniak [27] noted twice higher sodium contents in the legumes from meadows in the San River valley than in mixed sward. These contents were approximate to observed in the plants in the presented experiments. Wisniowska-Kielian and Pazdziorko [14] noted up to 450 mg Na · kg^{-1} d.m. in meadow sward in the Beskid Zywiecki Mts. The contents similar to presented by these authors were assessed only in horse bean, when the bottom sediment supplement exceeded 50 % of the substrata mass prepared both on the basis of sand and soil.

Much higher sodium contents in oat and maize were registered by Czapla and Nowak [19], but they resulted from the soil fertilization with this element. Sodium contents in the aboveground oat biomass ranged from 1.8–3.4 g Na · kg^{-1} d.m., while in maize from 0.6 to 0.8 g Na · kg^{-1} d.m. Gorlach and Curylo [22] noted over twice higher sodium contents in maize biomass than assessed in the presented experiments, both on the control treatments and on those with added bottom sediment.

In the Authors' own research sodium content in maize, lupine and oat biomass did not change definitely under the influence of the sediment admixture, despite its much higher contents in the sediment than in the soil or sand. Sodium contents in horse bean were increasing considerably in result of growing proportions of the sediment in the substratum. This element contents noted in the first year of the presented investigations in the plants from the treatments with 20–30 % sediment share in the substratum were approximate to registered in horse bean straw by Benedycka and Nowak [20], which remained on the level of 500 mg Na · kg^{-1} d.m. Wisniowska-Kielian [11] observed much lower amounts of sodium in maize and oat biomass, between 20 and 50 mg · kg^{-1} d.m., whereas Wyszkowski and Wyszkowska [12] assessed greater contents of sodium, 720 mg Na · kg^{-1} d.m. in oat biomass [20].

Sodium contents in the plants biomass differed considerably from the optimum values in feeds, ie 1500–2500 mg Na · kg^{-1} [6].

Literature data [22] corroborate a lack of unambiguous relationships between the quantity of sodium absorbed by plants and soil pH, because a decrease in sodium content in grass biomass was observed with increasing pH value to 4.3,whereas further increase in pH did not cause any changes in this element content in grass biomass. Growth in sodium content noted in plant biomass in the Authors' own investigations in effect of bottom sediment supplement to the substratum in the first place resulted from increasing total sodium amount in the substratum.

Because of high content of calcium and magnesium, application of big doses of bottom sediment as a supplement to the soil may be treated as a deacidifying measure. Total alkalinity of the sediment used in the presented experiments was 5.7 % $CaCO_3$. The smallest applied admixture of the sediment introduced to the substratum the amounts of calcium equaling almost twenty-fold value of the soil hydrolytic acidity and over twenty-fold sand hydrolytic acidity. Observed results of its application as changes in chemical composition of the plants are characteristic for limed soils [16, 22, 26, 28]. For this reason environmental management of this sediment is possible on light soil for improving their properties and yielding and chemical composition of plants at simultaneous controlling harmful substances contents in the biomass.

Conclusions

1. Bottom sediment supplied to the soil considerably increases its contents of all investigated macroelements.
2. Application of the bottom sediment from the Roznow Reservoir to a considerable extent limits phosphorus absorption by plants, due to its deacidifying activity.
3. Increase in calcium and sodium contents was observed in result of sediment application.
4. Bottom sediment applied on light soil and sand improved fodder value of plants in view of the contents of investigated elements, except for phosphorus.
5. Phosphorus fertilization should be increased when bottom sediments are applied.
6. Application of the sediment amounts equaling 10 or 20 % of the substratum mass caused the greatest changes of the analyzed elements contents in the test plants.
7. Environmental management of the bottom sediment dredged from the Roznow Reservoir is possible on light acid soils to improve their physicochemical properties and yielding and chemical composition of plants but at the same time harmful substances contents in the biomass must be monitored.

References

[1] Garcia G., Zamuzzi A.L. and Faz A.: Biodegradation 2005, **16**(2), 187–194.
[2] Alvarenga P., Gonçalves A.P., Fernandes R.M., de Varennes A., Vallini G., Duarte E. and Cunha-Queda A.C.: Sci. Total Environ. 2008, **406**(1–2), 43–56.
[3] Verstraeten G. and Prosser I.P.: Geomorphology 2008, **98**(3–4), 199–212.
[4] Alvarez-Rivera U., Rosalez-Hoz L. and Carranza-Edwards A.: Ann. del Inst. Cienc. del Mar y Limnologia 1984, **9**, 198–209.
[5] Mwendera E.J.: Phys. Chem. Earth, Parts A/B/C 2006, **31**(15–16), 952–959.
[6] Falkowski M., Kukułka I. and Kozłowski S.: Właściwości chemiczne roślin łąkowych. Wyd. AR, Poznań 2000, 132 p.
[7] Finck A.: Landw. Fak. Univ. Kiel. 1970, **47**, 159–170.
[8] Cerling V.V. and Žubrickij Z.I.: Methodische Hinweise zur Diagnostik der Mineralernährung von Futter Gemüse und Feldkulturen. Iztad. Kolos 1972, Moskva 40 p.
[9] Bednarek W. and Lipiński W.: Zesz. Probl. Post. Nauk Rol. 1994, **413**, 41–46.
[10] Micek P., Zając T. and Borowiec F.: Biul. Inst. Hodow. i Aklimat. Rośl. 2003, **229**, 349–357.
[11] Wiśniowska-Kielian B.: Ecol. Chem. Eng. 2003, **10**(9), 1001–1010.
[12] Wyszkowski M. and Wyszkowska J.: Polish J. Environ. Stud. 2006, **15**(2a), 212–221.
[13] Czyż H., Dzida M. and Jakubowski P.: Zesz. Probl. Post. Nauk Rol. 1998, **462**, 93–99.
[14] Wiśniowska-Kielian B. and Paździorko A.: J. Elementol. 2004, **9**(4), 837–846.
[15] Wyszkowska J.: Biul. Nauk. 1999, **5**, 65–73.
[16] Malińska H. and Pietrasz-Kęsik G.: Pamięt. Puław. 1988, **91**, 89–107.
[17] Kowalik S.: Pr. Nauk. Uniwer. Ekonom. Wrocław., Chemia – związki fosforu w chemii, rolnictwie, medycynie i ochronie środowiska. T. Znamierowska (ed.) 2008, **4**(1204), p. 49–59.
[18] Wyszkowski M.: Biul. Magnezol. 2000, **5**(2), 112–123.
[19] Czapla J. and Nowak G.A.: Acta Acad. Techn. Olst., Agric. 1995, **61**, 93–99.
[20] Benedycka Z. and Nowak G.A.: Acta Acad. Tech. Olst., Agric. 1995, **61**, 39–54.
[21] Wyszkowski M. and Wyszkowska J.: J. Elementol. 2004, **9**(1), 61–70.
[22] Gorlach E. and Curyło T.: Roczn. Glebozn. 1990, **41**(1–2), 117–129.
[23] Alvares de Oliveira F., Camargo Camarello Q.A. and Mascarenhas H.A.A.: Sci. Agric. 2001, **58**(2), 34–47.
[24] Poulík Z.: Zesz. Probl. Post. Nauk Rol. 1997, **448**a, 291–296.
[25] Mazur K. and Wiśniowska-Kielian B.: Biul. Magnezol. 1994, **4**, 134–138.
[26] Kuht J. and Reintam E.: Agron. Res. 2004, **2**(2), 187–194.
[27] Woźniak L.: Zesz Nauk. AR w Krakowie, 347, Ses. Nauk. 1999, **62**, 369–374.
[28] Łabuda S., Filipek T. and Dechnik I.: Roczn. Glebozn. 1992, **43**(3/4), 29–36.

WPŁYW DODATKU BAGROWANEGO OSADU DENNEGO DO PODŁOŻA NA WARTOŚĆ PASZOWĄ MATERIAŁU ROŚLINNEGO Cz. 1. ZAWARTOŚĆ MAKROELEMENTÓW

Katedra Chemii Rolnej
Uniwersytet Rolniczy im. Hugona Kołłątaja w Krakowie

Abstrakt: W 2004 i 2005 r. przeprowadzono doświadczenia wazonowe, w których jako podłoża użyto glebę lekką i piasek kwarcowy oraz osad denny bagrowany ze Zbiornika Rożnowskiego. Celem badań była ocena wpływu wzrastających dodatków osadu dennego do podłoża na jakość biomasy uprawianych roślin. Roślinami testowymi były kukurydza i bobik oraz owies i łubin uprawiane po sobie w 2004 r., a w 2005 r. jęczmień uprawiany na tych samych podłożach. Oceny biomasy dokonano na podstawie wartości granicznych dla pasz dobrej jakości, biorąc pod uwagę zawartości makroelementów (P, K Ca, Mg i Na).

Wyniki przeprowadzonych badań wskazują, że biomasa większości roślin testowych zawierała zbyt mało makroelementów z punktu widzenia wykorzystania jej na cele paszowe. Dodatek osadu dennego do gleby lekko kwaśnej tylko nieznacznie zmieniał zawartość magnezu, wapnia, potasu i sodu w biomasie wszystkich roślin testowych, pomimo znacznego zwiększenia ilości tych pierwiastków w podłożu. W przypadku podłoży z piaskiem stwierdzono znaczne zwiększenie zawartości wapnia i magnezu w biomasie roślin. Zaobserwowano zmniejszenie zawartości fosforu w biomasie wszystkich roślin już przy najmniejszym dodatku osadu, przy czym było ono wyraźniejsze w przypadku podłoży z glebą. Większe dodatki osadu nie powodowały już dalszego ograniczenia pobierania fosforu przez rośliny. W drugim roku doświadczenia stwierdzono średnio większe zawartości wszystkich makroelementów w biomasie jęczmienia, co poprawiło jej wartość paszową.

Dodatek osadu do podłoża pogarszał jakość biomasy wszystkich roślin ze względu na małą zawartość fosforu, natomiast zwiększające się ilości wapnia i magnezu poprawiały jakość biomasy uzyskanej w doświadczeniach.

Można zalecić przyrodnicze zagospodarowanie osadu bagrowanego ze Zbiornika Rożnowskiego na glebach lekkich, kwaśnych w celu poprawy ich właściwości fizykochemicznych oraz plonowania i składu chemicznego roślin, przy jednoczesnym monitoringu zawartości substancji szkodliwych w biomasie.

Słowa kluczowe: gleba lekka, piasek kwarcowy, osad denny, makroelementy P, K Ca, Mg, Na, zawartość, jakość biomasy