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POST-EFFECT OF BOTTOM SEDIMENT ADDITION TO THE SUBSTRATUM ON CHEMICAL COMPOSITION OF WHITE MUSTARD (*Sinapis alba* L.) BIOMASS PART 1. MACROELEMENTS CONTENT

NASTĘPCZY WPŁYW DODATKU OSADU DENNEGO DO PODŁOŻA NA SKŁAD CHEMICZNY BIOMASY GORCZYCY BIAŁEJ (*Sinapis alba* L.) CZ. 1. ZAWARTOŚĆ MAKROELEMENTÓW

Abstract: The paper aimed to investigate the effect of bottom sediment supplement to the substratum on chemical composition of cultivated plant biomass considering the optimal macroelements content in plants destined for fodder, as well as an assessment of potential bottom sediment utilization in agriculture. The researched material was the aboveground biomass of white mustard (*Sinapis alba* L.), cultivated in the third year after the application of bottom sediment dredged from the Roznow Reservoir to very light and very acid soil. The experiment was a continuation of research conducted in 2005 and 2006 on: Italian ryegrass (*Lolium multiflorum* L.) and maize (*Zea mays* L.), respectively. The proportion of sediment in the substratum was between 1 and 20 %.

Macroelements content in mustard shoot biomass was diversified depending on the share of bottom sediment in the substratum and ranged as follows: 36.8–47.1 g N, 2.25–5.20 g P, 7.52–47.47 g K, 26.25–42.50 g Ca, 2.3–4.5 g Mg and 1.11–4.67 g Na per 1 kg of dry mass. Among the analyzed elements the most diversified were content of K (V = 51.85 %) and Na (V = 44.53 %), less diverse were P (V = 23.27 %) and Mg (V = 19.73 %), whereas the least diversity was registered in case of N (V = 6.63 %) and Ca (V = 13.27 %).The highest contents of P, Ca and Mg were observed when the share of the sediment in the substratum amounted to 4 %, whereas mustard biomass accumulated the greatest quantities of N and Na when the sediment share in the substratum was 1 % and 3 %, respectively, while K contents were the highest on the control. Bottom sediment supplements to the substratum caused a decline in N, P and K contents at simultaneous increase in Ca and Mg content in mustard biomass in comparison with plants from the control object. A 7 % sediment supplement of the substratum caused an increase in Na content in mustard biomass, whereas a bigger admixture caused a decrease in this element content in comparison with the control.

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Obtained mustard shoot biomass on a majority of treatments revealed excessive contents of P, Ca and Mg and either excessive or too low contents of K and Na.

Applied bottom sediment led to the soil deacidification, positively affected plant yielding, so it may be used for improvement of light acid soils properties but the simultaneous control of plant chemical composition is necessary.

Keywords: bottom sediment, macroelements, N, P, K, Ca, Mg, Na, content

Bottom sediments are counted to by-products formed during recultivation of water reservoirs. Their granulometric composition contains considerable amounts of silt and clay fraction and also phosphorus, nitrogen and calcium compounds [1]. Waste materials such as bottom sediments, sewage sludge or furnace ashes may be a valuable source of minerals for crops. However, their concentrations of toxic substances should be taken into consideration because of their possible entering human food chain [2, 3]. The condition on which these materials may be used in agriculture is analyzing their chemical composition and testing their effect on yielding and quality of plant biomass [4].

Sediments develop on the bottom of a reservoir in result of accumulation of allochtonic deposits carried by the water feeding the reservoir and autochtonic deposits forming in the reservoir. Organic and mineral substances accumulate in bottom sediments. Intensive chemical and microbiological processes occur in their surface layer [5]. Chemical composition of the sediment depends on geological structure of respective catchment, morphological features of the reservoir, climatic conditions and the way of the area management [2].

The aim of the investigations was an assessment of usability of bottom sediment as a source of nutrients for plants and post-effect of its additions to the substratum on the essential macroelements content in the biomass of crops.

Material and methods

The experimental material was the aboveground biomass of mustard (*Sinapis alba* L.) cultivated in pot experiment in the third year after the application of bottom sediment dredged from the Roznow Reservoir to very light and very acid soil with granulometric composition of loose sand. Prior to the experiment outset, the sediment and the soil were dried in the open air, crushed mechanically and sifted. Subsequently their essential properties were assessed and the content of bioavailable P and K forms (Table 1).

Table 1

The basic properties of components of the substrate

Component	pH		Hh [mmol$^{(+)}$ · kg^{-1}]	Organic C	Total N	Bioavailable	
						P_2O_5	K_2O
	KCl	H_2O		[g · kg^{-1}]		[mg · kg^{-1}]	
Sediment	7.20	8.31	—	3.65	1.19	41.3	116
Soil	4.40	5.86	12.2	4.73	0.524	94.3	246

The total content of macroelements was determined in soil and sediment (Table 2).

Tabela 2

Total content of macroelements in components of the substratum

Component	P	Mg	Ca	Na	K
	$[g \cdot kg^{-1}]$				
Sediment	0.532	3.833	17.46	0.973	8.632
Soil	0.333	0.565	1.002	0.091	0.915

Basic parameters of the soil and bottom sediment were determined using commonly applied analytic methods. The experiment was a continuation of former research conducted in 2005 and 2006, when the test plants were Italian ryegrass (*Lolium multiflorum* L.) and maize (*Zea mays* L.), respectively.

The bottom sediment, in doses constituting between 1 and 20 % of the substratum, was added to the soil, whereas the control treatment was very acid light soil without the sediment admixture (Table 3).

Table 3

Share of the components of the substratum in individual objects

Component	Share [%]												
Soil	100	99	98	97	96	95	94	93	92	91	90	85	80
Sediment	0	1	2	3	4	5	6	7	8	9	10	15	20

Substratum mass in each pot was 4 kg. Soil moisture during the experimental period was initially maintained on the level of 40 % and increased to 50 % and 60 % of MWC (*maximum water capacity*) with plant development. Plant vegetation period lasted from 24 April to 12 June. After the vegetation period the plants were harvested, dried and their macroelements contents were assessed using AAS and ICP-AES methods following dry mineralization and ash dissolving in HNO_3 (3:1, v/v).

Results and discussion

The yield of mustard aboveground biomass cultivated on the control treatment (soil without the sediment) was 1.01 g d.m. per pot (Fig. 1).

Admixture of bottom sediment to the soil caused increase in produced mustard aboveground biomass in comparison with the control treatment. The exception was the supplement constituting 1 % of the substratum mass, which caused an apparent worsening of yielding. On the other hand the admixtures of 2–20 % of the substratum mass led to almost linear increase in yields. Supplements of between 9 and 20 % caused significant increase in yields in comparison with the control treatment ($LSD_{0.05}$ = 0.74 g per pot). The yield of mustard shoots reached the highest mass of 8.6 g per pot when the

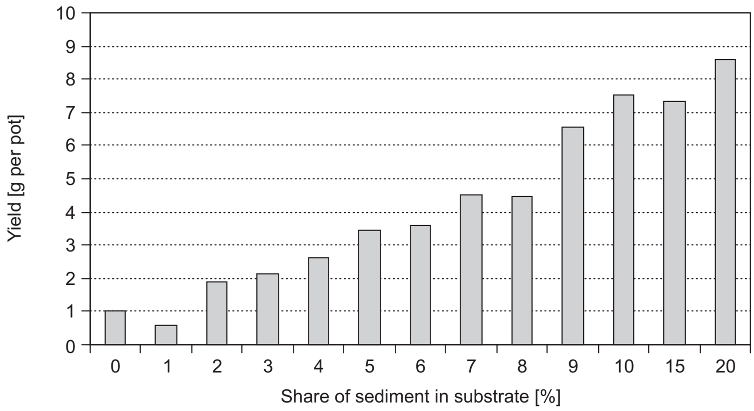

Fig. 1. Yield of the aboveground parts of mustard biomass depended on share of the bottom sediment in the substratum

share of bottom sediment in the substratum was 20 %. Average yield of the mustard shoots was 4.77 g per pot.

The content of N, P, K, Ca, Mg and Na in mustard shoots was presented depending on the bottom sediment share in the substratum. Macroelements content in plant biomass from individual treatments was distinctly diversified (Table 4).

Tabela 4

The statistic parameters of macroelements content in aboveground part of mustard

Parameter	N	P	K	Ca	Mg	Na
	Content [g · kg^{-1} d.m.]					
Minimum	36.8	2.25	7.52	26.25	2.3	1.11
Maximum	47.1	5.20	47.47	42.50	4.5	4.67
Arithmetic mean	42.08	4.16	22.07	34.08	3.58	2.50
Standard deviation	2.79	0.94	12.78	5.07	0.77	1.19
Coefficient of variation [%]	6.63	22.71	57.94	14.87	21.52	47.89

The most frequently stated limit values of macrolements content in plant material destined for animal feeds are: 3.0 g P, 17.0 g K, 7.0 g Ca, 2.0 g Mg and 1.5 g Na · kg^{-1} dry mass [6].

Nitrogen content in mustard shoot mass ranged from 36.8 to 47.1 g N · kg^{-1} d.m., on average 42.08 g N · kg^{-1} d.m. (Table 4, Fig. 2).

Average nitrogen content in plant biomass in the presented experiment was 1.5-fold higher than assessed by Traba et al [7] in legumes from permanent meadows in the San River valley and on the Dynowskie Uppland, on soils formed from alluvial deposits of a mountain river. The aboveground biomass of plant cultivated on the control treatment contained 45.7 g N · kg^{-1} d.m. and it was one of the highest contents in the analyzed plant material, whereas biomass of plants grown in the substratum with 1 % of sediment had the greatest amount of nitrogen (47.1 g N · kg^{-1} d.m.). Larger admixtures led to

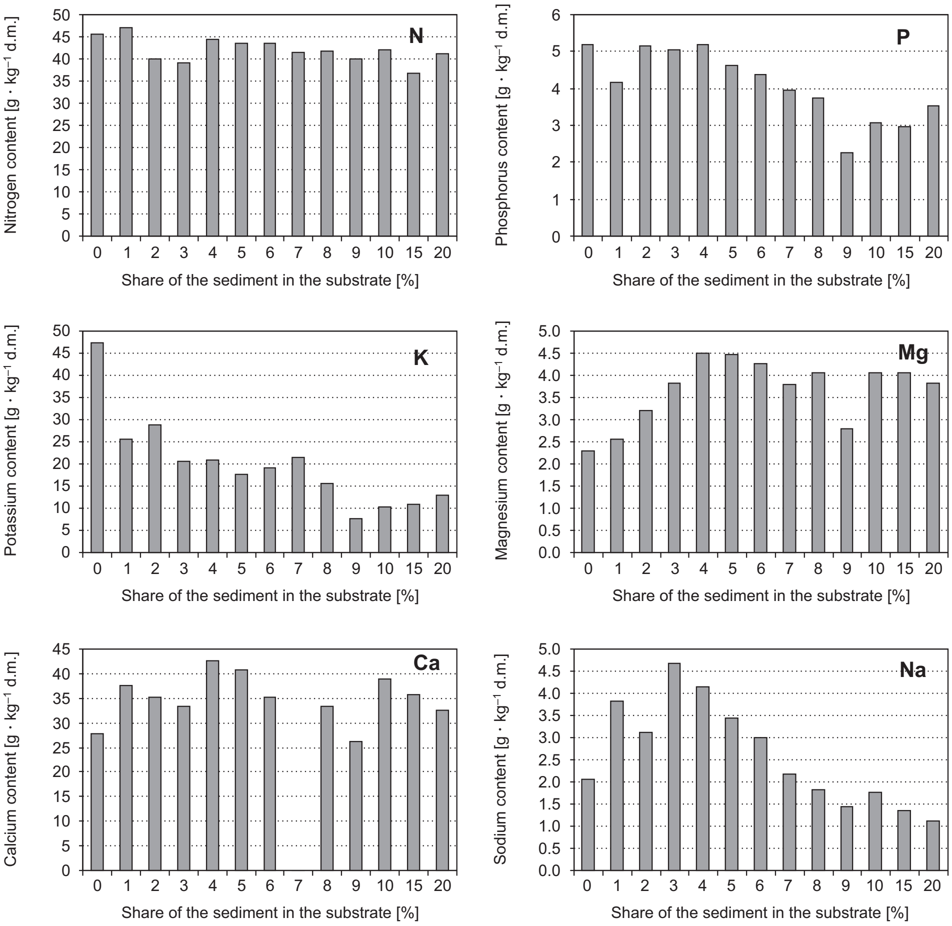

Fig. 2. N, P, K, Mg, Ca and Na content [g · kg^{-1} d.m.] in aboveground biomass of mustard, depending on the share of sediment in the substrate (0 to 20 %)

a decrease in nitrogen content in plant biomass on the substratum with 15 % sediment admixture contained the smallest amounts (36.8 g N · kg^{-1} d.m.).

Underwood [8] states 3.0 g P · kg^{-1} as the optimal amount of phosphorus in plants destined for animal feed. Plant material from all treatments of the presented experiment contained approximated to optimal or higher its amounts but twice exceeded average content of this element assessed by Traba et al [7]. The shoots of mustard grown on the control (soil without the sediment) contained the highest amounts of phosphorus (Fig. 2). Small admixtures of the sediment, between 2 and 4 %, had a similar effect on phosphorus accumulation so its content was not changing clearly after these doses application in comparison with the control. Larger doses caused a decrease in phosphorus content and the smallest amounts were assessed in the biomass of plants grown on the substratum with 9 % admixture of bottom sediment (Fig. 2). Lower content of P at over 9 % sediment supplements might have been due to this macroelement dilution in the plant biomass, which production was larger on the substratum with these additions of bottom sediment.

Potassium content in mustard biomass ranged from 7.52 to 47.47 g K · kg^{-1} d.m., with average of 22.07 g K · kg^{-1} d.m. (Table 4, Fig. 2) which in the Authors' own experiment approximated the average assessed by Kozlowski [9] in his research on fodder value of permanent grassland swards. Mustard cultivated in the soil without any admixture contained the highest amounts of potassium. With increasing share of bottom sediment in the substratum, potassium content was decreasing in comparison with the control object. The aboveground biomass of plant which grew on the substratum with a 9 % supplement of bottom sediment contained the least of potassium. Kopec and Gondek [10] state that the right amount of potassium in hay is *ca* 10 g · kg^{-1} d.m. Considering this criterion the obtained average content of this element was over twice higher than optimum. The content most approximate to the optimal was registered when the sediment share in the substratum amounted 15 %. Using criteria proposed by Falkowski et al [6], plants from objects with share of 3–8 % sediment in substratum contained K quantity approximated to optimum.

Calcium content in the aboveground mustard biomass fell within the range of 26.25 to 42.50 g Ca · kg^{-1} d.m., with the average content of 34.08 g Ca · kg^{-1} d.m. (Table 4, Fig. 2) which was about five-fold higher than the average Ca content assessed by Kalembasa and Godlewska [1] in Italian ryegrass on the control object. Even after the application of 1 % sediment supplement calcium content in biomass raised in comparison with the control. Only the 9 % sediment supplement slightly lowered calcium content in plants in comparison with the control. The highest increase in this element content was observed when sediment admixture to the substratum amounted from 4 to 5 %. Independent on sediment addition, plant biomass contained excessive quantity of calcium as compared with optimal value [6].

Magnesium content in mustard aboveground biomass ranged from 2.25 and 5.20 g Mg · kg^{-1} d.m., (Table 4, Fig. 2) and was about twice higher than this element content assessed by Czyz et al [11] and Wojcikowska-Kapusta [12]. On the other hand, Jones and Eck [13] reported that the most frequent magnesium content determined in maize biomass fluctuates from 2.0 to 6.0 g Mg · kg^{-1} d.m. Mg contents assessed in mustard biomass in the Authors' own research were similar. Plants grown in the soil without any admixtures contained the least quantities of magnesium (Fig. 2). Growing share of the sediment in substratum caused an increase of magnesium content in the aboveground biomass of mustard. The weakest effect was observed in plants growing in the substratum with 9 % share of bottom sediment and the strongest one in these cases when its additions amounted 4–5 %. Plant material from all objects contained optimal quantity of magnesium [6].

Sodium contents in mustard shoot biomass ranged from 1.11 to 4.67 g Na · kg^{-1} d.m. with an average of 2.50 g Na · kg^{-1} d.m. (Table 4, Fig. 2). The mean value was about twice higher than this element contents determined by Czyz et al [11] and over five-fold higher than the average assessed in grass mixture by Antonkiewicz [14]. Mustard cultivated in the soil without sediment addition contained 2.06 g Na · kg^{-1} d.m. (Fig. 2).

Admixtures of bottom sediment between 1 and 7 % caused an increase in sodium content in mustard shoot biomass in comparison with the control, which was the biggest when the share of the sediment in the substratum amounted 3 %. Larger admixtures of the sediment decreased sodium content in the plant and when the sediment share in the substratum raised to 8 % and more, gradual decline in this element content was noted in mustard aboveground biomass, below the amount assessed in mustard grown in the soil without supplements. The least quantities of sodium were noted in plants cultivated in the substratum with 20 % share of the sediment. In majority of objects content of sodium was higher than optimal [6].

The highest contents of P, Ca and Mg in plants were noted when the sediment share in the substratum equaled 4 %, whereas the highest N, Na and K values were registered in mustard from the control object and when the sediment share in the substratum was 1 % and 3 %. Large contents of N, Na and K in plants from these objects might have been caused by a higher content of the elements in smaller biomass produced on soil with acid reaction. When soil reaction increase and the plant biomass production is significantly higher mineral elements dilution may be observed. The similar results obtained Niemiec [15] who studied an effect of the same sediment additions to the soil and sand in amounts increasing from 10 to 90 %.

The greatest diversification of the contents was noted for K and Na, whereas P and Mg contents were much less diversified, and the smallest variability was registered for N and Ca (Table 4). The relative standard deviations assumed the following values: 57.9; 47.9; 22.7; 21.5; 15.0 and 6.6 %, respectively.

Conclusions

1. Increasing bottom sediment supplements to the substratum caused increase in yield of the mustard shoot biomass in comparison with that obtained on the control treatment. The best effects were achieved when the sediment share in substratum amounted to 20 %.

2. The contents of studied macroelements in mustard aboveground biomass fell within the following ranges: 36.8–47.1 g N $\cdot$ kg^{-1}; 2.25–5.20 g P $\cdot$ kg^{-1};7.52–47.47 g K $\cdot$ kg^{-1}; 26.25–42.50 g Ca $\cdot$ kg^{-1}; 2.3–4.5 g Mg $\cdot$ kg^{-1} and 1.11–4.67 g Na $\cdot$ kg^{-1} of dry mass.

3. Additions of bottom sediment to the substratum caused a slight decline in N content in mustard biomass as compared with the control. Higher decreases were registered for P and the greatest for K, which content diminished even after the application of the smallest, 1 % or 2 % sediment additions.

4. Bottom sediment supplements to the substratum caused an increase of Ca and Mg content in mustard biomass in comparison with the plants from the control object.

5. Bottom sediment addition amounting to 7 % caused an increase of Na content in mustard shoot biomass, whereas larger supplements lowered this element content in comparison with the control plants.

6. Considering the optimal macrolement content in animal fodder, obtained mustard shoot biomass did not meet the fodder usability criteria on most treatments due to

excessive amount of P, excessive or too low content of K and Na. Biomass from all experimental treatments revealed too high Ca and Mg content.

7. Applied bottom sediment caused soil deacidification and improved plant yielding, so it may be used for improving the properties of light acid soils, but simultaneous control of the plant chemical composition is necessary.

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NASTĘPCZY WPŁYW DODATKU OSADU DENNEGO DO PODŁOŻA NA SKŁAD CHEMICZNY BIOMASY GORCZYCY BIAŁEJ (*Sinapis alba* L.) CZ. 1. ZAWARTOŚĆ MAKROELEMENTÓW

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Abstrakt: Celem pracy było zbadanie wpływu dodatku osadu dennego do podłoża na skład chemiczny biomasy uprawianych roślin biorąc pod uwagę optymalne zawartości makroelementów w roślinach przeznaczonych na paszę oraz ocena możliwości rolniczego wykorzystania osadu dennego. Materiał do badań stanowiła nadziemna biomasa gorczycy białej (*Sinapis alba* L.), uprawianej w trzecim roku po zastosowaniu osadu dennego bagrowanego ze Zbiornika Rożnowskiego do gleby bardzo lekkiej oraz bardzo kwaśnej. Doświadczenie było kontynuacją badań prowadzonych w latach 2005 i 2006, w których roślinami testowymi były kolejno życica wielokwiatowa (*Lolium multiflorum* L.) i kukurydza (*Zea mays* L.). Udział osadu w podłożu wynosił od 1 do 20%.

Zawartość makroelementów w nadziemnej biomasie gorczycy była zróżnicowana w zależności od udziału osadu dennego w podłożu i mieściły się w zakresach 36,8–47,1 g N, 2,25–5,20 g P, 7,52–47,47 g K, 26,25–42,50 g Ca, 2,3–4,5 g Mg i 1,11–4,67 g Na w 1 kg suchej masy. Spośród badanych pierwiastków najbardziej zróżnicowana była zawartość K (V = 51,85 %) i Na (V = 44,53 %), w znacznie mniejszym stopniu zawartość P (V = 23,27 %) i Mg (V = 19,73 %), a najmniejsze zróżnicowanie zanotowano w przypadku Ca (V = 13,27 %) i N (V = 6,63 %). Największe zawartości P, Ca i Mg zaobserwowano, gdy udział osadu w podłożu wynosił 4 %, a najwięcej N i Na zawierała biomasa gorczycy, gdy udział osadu w podłożu wynosił odpowiednio 1 % i 3 %, a K w roślinach z obiektu kontrolnego. Dodatki osadu dennego do podłoża powodowały zmniejszenie zawartości N, P oraz K, jednocześnie następowało zwiększenie zawartości Ca i Mg w biomasie gorczycy w porównaniu z roślinami z obiektu kontrolnego. Dodatek do 7 % osadu do podłoża powodował wzrost zawartości Na w biomasie gorczycy, a większe dodatki wywołały obniżenie zawartości tego pierwiastka w porównaniu z roślinami wyrosłymi w obiekcie kontrolnym. Uzyskana nadziemna biomasa gorczycy z większości obiektów cechowała się nadmierną zawartością P, Ca i Mg oraz nadmierną lub za małą zawartością K i Na.

Zastosowany osad denny powodował odkwaszanie gleby, oddziaływał pozytywnie na plonowanie roślin, dlatego można go użyć do poprawy właściwości gleb lekkich kwaśnych, jednocześnie jest konieczna kontrola składu chemicznego roślin.

Słowa kluczowe: osad denny, makroelementy, N, P, K, Ca, Mg, Na, zawartość