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POST-EFFECT OF BOTTOM SEDIMENT ADDITION TO THE SUBSTRATUM ON CHEMICAL COMPOSITION OF WHITE MUSTARD (*Sinapis alba* L.) BIOMASS Part 2. QUANTITATIVE RATIOS BETWEEN MACROELEMENTS*

NASTĘPCZY WPŁYW DODATKU OSADU DENNEGO DO PODŁOŻA NA SKŁAD CHEMICZNY BIOMASY GORCZYCY BIAŁEJ (*Sinapis alba* L.) Cz. 2. STOSUNKI ILOŚCIOWE MIĘDZY MAKROELEMENTAMI*

Abstract: The aim of the work was an assessment of a bottom sediment supplement to the substratum on the composition of plant biomass determined on the basis of quantitative relationships between macroelements. The experiment was a continuation of previous research conducted in 2005 and 2006, when the test plants were: Italian ryegrass (*Lolium multiflorum* L.) and maize (*Zea mays* L.), respectively. The quality of white mustard (*Sinapis alba* L.) shoot biomass cultivated in the third year after the application of bottom sediment dredged from the Roznow Reservoir was assessed. The sediment was added to the soil in quantities constituting between 1 and 20 % of the substratum mass. Macroelement content was determined in the obtained material and subsequently weight ratios Ca : P, Ca : Mg, K : Ca, K : Mg and K : Na, as well as K : (Ca + Mg) ionic ratio were computed.

A considerable diversification of relationships between macroelements was revealed in mustard shoot biomass growing on substrata with diverse share of bottom sediment. In white mustard biomass from the control treatment (soil without sediment addition) K:Ca ratio assumed a value close to optimal, Ca : P, K : Mg and K : Na ratios were about 3-fold higher, Ca : Mg was 4-fold higher than optimal, whereas K : (Ca + Mg) ratio was over twice lower than optimal. Increasing share of the sediment in the substratum generally caused a widening of Ca : P ratio and narrowing of K : Ca, K : Mg, K : Na, Ca : Mg and K : (Ca + Mg) ratios in mustard biomass. The changes led to a serious worsening of Ca : P, K : Ca and K : (Ca + Mg) ratios in mustard biomass but caused a marked improvement of K : Mg and K : Na ratios bringing them close to the optimum. They also bettered Ca : Mg ratio but did not lead it to the optimal value. The reason of worsening Ca : P, K : Ca and K : (Ca + Mg) ratios was a large Ca content in plant biomass resulting from a relatively high its content in bottom sediment despite applied NPK mineral fertilization and the antagonism among the

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elements. The cause of modification of the relationships between the elements may be changes of the substratum pH resulting from bottom sediment addition to the soil, particularly in the range of between 3 to 20 % which induced a raise in pH value, proportional to the sediment share in the substratum. The highest sediment admixtures led the substratum pH to approximate neutral.

Bottom sediment dredged from the Roznow Reservoir may be used for improvement of light acid soil properties, but it may cause a worsening of the weight ratios between calcium and other macroelements, particularly P and K.

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

Fodder plant production makes use of fertilizers which affect chemical composition of plants and nutrient resources in soil. Qualitative and quantitative changes of mineral elements occurrence in plants are determined by such factors as the species and development stage of a plant, the weather changing during their growth and development as well as soil properties. Therefore, it is necessary to assess plant chemical composition, also with reference to mineral components [1].

Macroelement content in fodder and proper ratios between them condition animal health. As reported by Czuba and Mazur [2] optimal ratios between individual elements should be as follows: Ca : P = 2 : 1, Ca : Mg = 2 – 3 : 1, K : Mg = 6 : 1, K : Ca = 2 : 1 and K : Na = (5–8) : 1. The quality indicator used for the assessment of plant nutritional value of ruminant feed K :(Ca + Mg) should be 1.62 but may not exceed 2.2 [3].

The aim of the investigations was an assessment of post-effect of bottom sediment additions to the substratum on the quantitative ratios between essential macroelements in obtained plant biomass and indirectly the estimation of possibility of agricultural application of this sediment.

Material and methods

The researched material was shoot biomass of white mustard (*Sinapis alba* L.) cultivated in pot experiment in the third year after the bottom sediment, dredged from the Roznow Reservoir, application to very light and very acid soil. The experiment continued the research conducted in 2005 and 2006 on test plants, first Italian ryegrass (*Lolium multiflorum* L.) and then maize (*Zea mays* L.).

Before the experiment, the sediment and soil were air-dried, crushed mechanically and sifted and then their essential properties and bioavailable forms of P and K were determined (Table 1 and 2).

Table 1

The basic properties of components of the substrate

Component	pH		Hh	C_{org}	N_{tot}	Bioavailable	
						P_2O_5	K_2O
	KCl	H_2O	$[mmol^{(+)} \cdot kg^{-1}]$	$[g \cdot kg^{-1}]$		$[mg \cdot kg^{-1}]$	
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

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

Bottom sediment was added to the soil in the amounts constituting between 1 and 20 % of the substratum mass, whereas the control treatment was light, very acid soil without the sediment addition (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

After harvesting mustard shoot biomass was dried and ground, and in the material prepared in this way macroelement content was determined by means of AAS and ICP-AES methods after previous dry mineralization and ash dissolving in HNO_3 (3:1, v/v). On the basis of macroelements content the reciprocal quantitative ratios between them were calculated.

Results and discussion

The contents of analyzed macroelements in the aboveground mustard biomass were assessed in the following ranges: (36.8–47.1) g N, (2.25–5.20) g P, (7.52–47.47) g K, (26.26–42.50) g Ca, (2.3–4.5) g Mg and (1.11–4.67) g Na in 1 kg of dry mass [4].

The quality of plant material is determined not only by the absolute element content but also by the quantitative relationships between them. Many authors point to the ratios between elements in plants due to various interactions between them, which may causes element deficiencies, even when their contents are regarded as adequate [1, 5, 6]. The quality of obtained plant biomass was determined on the basis of quantitative ratios between mineral elements content in aboveground parts of white mustard. The most frequently assessed are weight ratios: Ca : P, Ca : Mg, K : Ca, K : Mg and K : Na as well as ionic ratio K : (Ca + Mg).

Value of weight Ca : P ratio in good quality plant material should be 2 : 1 [1]. In biomass of mustard obtained on the soil without the sediment supplement, the ratio was almost thrice higher than the optimal (Fig. 1). Subsequent additions of the sediment led to further widening of this ratio, from 3.6 to about 6 times larger in comparison with the optimal value.

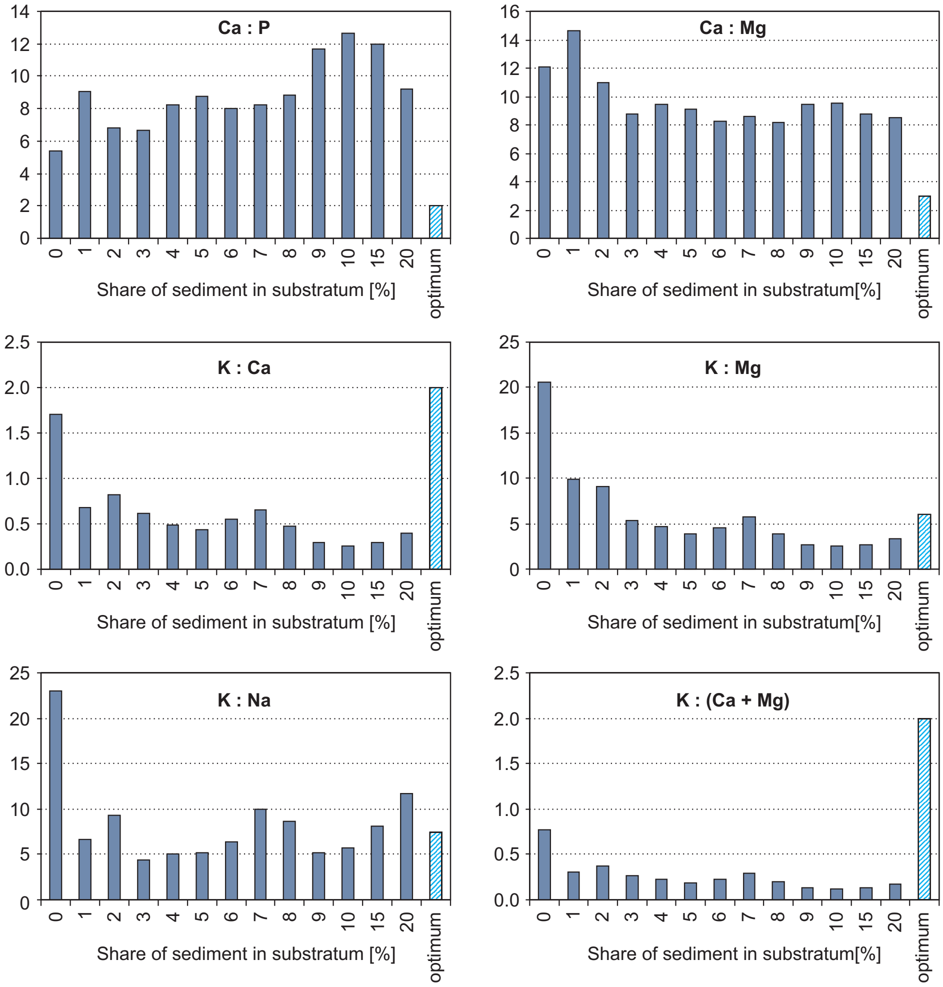

Fig. 1. Values of reciprocal ratios between individual elements in the aboveground biomass of mustard depending on the share of sediment in the substratum

Mustard revealed a disadvantageous value of Ca : Mg weight ratio, because the right one should be 3 : 1 [5] (Fig. 1). Weight Ca : Mg ratio in mustard biomass from all studied treatments exceeded the optimal value between 2.5 and 5-fold. The least difference in relation to the optimal value might be observed in the plants grown in treatment with 8 % share of the sediment in the substratum and the greatest when sediment share amounted 1 %.

K : Ca weight ratio in the analyzed plant biomass assumed too low values (Fig. 1). Only on the soil without the sediment supplement this ratio was close to optimal, *ie* 2 : 1, whereas successive sediment additions caused its narrowing and then it assumed the values between 2.5 to 10-fold smaller than optimum.

In shoot biomass of mustard grown in the control and in the treatment with the smallest sediment additions to the substratum (1; 2) % K content in relation to Mg was excessive (Fig. 1). In mustard grown on treatments with 3 and 7 % suplements of bottom sediment to the substratum K:Mg weight ratio was 6:1, *ie* close to optimal. In plant material from the other treatments the ratio had value between about 30 and 60 % lower than optimal.

K : Na weight ratio in good quality plant material should be (5–8) : 1 [1, 5]. In about 60 % of samples the ratio had value approximate to optimal. In about 40 % samples K : Na ratio indicated an excessive K content in relation to Na (Fig. 1), therefore it was by 30 % to 300 % higher than optimal.

K : (Ca + Mg) ratio in good quality plant material should be 2 : 1 [1]. In this respect mustard shoot biomass revealed unsatisfactory quality (Fig. 1). The highest value of this ratio was observed in the control plants, however it was about twice lower than the optimal. K : (Ca + Mg) ratio assumed the lowest value when sediment share in the substratum amounted 10 % and it was about 17-fold lower than the optimal value of this ratio.

Too big prevalence of calcium over phosphorus, potassium and magnesium in the assessed plant material may be explained by the fact that the sediment already contained considerable amounts of this element, *ie* 17.46 gCa $\cdot$ kg^{-1}. Lower content of K in relation to Ca and Mg may be explained by the antagonism of these elements. Sediments from dam reservoirs as well as from lakes are characterized by a great share of silt and clay fractions in their granulometric composition, reaching around 50 % each [7, 8], relatively high pH values, corresponding to neutral reaction [9], and high calcium content, up to 125.93 gCa $\cdot$ kg^{-1} d.m., even in case of pH lower than 6.5 [10]. In Authors own studies addition of bottom sediment to the soil caused changes of reaction depending on its share in the substratum (Fig. 2).

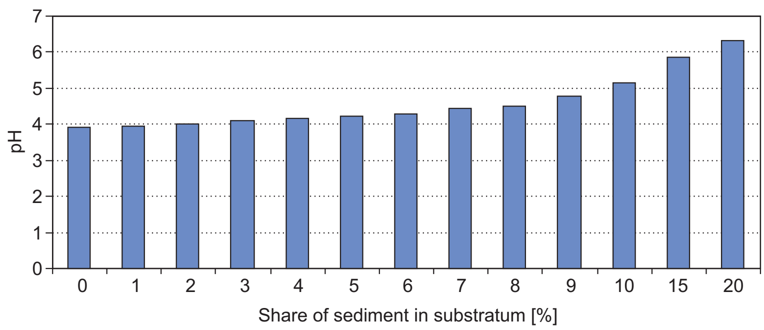

Fig. 2. pH value of substratum after white mustard harvest depending on a share of bottom sediment

An addition of 1 and 2 % of the sediment did not bring about any visible changes of the soil reaction, only bigger supplements, from 3 to 20 % caused a linear growth of pH value, proportionally to the amount of added sediment. Application of the highest additions of the sediment brought the substratum reaction to almost neutral.

Quantitative ratios between the macroelements in most cases were improper. Niemiec [11] obtained similar interrelationships in his research on potential environmental applications of bottom sediment. An addition of bottom sediment improved K : Mg and K : Na ratio, but worsened calcium relation to other macroelements. Causes of these dependencies should be sought in relatively high calcium contents in the used sediment.

Conclusions

1. In mustard biomass from the control treatment (soil without bottom sediment addition) only K : Ca weight ratio approximated the optimal value, Ca : P, K : Mg and K : Na weight ratios assumed thrice higher values, Ca : Mg was four-fold higher than optimal, whereas K : (Ca + Mg) ionic ratio was over twice lower than the optimum.

2. Increasing share of sediment in the substratum generally caused a widening of Ca : P ratio and narrowing of K : Ca, K : Mg, K : Na, Ca : Mg and K : (Ca + Mg) ratios in mustard aboveground biomass. The changes led to a considerable worsening of Ca : P, K : Ca and K : (Ca + Mg) ratios and to an apparent improvement of K : Mg and K : Na ratios approximating them to the optimum. They also improved Ca : Mg ratio but did not bring this relationship to the optimal value.

3. The reason for worsening of Ca : P, K : Ca and K : (Ca + Mg) ratios was an excessive Ca content in the plant biomass resulting from a relatively high Ca amount in bottom sediment, despite the applied mineral NPK fertilization and the antagonism between the elements.

4. The cause of modification of the rations between the macroelements may be changes of the substratum reaction due to an addition of bottom sediment to the soil, particularly within the (3–20) % range, which caused an increase in pH value, proportional to the sediment share in the substratum. The highest sediment additions approximated the substratum pH almost to neutral.

5. Bottom sediment dredged from the Roznow Reservoir may be used for improvement of light acid soil properties, however, it may cause worsening of weigh rations between calcium and the other macroelements, particularly P and K.

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Abstrakt: Celem pracy była ocena oddziaływania dodatku osadu dennego do podłoża na skład biomasy roślinnej ocenianej na podstawie stosunków ilościowych między makroelementami. Badania były kontynuacją doświadczeń prowadzonych w latach 2005 i 2006, w których roślinami testowymi były kolejno życica wielokwiatowa (*Lolium multiflorum* L.) i kukurydza (*Zea mays* L.). Oceniano jakość nadziemnej biomasy gorczycy białej *(Sinapis alba* L.), uprawianej w trzecim roku po zastosowaniu osadu dennego bagrowanego ze Zbiornika Rożnowskiego. Osad dodawano do gleby w ilości od 1 do 20% masy podłoża. W uzyskanym materiale roślinnym oznaczono zawartość makroelementów, a następnie obliczono stosunki masowe Ca : P, Ca : Mg, K : Ca, K : Mg i K : Na oraz stosunek jonowy K : (Ca + Mg).

Wykazano znaczne zróżnicowanie stosunków między makroelementami w nadziemnej biomasie gorczycy rosnącej na podłożach ze zwiększającym się udziałem osadu dennego. W biomasie gorczycy białej z obiektu kontrolnego (gleba bez dodatku osadu dennego) stosunek K : Ca przyjmował wartość bliską optymalnej, stosunki Ca : P, K : Mg i K : Na – około 3-krotnie wyższe, a Ca : Mg – 4-krotnie wyższy niż optymalne, natomiast stosunek K : (Ca + Mg) miał wartość ponad 2-krotnie niższą od optymalnej. Wzrastający udział osadu w podłożu powodował na ogół rozszerzenie stosunku Ca : P oraz zacieśnienie stosunków K : Ca, K : Mg, K : Na, Ca : Mg i K : (Ca + Mg) w biomasie gorczycy. Zmiany te prowadziły do znacznego pogorszenia stosunków Ca : P, K : Ca i K : (Ca + Mg) w biomasie gorczycy oraz wyraźnej poprawy stosunków K : Mg i K : Na, których wartość zbliżała się do optimum, a także Ca : Mg, jednak nie doprowadzając tej relacji do wartości optymalnej.

Przyczyną pogorszenia stosunków Ca : P, K : Ca i K : (Ca + Mg) jest duża zawartość Ca w biomasie roślin wynikająca ze względnie dużej zawartości Ca w osadzie dennym, mimo zastosowanego nawożenia mineralnego NPK oraz antagonizm między pierwiastkami. Przyczyną modyfikacji relacji między makroelementami mogą być zmiany odczynu podłoża w następstwie dodatku osadu dennego do gleby, zwłaszcza wynoszącego (3–20) % masy podłoża, które powodowały wzrost wartości pH proporcjonalny do udziału osadu. Największe dodatki osadu doprowadzały odczyn podłoże do zbliżonego do obojętnego.

Osad denny bagrowany ze Zbiornika Rożnowskiego może być użyty do poprawy właściwości gleb lekkich kwaśnych, może jednak powodować pogorszenie się stosunków masowych między wapniem a pozostałymi makroelementami, zwłaszcza P i K.

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