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CONTENT OF ZINC IN PLANTS DEPENDING ON ITS FRACTIONAL COMPOSITION IN SOIL AND PROPERTIES OF SOIL

ZAWARTOŚĆ CYNKU W ROŚLINACH W ZALEŻNOŚCI OD JEGO SKŁADU FRAKCYJNEGO W GLEBIE ORAZ WŁAŚCIWOŚCI GLEBY

Abstract: Metals in soils occur in different forms, which are more or less mobile, which means bioavailable. The aim of this study was to assess the content of zinc in cultivated plants, depending on soil properties but also its content in soil and fractions in typical and unpolluted region, which is the Podlasie Province. The research material consisted of samples taken from arable soil in 81 points of Podlasie Province. Basic physicochemical properties and content of soil fraction < 0.02 mm in samples were determined. Pseudo-total content of zinc and its fractional composition in soil as well as zinc content in plants was evaluated. Correlation coefficients between the content of zinc in plants and physicochemical properties of soil were calculated.

It was found that examined soil contained natural amount of zinc, characteristic for uncontaminated soils. The most of zinc was associated with the organic matter fraction and the least with residual fraction. Among the analysed plants from light soils, the most of zinc was found in rye. Plants from medium-heavy soils contained similar amount of zinc, with the exception of maize. Correlation coefficients do not confirm the significant relationship between soil properties and zinc in plants. Significant relationship was stated between bioaccumulation factors and the content of zinc in plants.

Keywords: zinc in plant, soil, BCR method, zinc fraction

Introduction

Zinc – apart from boron, manganese, molybdenum and copper, belongs to the most important micronutrients for plants, but together with its increasing content, it belongs

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to dangerous elements for living organisms. It is one of the most mobile metals in soil [1, 2]. It is known that in soils it occurs in a variety of forms that are more or less mobile, and in the same way bioavailable. Zinc mobility is mainly determined by the physicochemical properties of soils, pH, organic matter content and granulometric composition [3]. The intensity of agrotechnical management is not without significance. Zinc uptake by plants is proportional to the content of available forms in soil [4, 5].

The aim of this study was to assess the content of zinc in plants, depending on soil properties but also its content and fractional composition in soils of unpolluted region, which is Podlasie Province.

Materials and methods

The research material consisted of samples taken from arable soil in 81 points of Podlasie Province. One point was selected in the majority of its districts. Each point was located on mineral soil used as arable land, without external source of contamination, like roads or industrial plants. The samples were collected from arable layer (0–30 cm) after plant harvest. Maize was cultivated in 14 points, cereals in 57 points and grass in 10 ones. The following basic physicochemical properties in soil samples were determined: granulometric composition by particle analyser, content of organic carbon by Tiurin's method and pH potentiometrically in 1 mol · dm^{-3} KCl suspension. Based on the content of soil fraction < 0.02 mm, soils were divided into two groups: very light and light and medium-heavy soils. The pseudo-total content of zinc was determined after mineralization in *aqua regia*, by means of FAAS technique using Varian AA-100 apparatus. Zinc fractions were evaluated using the BCR method. Extraction included four stages: acid soluble and exchangeable fraction (fraction I), reducible fraction, bound to Fe/Mn oxides (fraction II), oxidizable fraction, bound to organic matter (fraction III) and residual fraction (fraction IV). The scheme of extraction was described in detail in the article, which is in press [6].

From the points where soil samples were collected to the analysis, the following plants were also taken: cereal grains, maize for silage and grass on field crops. The content of zinc in plants was determined, after previous digestion in microwave oven, by means of FAAS technique using Varian AA-100 apparatus. Bioaccumulation factors were calculated as the ratio of zinc content in plants to the pseudo-total zinc content in soils. Correlation coefficients between zinc content in plants and physicochemical properties of soil, zinc fractions and bioaccumulation factors were determined.

Results and discussion

The granulometric composition of soil from both groups was slightly differentiated. The content of soil fraction < 0.02 mm in very light and light soil ranged from 4.0 to 17.0 %, 12.0 % on average, and in medium-heavy soil – 22.0 % on average, with the range of 21.0–28.0 % (Table 1).

Table 1

Physicochemical properties of soils

Soil	Value	Content of soil fraction < 0.02 mm	pH	Organic carbon	Pseudo-total content of Zn
		[%]		[g · kg^{-1}]	[mg · kg^{-1}]
Very light and light n = 35	range	4.0–17.0	4.0–7.6	6.0–31.0	13.5–52.5
	$\bar{x}$	12.0		16.0	32.4
Medium-heavy n = 46	range	21.0–28.0	4.1–7.8	7.0–42.0	14.5–58.8
	$\bar{x}$	22.0		24.0	35.1

The pH of the first group of studied soils was very differentiated and varied from 4.0 to 7.6. Among 35 soil samples, twelve were very acid (pH < 4.5), eight were acid (pH 4.6–5.5), nine were slightly acid (pH 5.6–6.5) and the rest 6 soil samples were neutral (pH 6.6–7.2). Medium-heavy soils were characterized by higher pH values. Only three samples were counted to very acid soils, eleven samples were acid and the rest were light acid and neutral. Investigated soils were typical for Podlasie Province, which typical soils are light and acid ones.

The content of organic carbon in both groups of soil was differentiated. In very light and light soils ranged from 6.0 to 31.0 g · kg^{-1} (16.0 g · kg^{-1} on average). In medium-heavy soils, there was more carbon – 24.0 g · kg^{-1} on average, with the range of 7.0–42.0 g · kg^{-1}.

The pseudo-total content of zinc in very light and light soils ranged from 13.5 to 52.5 mg · kg^{-1} (32.4 mg · kg^{-1} on avarage). In the second group of soils (medium--heavy) the average pseudo-total content of zinc was slightly higher than in very light and light group and ranged from 14.5 to 58.8 mg · kg^{-1}. This diversity indicates the correlation of pseudo-total zinc and granulometric composition of soil. The pseudo-total content of zinc in studied soils corresponds to the natural content in soils of Poland [8]. It is in terms of the results given by Skorbilowicz et al [9]. He claims that total zinc in acid soils of Podlasie Province was in the range from 13.2 to 54.8 mg · kg^{-1}. The content of zinc in analysed soils in individual fractions was differentiated (Fig. 1). In a group of very light and light soils, the content of fraction I (exchangeable) ranged from 5.0 to 19.1 mg · kg^{-1} (10.2 mg · kg^{-1} on average), which makes 32 % of total content. This fraction contains the most available part of zinc, which consists of zinc in soil solution and the exchangeable one but also bound with carbonates. In medium-heavy soils, the content of this fraction was slightly less than in very light and light soils. While more zinc in medium-heavy soils was bound with iron and manganese oxides (fraction II), the organic matter (fraction III) and residual fraction (fraction IV). Average content in fraction II was 13.1 mg · kg^{-1} (from 2.4 to 26.9 mg · kg^{-1}), and in fraction III – 14.9 mg · kg^{-1} on avarage. The least amount of zinc was in residual fraction and the most in fraction of organic matter.

Kalembasa and Pakula [10] determined the content of zinc in grey-brown podzolic soils of south Podlasie Province with the use of Tessier's method and obtained different

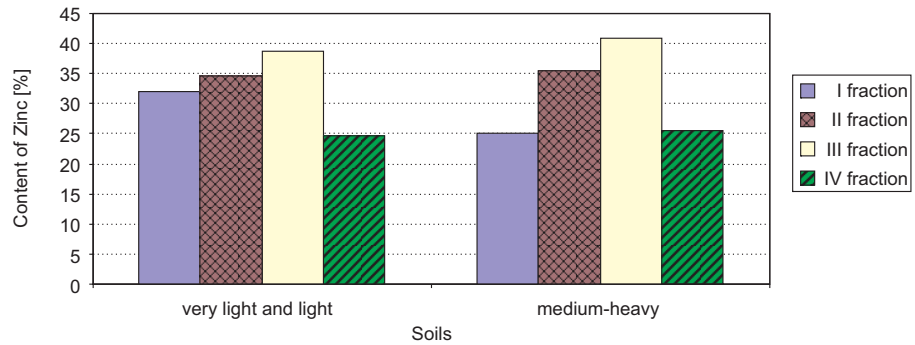

Fig. 1. Zinc percentage in pseudo-total content, in very light, light and medium-heavy soils

results in relation to those shown in Authors' own studies. In the humus layer, the most of zinc was in the residual fraction, and less in the fraction bonded with the organic matter and exchangeable fraction.

The content of zinc in cultivated plants reached the range from 11.0 to 40.2 mg · kg^{-1} d.m. depending on the species and the content of soil fraction < 0.02 mm (Table 2). The average content of this microelement was similar in the analysed species grown on very light and light soils. In cultivated plants from medium-heavy soils, content of zinc was less (a few mg on average) than in plants from very light soils. Among cereal plants, the most zinc contained rye grain cultivated on very light and light soils, and other cereals had similar content. Similar contents of this element among the crops grown on medium-heavy soils had a mixture of cereals, triticale and oat. The least Zn amount contained wheat, which appeared only on medium-heavy soils.

Table 2

Content of zinc in plants

Soils	Value	Maize for silage	Grasses	Mixture of corns	Triticale	Oat	Rye	BF*
		[mg · kg^{-1} d.m.]						
Very light and light n = 35	range	19.6–36.2	21.3–36.7	22.9–35.2	15.7–36.5	19.0–34.5	23.9–36.7	0.4–2.1
	$\bar{x}$	27.7	25.6	26.5	27.5	27.3	29.8	2.9
	n	7	5	7	5	6	5	
							Wheat	
Medium--heavy n = 46	range	11.0–30.1	16.1–24.5	21.2–33.9	19.6–40.2	22.7–29.9	17.4–27.8	0.3–2.1
	$\bar{x}$	19.6	23.5	25.0	25.7	25.5	23.2	0.7
	n	7	8	15	7	4	5	

* BF – Bioaccumulation factor.

The content of zinc in plants is determined by many factors and according to Terelak and Lipinski [11], there are mainly pH of soils, clay content and organic matter. The

difference of zinc content between plants from light soils and those from medium-heavy soils is caused by the physicochemical properties of two groups of soils. It is confirmed by the contents of this element in maize. Zinc content in maize from very light and light soils was higher than in the one from the medium-heavy soil, and this is mainly caused by the reaction of these soils (there were more acid soils). These results are consistent with observations of Kaniuczak et al [12]. The authors have proved that liming causes the reducing of zinc content in potato tubers and forage of sunflower.

The average zinc content in analysed cereals was located in the lower level of content for cereals grown in Poland, which in wheat ranged from 24.2 to 47.0 mg · kg^{-1} d.m., according to Terelak and Lipinski [11]. Similar content in cereals in other countries was determined by Cubadda et al [13] as well as by Vijayan et al [14], while Wlasniewski [15] provides a wider range of Zn content in wheat, from 23.8 to 72.7 mg · kg^{-1} d.m. According to many authors [4, 5, 11, 15] the content of zinc in plants depends on this element content in soil, and especially on the content of its available forms.

Correlation coefficients between zinc content in plants and content in fractions, in both groups of soils, were low and not significant (Table 3).

Table 3

Correlation coefficients

Variable	Zn in plant [mg · kg^{-1} d.m.]	
	Very light and light soils	Medium-heavy soils
Pseudo-total Zn [mg · kg^{-1}]	0.06	–0.08
Fraction I [%]	–0.21	0.03
Fraction II [%]	–0.30	–0.11
Fraction III [%]	0.04	0.03
Fraction IV [%]	0.27	–0.01
Content of soil fraction < 0.02 mm [%]	0.29	0.02
Bioaccumulation factor	0.50*	0.71*
pH	0.26	–0.07
Organic carbon [g · kg^{-1}]	–0.27	–0.09

* – significant for $p \leq 0.05$.

Jeske and Gworek [16] discussing the method of bioavailability determination of heavy metals in soils, claim that the results of the research does not indicate the existence of strong relationship between the occurrence of bioavailability of metals and their contents in plants. The authors argue that the correlations are not observed very commonly or are not significant, which is proved by the obtained results. Correlation coefficients do not confirm the significant relationship between soil properties such as pH, content of soil fraction < 0.02 mm and the content of organic carbon and zinc in plants. Significant relationship between the value of bioaccumulation factor and zinc content in plants was stated (Table 3, Fig. 2).

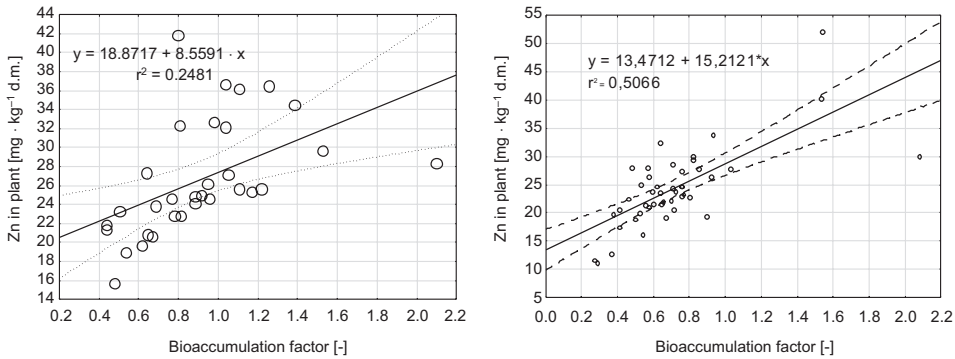

Fig. 2. Relationship between the content of Zn in plants and the bioaccumulation factor (a – very light and light soils, b – medium-heavy soils)

Conclusions

1. Analysed soils contained natural amount of zinc, which is characteristic for uncontaminated soils.

2. The highest content of zinc was stated in fraction bound with organic matter, and the lowest in residual fraction in both groups of soils.

3. Among analysed plants from light soils, the highest content of zinc was observed in rye. Plants from medium-heavy soils contained similar amount of zinc, except of maize.

4. Significant relationship between zinc content in plants, soil properties and zinc fractions was not stated. Significant correlation was observed only in the case of bioaccumulation factors.

Acknowledgements

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Abstrakt: Metale występują w glebie w różnych formach, które są bardziej lub mniej rozpuszczalne, a tym samym w różnym stopniu biodostępne. Celem pracy było określenie zawartości cynku w roślinach uprawnych w województwie podlaskim, w zależności od właściwości gleby oraz jego zawartości w glebie i w poszczególnych frakcjach. Materiał badawczy stanowiły próbki gleb i roślin uprawnych pobrane w 81 punktach woj. podlaskiego. W próbkach oznaczono podstawowe właściwości fizykochemiczne gleby, określono kategorię agronomiczną gleb i podzielono je na dwie grupy: gleby bardzo lekkie i lekkie oraz gleby średnie. Oznaczono zawartość cynku w roślinach oraz zbliżoną do ogólnej jego zawartość w glebie i skład frakcyjny. Obliczono współczynniki korelacji między zawartością cynku w roślinach a właściwościami fizykochemicznymi gleb i frakcjami cynku w glebie oraz jego współczynnikami bioakumulacji.

Stwierdzono, że badane gleby zawierały naturalne ilości cynku, charakterystyczne dla gleb niezanieczyszczonych. Zawartość cynku w poszczególnych frakcjach układała się w następujący szereg: frakcja związana z substancją organiczną > frakcja związana z tlenkami i wodorotlenkami > frakcja wymienialna > frakcja rezydualna. Wśród analizowanych roślin uprawianych na glebach lekkich najwięcej cynku zawierało żyto. Rośliny uprawiane na glebach średnich, z wyjątkiem kukurydzy, zawierały zbliżone ilości cynku. Nie stwierdzono istotnych zależności pomiędzy zawartością cynku w roślinach a właściwościami gleb. Istotne zależności wystąpiły tylko w przypadku współczynnika bioakumulacji.

Słowa kluczowe: cynk w roślinie, gleba, metoda BCR, frakcje cynku