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ACCUMULATION OF SELENIUM BY WINTER WHEAT (*Triticum aestivum* L.) AS THE RESULT OF LONG-TERM FARMYARD MANURE FERTILIZATION

AKUMULACJA SELENU PRZEZ PSZENICĘ OZIMĄ (*Triticum aestivum* L.) POD WPŁYWEM WIELOLETNIEGO NAWOŻENIA NAWOZEM NATURALNYM

Abstract: The objective of this study was to determine the selenium content in soil and its accumulation and distribution in winter wheat plants affected by organic fertilization. There was found a significant effect of FYM application on the total selenium in soil. The total selenium content in soil was significantly correlated with organic carbon content. The highest selenium concentrations were observed in aboveground biomass of winter wheat gathered from plots treated with FYM with the doses of 20 and 40 Mg · ha⁻¹, which was about 70% higher in comparison with the control plants. The selenium content in winter wheat roots from the control plots was on average above 30% higher than from the FYM plots.

Keywords: selenium, soil, winter wheat, organic fertilization

The concentration of selenium in plants depends on the chemical form of Se, its concentration and bioavailability in soils and on the accumulation capacity of the plant [1]. Although all the plants are able to take up and to metabolize selenium, the assumption about its necessity for plants has not been fully confirmed yet. Numerous studies have shown that at low concentrations Se exerts a beneficial effect promoting growth and increasing stress tolerance of plants by enhancing their antioxidative capacity, reducing lipid peroxidation and enhancing the accumulation of starch and sugars [2-4]. Higher plants vary in their capacity to accumulate and tolerate selenium and they are classified into non-accumulators, indicators and accumulators [5]. According to Whanger [6], the currently observed interest in selenium focuses on the health benefits of high-Se plants as a source of cancer-preventative Se compounds, for its unique role in recycling and delivering selenium from the soil to the food chain. The objective of this study was to determine the selenium content in soil and its accumulation and distribution in winter wheat plants affected by organic fertilization.

Materials and methods

Soil and plant samples were taken from a long-term static field experiment carried out since 1980 by the Department of Plant Nutrition of the Institute of Soil Science and Cultivation in Pulawy in the area of the Agricultural Experimental Station at Grabow on the Vistula River. Soil samples were collected in the 22nd year of the experiment, in May 2002, from the 0-20 cm layer in the winter wheat interrows (cv. Korweta). The experiment was designed in a split-plot with four replications. Crop rotation included: potato - winter wheat + intercrop - spring barley + undersown and red clover + grasses. The soil was treated with

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cattle *farmyard manure* (FYM) under potato in the doses of 0, 20, 40, 60 and 80 Mg·ha⁻¹. Plant material was sampled at the beginning of the shooting stage into blade, rinsed in deionised water to remove soil particles, separated into aboveground biomass and roots, and dried. The total selenium content in soils and plants was determined using the method of Watkinson [7] with a Hitachi F-2000 spectrofluorometer. The analytical procedures provided satisfactory values for the standard reference material CRM024-050 (RTC). The soil samples were analysed for granulometric composition according to Bouyoucos-Casagrande method, organic carbon - using wet oxidation with potassium dichromate, and pH in distilled water and 0.1 M KCl - potentiometrically.

Results and discussion

The general properties of the soil under study are given in Table 1. The soil, according to the FAO classification, was classified as Haplic Luvisols and demonstrated the texture of loamy sand and sandy loam. The soil pH values were found in the slightly acidic range 5.7-6.2. The application of manure resulted in the highest amounts of organic carbon in soil, especially in soil from the plots fertilized with FYM with the doses of 60 and 80 Mg · ha⁻¹. The selenium content from the control plots ranged from 0.086 to 0.117 mg · kg⁻¹ (average 0.101 mg · kg⁻¹) (Table 1). Statistical analyses confirmed that the FYM application resulted in the highest amounts of total selenium content in soil (Table 1), which increased with increasing doses of manure. The soil fertilized with the highest dose of manure showed a two-fold higher rate of total selenium than the soil from the control plots, which could have been due to the amount of this microelement in farmyard manure since, as reported in literature, in various FYM the selenium content varies from 0.32 to 2.4 mg · kg⁻¹ [8, 9].

Table 1

General properties and total selenium content in soil under study

Dose of manure [Mg · ha ⁻¹]	Soil particle size fraction [%]		pH		Organic carbon [g · kg ⁻¹]	Total Se [mg · kg ⁻¹]
	< 0.02 mm	< 0.002 mm	H ₂ O	KCl		
0	18	7	6.2	5.8	8.6	0.099
20	16	7	6.2	5.8	9.9	0.171
40	17	6	6.0	5.7	10.3	0.179
60	18	6	6.2	5.8	10.6	0.184
80	15	5	6.2	5.8	11.1	0.191
LSD _{0.05}						0.010

According to Kabata-Pendias [3], the mean total selenium content in the soils worldwide is estimated as 0.44 mg · kg⁻¹, while its background contents in various soil groups range from 0.05 to 1.5 mg · kg⁻¹. Hartikainen [2] claim that soils containing less than 0.5 mg Se · kg⁻¹ are likely to lead to crops and pastures with inadequate selenium concentrations (< 0.05 mg · kg⁻¹ d.m.). The total selenium content in soil under study was significantly correlated with the organic carbon content, which coincides with our earlier findings [10] and those reported by other authors [3, 8, 11]. Navarro-Alarcon and Cabrera-Vique [12] report on selenium levels in soil generally being reflected in food and

the Se levels in human populations. In the present study the average selenium content in upper parts of winter wheat from control plots reached $0.133 \text{ mg} \cdot \text{kg}^{-1} \text{ d.m.}$ (Fig. 1).

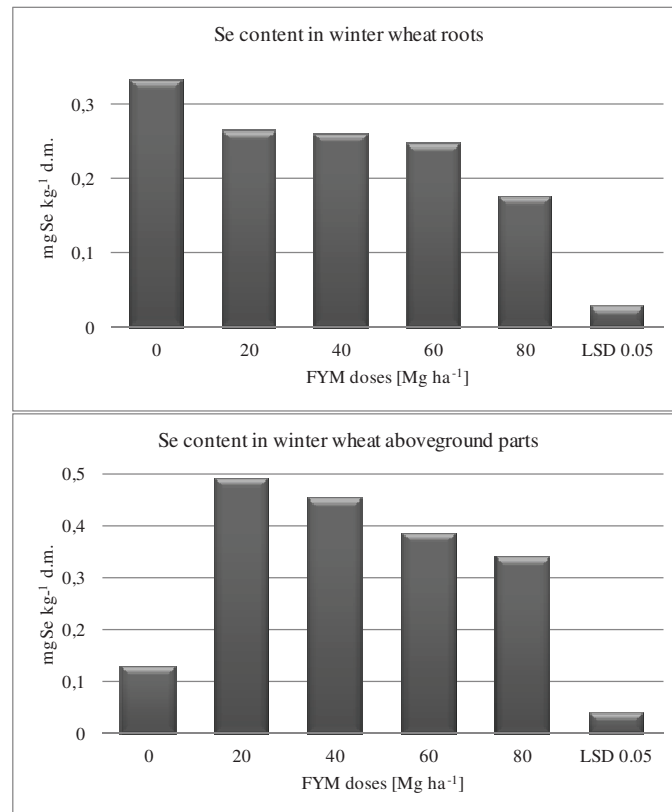


Fig. 1. Selenium content in winter wheat aboveground parts and roots

There were observed the highest selenium concentrations in aboveground parts of winter wheat from the plots treated with the doses of 20 and 40 $\text{Mg} \cdot \text{ha}^{-1}$, the Se content increased on average above 70% against the control. The application of manure in the doses of 60 or 80 $\text{Mg} \cdot \text{ha}^{-1}$ resulted in the decrease in selenium content in aboveground biomass of winter wheat. The selenium content in winter wheat roots from the control plots was on average above 30% higher than from the FYM plots (Fig. 1). The distribution of selenium in various parts of the plant differs according to the species, its phase of development and its physiological conditions. In Se-accumulators, Se is accumulated in young leaves during the early vegetative stage of growth, however at the reproductive stage, high levels of selenium were found in seeds, while the Se content in leaves is reduced [13]. The selenium concentration in grain and roots of cereal plants is often the same level, with lower amounts in the stems and leaves. Zayed et al [14] report on the distribution of selenium in plants also depending on the form and the concentration of selenium supplies to the roots and on the

nature and concentration of other ions, especially sulphates and on the degree of Se fixation in soils. Plants absorb Se easily from alkaline soils, where it often exists in water-soluble forms. Although acid soils may contain high selenium concentrations, plants assimilate only small amounts since Se is bound by insoluble iron compounds or by organic matter of soil [11].

Conclusions

1. There was found a significant effect of FYM application on the total selenium content in the soil investigated. A supplement of manure at the dose of $80 \text{ Mg} \cdot \text{ha}^{-1}$ resulted in the significantly highest increase in total selenium content (almost 50%) in soil, as compared with the control soil. The total selenium content in soil was significantly correlated with the organic carbon content.
2. There were observed the highest selenium concentrations in the upper parts of winter wheat from the plots treated with FYM with the doses of 20 and $40 \text{ Mg} \cdot \text{ha}^{-1}$, namely about 70% higher in comparison with the control plants. The FYM application in the dose of $80 \text{ Mg} \cdot \text{ha}^{-1}$ resulted in a decrease in the selenium content in aboveground parts of wheat.

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**AKUMULACJA SELENU PRZEZ PSZENICĘ OZIMĄ (*Triticum aestivum* L.)
POD WPLYWEM WIELOLETNIEGO NAWOŻENIA
NAWOZEM NATURALNYM**

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Abstrakt: Celem przeprowadzonych badań było określenie zawartości selenu w glebie oraz jego akumulacji i rozmieszczenia w roślinach pszenicy ozimej po wieloletniej aplikacji nawozu naturalnego. Aplikacja obornika istotnie wpływała na zawartość selenu ogółem w badanej glebie, a zastosowanie nawozu naturalnego na poziomie $80 \text{ Mg} \cdot \text{ha}^{-1}$ zwiększyło zawartość tego mikroelementu o prawie 50% w odniesieniu do jego zawartości w glebie z obiektu kontrolnego. Zawartość selenu ogółem w glebie była dodatnio skorelowana z zawartością węgla organicznego. Najwyższą zawartość selenu w nadziemnych częściach pszenicy ozimej wykazano na obiektach, na których obornik stosowano w dawce 20 i $40 \text{ Mg} \cdot \text{ha}^{-1}$, w porównaniu z roślinami kontrolnymi. Po zastosowaniu obornika w tych dawkach zawartość selenu wzrosła o ponad 70%. Aplikacja obornika w dawce $80 \text{ Mg} \cdot \text{ha}^{-1}$ spowodowała natomiast istotne zmniejszenie zawartości tego pierwiastka w częściach nadziemnych pszenicy.

Słowa kluczowe: selen, gleba, pszenica ozima, obornik