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CONTENT OF SELENIUM IN ARABLE SOILS NEAR WROCLAW*

Barbara Patorczyk-Pytlik, Grzegorz Kulczycki

Chair of Plant Nutrition
Wroclaw University of Environmental and Life Science

Abstract

The material for this study consisted of 60 soil samples collected from the arable layer of cultivated fields located in the vicinity of Wrocław. The samples varied in their properties and reflected a whole range of soil types to be found in the region of Lower Silesia. The examinations proved that selenium content in arable soils near Wroclaw ranged from 81 to 449 $\mu g \cdot kg^{-1}$ and the average value of Se content in these soils was 202 $\mu g \cdot kg^{-1}$.

The lowest Se content appeared in sandy soils (174 $\mu g \cdot kg^{-1}$), while the highest value was found in loamy soils. The mean value of Se content calculated for this group of soils was 228 $\mu g \cdot kg^{-1}$. Selenium content in soils varied to a high degree (V=42%). The value lower than 100 $\mu g \cdot kg^{-1}$, assumed as a critical one for the quality of plant yield, was recorded for 4 samples, while in 33 soil samples the Se content fell in the range of 101--200 $\mu g \cdot kg^{-1}$ and in 14 samples it ranged from 201 to 300 $\mu g \cdot kg^{-1}$. Only 9 soils out of these subjected to investigation characterized selenium value higher than 300 $\mu g \cdot kg^{-1}$, i.e. the value regarded as medium soil fertility. Se content in soils was highly correlated with their content of silt and clay, as well as colloidal parts and also with the amount of C and total content of such chemical elements as P, S, Fe, Cu, Zn and Ni.

Key words: Se, soil properties.

ZAWARTOŚĆ SELENU W GLEBACH GRUNTÓW ORNYCH OKOLIC WROCŁAWIA

Abstrakt

Materiał do badań stanowiło 60 prób glebowych pobranych z warstwy ornej pól uprawnych położonych w okolicach Wrocławia. Ich właściwości były w znacznym stopniu zróżni-

dr hab. Barbara Patorczyk-Pytlik, associate prof. UP, Chair of Plant Nutrition, Wroclaw University of Environmental and Life Sciences, ul. Grunwaldzka 53, 50-357 Wroclaw, Poland, e-mail: barbara.patorczyk-pytlik@up.wroc.pl

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cowane i odzwierciedlały przekrój gleb występujących na terenie województwa dolnośląskiego. Wykazano, że zawartość selenu w glebach gruntów ornych okolic Wrocławia wahała się od 81 do 494 μg·kg^{-1}, wartość uśredniona wyniosła 202 μg·kg^{-1}.

Najniższą zawartość Se stwierdzono w glebach piaszczystych (174 μg·kg^{-1}), a najwyższą w glebach gliniastych. Określona dla tej grupy średnia zawartość Se kształtowała się na poziomie 228 μg·kg^{-1}. Zawartość selenu w glebach była w znacznym stopniu zróżnicowana (*V*=42%). Wartość niższą niż 100 μg·kg^{-1} – uznawaną za krytyczną dla jakości zbieranych plonów roślin – stwierdzono w 4 próbkach, a w 33 glebach zawartość Se mieściła się w przedziale 101-200 μg·kg^{-1}, natomiast w 14 od 201 do 300 μg·kg^{-1}. Spośród badanych gleb jedynie w 9 zawartość ta była większa niż 300 μg·kg^{-1} – wartość uznawana jako średnia zasobność. Zawartość selenu w glebach była wysoko istotnie skorelowaną z zawartością zarówno części spławianych, jak i koloidalnych, a także z ilością węgla oraz całkowitą zawartością P, S, Fe, Cu, Zn i Ni.

Słowa kluczowe: Se, właściwości gleb.

INTRODUCTION

Naturally occurring Se content in soils is conditioned by the origin and mineral composition of the mother rock, intensity of Se loss due to erosion and volatilization resulting from methylation (PIOTROWSKA 1984, BUTTERMAN, BROWN 2004, LASER 2004). The content of Se in soils worldwide ranges average 0.33 mg·kg^{-1}, yet it can vary between trace amounts to 230 mg·kg^{-1} (BUTTERMAN, BROWN 2004).

The soils of Poland generally feature low content of this microelement. According to PIOTROWSKA (1984), Se value equals 277 μg·kg^{-1}, while BOŻEK (1997) estimates Se content as 320 μg·kg^{-1}. BOROWSKA et al. (2007) reported that for mineral soils in the region of Pomerania and Kujawy, the Se content did not exceed 35-332 μg·kg^{-1}, with the mean content being 138 μg·kg^{-1}. The soils of arable lands in the vicinity of Bydgoszcz, examined by TRAFIKOWSKA and KUCZYŃSKA (2000), contained on average 56 μg·kg^{-1}. An equally low Se content (123 μg·kg^{-1}) for the soils of the western Pomerania was recorded by ZABŁOCKI (1991). The soils of Lower Silesia, examined by BOŻEK (1997), contained on average 240 μg·kg^{-1}.

The aim of his investigation was to determine selenium content in cultivated mineral soils in the region of Wrocław, as well as to assess the effect of some properties of these soils on the content of this microelement.

MATERIAL AND METHODS

Samples of soil from sixty cultivated fields were collected from the arable layer (0-20 cm). The sample collection was planned and performed so that soils could be considerably diversified and reflect a whole range of soil types typical for the region of Lower Silesia. Soil samples were subjected to the following determinations: granulometric composition according to the aerometric method by Bouyoucosa-Casagrande, modified by Prószyński, soil reaction in mol KCl·dm^{-3} with the potentiometric method, hydrolytic acidity with Kappena's method, organic C with Tiurin's method, the content of total sulfur with Butters and Chenry's method, total content of phosphorus as well as the content of Mn, Fe, Cu, Zn and Ni after mineralization of the samples with aqua regia. The Se content was assayed according to the AAS method combined with hydrides generation using a Spectr AA FS Varian device with a VGA-76 attachment, previously preparing soil samples according to the method by Beach (1992). All assays were done in three replications and the tables contain their mean values.

RESULTS AND DISCUSSION

Analysis of the granulometric composition proved that 27 of the examined soils characterized sand graining (Tables 1 and 2). The highest contribution in that group belonged to: slightly loamy (18%) and light loamy sand (12%). In the group of medium – heavy soils the highest percentage contribution featured light\loam (32%). The content of silt and clay ranged from

Table 1

Some properties of the examined soils

Soil properties	Arithmetic mean	SD	Range	*V* %
Fraction < 0.02 mm	21	10.8	5-46	50
Fraction < 0.002 mm	6.8	3.5	1-21	52
pH $mol_{KCl}\cdot dm^{-3}$	5.9	0.7	4.0-7.0	11
Hh cmol(+)·kg^{-1}	18.1	9.9	4.4-42.0	54
Total content, g·kg^{-1}				
Organic C	12.6	6.1	4.6-32.3	48
P	0.78	0.19	0.45-1.27	24
S	0.21	0.08	0.07-0.49	40
Total content, mg·kg^{-1}				
Mn	303	155	62-763	51
Fe	6542	3726	1987-18168	57
Cu	11.0	8.6	3.5-37.7	78
Zn	44.7	25.6	18-128	57
Ni	8.7	5.3	2.2-24.9	61

SD – standard deviation; *V* – coefficient of variation; Hh – hydrolytic acidity

Table 2

Selenium content as dependent on soil family and soil textural group ($\mu g \cdot kg^{-1}$)

Soil textural group					
Soils	sandy		loamy		silts
Subgroup	ls, wls *n*=12	lls, sls *n*=13	ll *n*=19	lsl *n*=9	cs *n*=4
Mean Range	156 85-238	197 144-336	206 94-392	268 81-494	200 168-228
V, %	28	36	42	45	
Mean Range for group	174 85-338		228 81-494		200

V – coefficient of variation; *n* – no of samples; ls – loose sand; wls – weak loamy sand; lls – light loamy sand; sls – strong loamy sand; ll – light loam; lsl – light silt loam; cs – clay silt

Table 3

Selenium content in soils depending on granulometric composition ($\mu g \cdot kg^{-1}$) soils

Content	*n*	Arithmetic mean	SD	Range	*V* %
Fraction <0.02 mm					
< 10	14	152	44	85-238	28
11-20	13	197	75	93-336	38
21-35	28	226	100	81-449	44
>35	5	215	45	168-278	21
Fraction <0.002 mm					
<5	23	172	68	85-338	39
5.1-10	28	212	81	81-392	38
10.1-15.0	5	298	126	154-491	42
>15.1	1	278			

SD – standard deviation; *V* – coefficient of variation; *n* – no of samples

5 to 46% (Tables 1 and 3). The highest contribution constituted medium – heavy soils (47%) and, subsequently, very light (23%) and light soils (22%). Heavy soils made up just 8% of the total soil samples, i.e. they were the least numerous.

The reaction of soil samples was highly diversified as it was found within the range of pH_{KCl} from 4.0 to 7.0 (Table 1). Most soils were slightly acid (48%). Acidic reaction was assayed in 25% of soils. A similar percentage of soils was neutral in reaction, while only one soil sample was classified as a very acid one.

Organic C content, as well as the total content of phosphorus and sulfur in the examined soils are specified in Table 1 and the number of samples in each class can be found in Tables 4 and 5.

Table 4

Content of selenium in soils depending on organic C content (μg · kg^{-1} soil)

Content organic C (g · kg^{-1})	< 11.0 n=33	11.1-20.0 n=22	> 20.1 n=5
Arithmetic mean	158	229	365
SD	53	68	80
Range	93-267	144-364	292-494
V, %	34	30	22

SD – standard deviation; V – coefficient of variation; n – no of samples

Table 5

Selenium content in soils as dependent on total content of P and S (mg · kg^{-1} soil)

Element	P (mg · kg^{-1})				S (mg · kg^{-1})	
Content	<500 n=2	501-750 n=27	750-1000 n=22	>1000 n=9	low n=26	medium n=34
Mean	89	184	225	220	169	221
SD		65	99	87	66	89
Range		81-307	120-491	122-364	85-307	93-491
V, %		35	44	39	116	40

SD – standard deviation; V – coefficient of variation; n – no of samples

The total content of microelements was highly varied (Table 1). The calculated values of variation coefficients ranged from 51% (Mn) to 78% (Cu). The majority of the sixty examined soils were characterized by a natural content of Mn, Fe, Cu, Zn and Ni. Considering the boundary values assumed by Kabata-Pendias et al. (1993), elevated values of zinc content were found only in 6 light and 4 medium-heavy soils.

Our examinations proved that the Se content in arable soils in the region of Wroclaw ranged from 81 to 449 μg · kg^{-1} and the mean value equaled 202 μg · kg^{-1}. Therefore, these values are lower than the mean values for the soils of Poland estimated by Piotrowska (1984) and Bożek (1997).

The content of selenium in soils varied to a high degree (V=42%). In 4 samples it was lower than 100 μg · kg^{-1}, i.e. the value assumed as critical for the quality of plant yield (Gupta and Gupta 2002). In 33 soils, Se content did not exceed 101-200 μg · kg^{-1} and in 14 (23%) it reached 201 to 300 μg · kg^{-1}. By comparing these results obtained with the figures cited by Zabłocki (1991) who, after Welles, claimed that Se content lower than 300 μg · kg^{-1} was regarded as Se deficit, it can be concluded that 85% of 60 examined soil samples were characterized by low Se content, while the remaining sampled contained moderate amounts of selenium.

Among the most often implied factors which condition the total Se content in soils there is soil granulometric composition. PIOTROWSKA (1984), ZABŁOCKI (1991) and BOROWSKA (1996) report that selenium content decreases as amounts of silt and clay decrease. This relationship has been confirmed by the present study.

By analyzing selenium content in soils classified to particular granulometric groups and subgroups (Table 2), it is possible to state that the lowest Se content was found in sandy soils (174 $\mu g \cdot kg^{-1}$). Both the range of values and calculated mean values did not differ from those reported by PIOTROWSKA (1984) for soils of this group. Among sandy soils, a markedly higher Se value appeared in light loamy sand and heavy loamy sand. The table does not contain any values regarding slightly loamy sand (123 $\mu g \cdot kg^{-1}$) and medium-heavy loam (278 $\mu g \cdot kg^{-1}$), since these subgroups were represented only by 2 and 1 soil, respectively. Loamy soils proved to be much richer in selenium than sandy soils. Se content determined for the former group was on average 228 $\mu g \cdot kg^{-1}$, being lower than the value reported by PIOTROWSKA (1984), who reported that the average Se content in light loamy soils was 280 $\mu g \cdot kg^{-1}$, and for medium-heavy loam – 360 $\mu g \cdot kg^{-1}$. Also YLÄRANTA (1983) recorded higher average Se content (290 $\mu g \cdot kg^{-1}$) for loamy soils than that determined for the same group of soils collected in the region of Wroclaw.

According to the data reported by YLÄRANTA (1983), PIOTROWSKA (1984), ZABŁOCKI (1991) and BOROWSKA (1996), selenium content in soils *did* significantly increase as the amount of silt and clay parts they contained increased up to 35% (Table 3). Slightly lower content of this microelement was determined for heavy soils than for medium–heavy soils, which may have been due to the small number of soils (n=5) in this agronomical category. Se content in soils also increased as the amount of colloidal parts in soils increased (Tables 3 and 6). This correlation found its statistical proof. Similar relations were obtained by YLÄRANTA (1983), ZABŁOCKI (1991) and BOROWSKA (1996).

Another factor which significantly affects Se content in soils is their abundance in organic matter, although scientific reports discussing this correlation are not univocal. YLÄRANTA (1983), ZABŁOCKI (1991), BOROWSKA (1996), as well as BOROWSKA et al. (2007) proved positively significant correlation between Se content and the quantity of organic matter. In contrast, PIOTROWSKA (1984) and LASER (2004) did not find evidence supporting such correlation. Our examination proved that selenium content in soils was highly correlated with their content of organic carbon (Tables 4 and 6).

In the literature pertaining to the influence of soils properties on Se amount, there is scarce information about correlation between phosphorus and selenium. According to the results of our investigation, the increase in the total content of phosphorus in soils immediately induced an increase in the content of selenium (Table 5).

Selenium is a chemical element featuring strong geochemical relation with sulphur. In sulphur deposits of volcanic origin, as well as in sulphite minerals, Se is an accompanying component. Soils rich in humus are most often characterized by increased content of both sulfur and selenium (BUTTERMAN, BROWN 2004, LASER 2004). Our examinations confirmed this correlation. Soils moderately abundant in total sulphur contained by about 24% more selenium than soils featuring low S content (Table 5). Statistical analysis proved that this was a significant correlation (Table 6).

Table 6

Correlation between selected soil properties (*x*) and selenium content in soils (*Y*), n=60

Soil properties	Content in soil *Y*, ($\mu g \cdot kg^{-1}$)	
	Se	
(*x*)	regression formula	(*r*)
Fraction <0.02 mm (%)	$Y= 2.32x+151.7$	0.30
Fraction <0.002 mm(%)	$Y=11.8x+121.8$	0.49
pH mol $KCl \cdot dm^{-3}$	$Y=31.6x+11.8$	n.s.
Hh ($cmol(+) \cdot kg^{-1}$)	$Y=0.91x-217.9$	n.s.
Organic C ($g \cdot kg^{-1}$ gleby);	$Y=10.5x+69.3$	0.75
P ($g \cdot kg^{-1}$)	$Y=0.13x+96.3$	0.30
S ($g \cdot kg^{-1}$)	$Y=628.1x+68.1$	0.62
Mn ($mg \cdot kg^{-1}$)	$Y=0.071x+179.8$	n.s.
Fe ($mg \cdot kg^{-1}$)	$Y=0.0126x+119.3$	0.55
Cu ($mg \cdot kg^{-1}$)	$Y=5.91x+136.4$	0.59
Zn ($mg \cdot kg^{-1}$)	$Y=1.61x+129.6$	0.48
Ni ($mg \cdot kg^{-1}$)	$Y=9.07x+122.9$	0.56

r – correlation coefficient; significant ($p<0.05$); n.s. – not significant;
Hh – hydrolytic acidity

Selenium content in soils was positively significantly correlated with the total content of Fe, Cu, Zn and Ni. However, no such correlation with the Mn content in soils was found (Table 6).

According to the results obtained by PIOTROWSKA (1984) and BAHNERSA (1987), no significant effect of pH and hydrolytic acidity on selenium content in soils was recorded. Contrasting results were reported by BOROWSKA et al. (2007).

CONCLUSIONS

1. The total content of selenium in arable soils in the region of Wrocław ranged from 81 to 494 $\mu g \cdot kg^{-1}$, with the average Se content being 202 $\mu g \cdot kg^{-1}$. Most of the examined soils (85%) were low in this element.

2. Loamy soils, in contrast to sandy soil, proved to be very rich in selenium.

3. Selenium content in soils depended on their granulometric composition as well as on the amount of organic C. There were also significant correlations between the total Se content and the total content of P, S, Fe, Cu, Zn and Ni.

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