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THE SENSITIVITY OF ROOTS TO SELENIUM IN THE CONDITIONS OF DIFFERENTIATED pH MEDIUM

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Introduction

Plant sensitivity to selenium (Se) is considerably differentiated [ZAYED et al. 1998]. *Astragalus*, *Stanleya* and other plant species tolerate selenium and accumulate really great amounts of it, which sometimes conditions their proper vegetation [TERRY et al. 2000]. However, most cultivated plants are sensitive to this aerobe. Trace amount of selenium is essential in animal tissues [SEMBRATOWICZ, GRELA 1997], whereas in plant tissues, biological activity of this element has not been known well yet [KABATA-PENDIAS, PENDIAS 1999]. Similary to metallic trace elements where a narrow „fluent" margin appears between beneficial and harmful concentrations, selenium is another example. Selenium phytotoxicity seems to result from competition of this element with sulphur at translocation. Formation of selenite amino acids, that are being built into proteins, disturb or hinder protein enzymatic activity [IHNAT 1989; TERRY et al. 2000]. These processes occurring at the boundary of root tissue and the nutrient environment, perform a dominant role at selenium uptake. The present studies aimed at determination of the sensitivity and physiological properties of root to selenium, depending on level of this element and medium pH.

Material and methods

Vegetation of plants was run with an aquaculture method (in jars of 1 dm^3), in a vegetative chamber at constant conditions i.e. luminosity (60 $W \cdot m^2$), temperature (26°C day/22°C night), relative humidity (75%) and, taking into account short vegetative period, a photoperiodic cycle – 14/10 h. The experimental plants were two plant species: maize (*Zea mays* L. var. *saccharata*) cv. Złota Karlowa and sunflower (*Helianthus annuus* L.). The experiments were carried out with 8–10–day–old plants, which were analysed 14 days after adding the selenium. Due to high nutritional requirements of the studied species plant, there was applied a Hoagland`s medium of double concentration supplemented with 2 $ml \cdot dm^{-3}$ 1% iron citrate and microelements in A–Z medium. With active iron use, at 5.8 pH range, there was established a medium selenium concentration that completely inhibited root elongation (EC_{100}). A differentiating factor in this experiment was a nutritional environment pH (4.5-acid, 5.8-neutral, 7.5-basic) as well as selenium concentration (0; 50; 100 μmol $Se \cdot dm^{-3}$ in medium). Selenium was given in a form of sodium selenite ($Na_2O_3Se \cdot 5\ H_2O$).

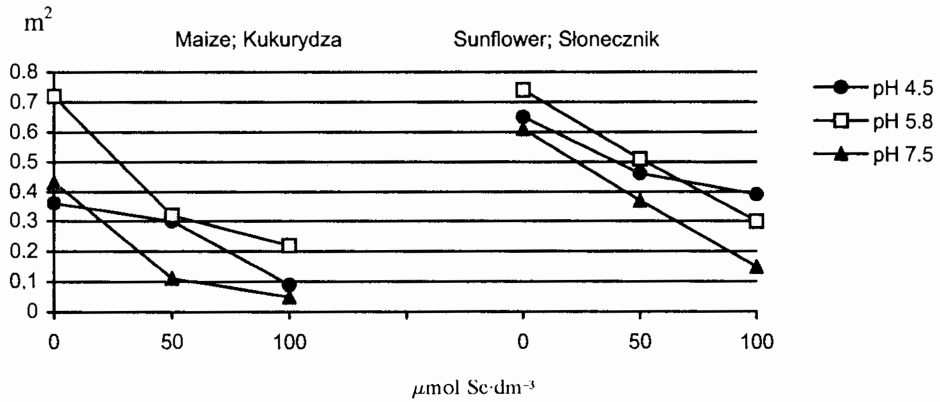

Fig. 1. Roots active adsorptive surface in relation to selenium concentration and medium pH

Rys. 1. Aktywna powierzchnia adsorpcyjna korzeni w zależności od stężenia selenu i pH pożywki

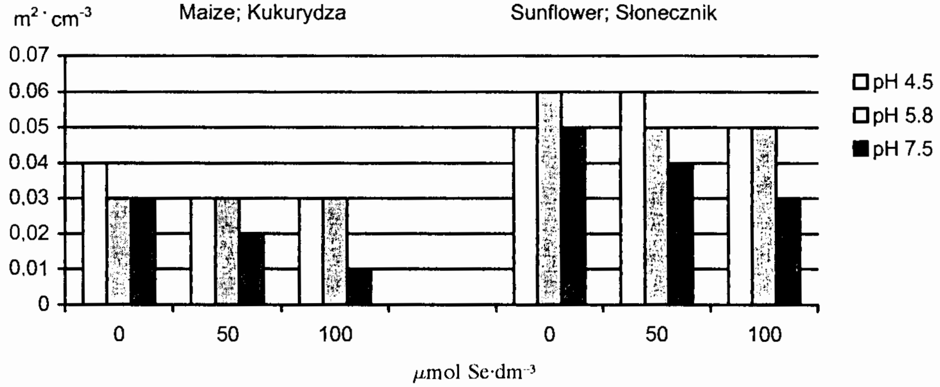

Fig. 2. Active adsorptive surface of 1 cm³ in relation to selenium concentration and medium pH

Rys. 2. Aktywna powierzchnia adsorpcyjna 1 cm³ w zależności od stężenia selenu i pH pożywki

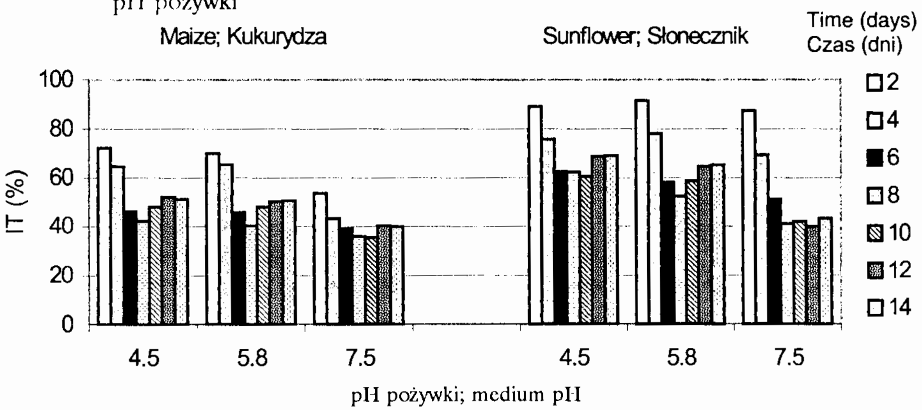

Fig. 3. Tolerance index – IT (%) in relation to time and medium pH

Rys. 3. Indeks tolerancji – IT (%) w zależności od czasu i pH pożywki

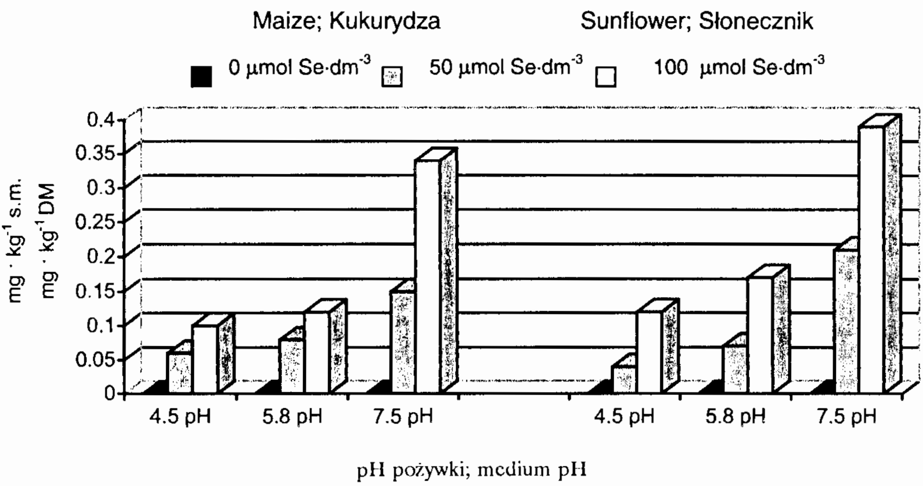

Fig. 4. Selenium concentration in roots
Rys. 4. Zawartość selenu w korzeniach

Sensitivity of roots to selenium was considered on the basis of root volume and adsorptive surface (total and active surface and active surface 1 cm^3) fixed after Sabinin and Kolosov`s method [BASŁAWSKA, TRUBIECKOWA 1964] and tolerance index (IT) [Mc NEILLY 1994]. Tolerance index expresses the ratio of length of roots in the selenium presence to length of roots at the absense of selenium, in percent. Length of roots was measured every two days. After 14 days of plant growth dry root matter was determined and observation of changes in morphology of these organs was performed. In root dry matter selenium concentration was determined using an atom absorption spectrophotometric method (AAS). Regarding the similar maintained trends, the data enclosed in Tab. 1 and presented at the Figs. 1–4 are arithmetic means from 6 replications in each series and 3 repetitions at a time.

Results and discussion

The results obtained show that medium pH value exerted a marked impact on the plants sensitivity to selenium. Although the studied species demonstrated different tolerance to this element, it was found that pH value increase was always accompanied with selenium toxicity increase in roots (Tab. 1, Fig. 1, 2) Moreover, as it was observed, Se concentration increase causes decrease of roots elongation (Fig. 3) and changes in their morphology. In the selenium presence there were recorded changes in root morphology: reduction of lateral root number, poorer root system development with thin and delicate main roots. Additionally, at longer exposure time there occurred brick red and brown coloring, in particular in maize. Out of the two plant species examined, maize turned out to be more sensitive to selenium than sunflower.

Tolerance index, fixed for 100 μmol Se·dm^{-3}, decreased increasing with pH values and exposure time length (Fig. 3). As early as after 48 h of exposure to selenium there was reported a clear drop of tolerance index that slightly went up after 240 h of this element application. The tolerance index decrease testifies of plant sensitivity increase on examinated factor. The lowest IT values were recorded for maize plants, whereas some higher ones were noticed for sunflower. Influence on IT value was also exerted by hydrogen ions concentration in a medium, this parameter decreased with pH value increase.

Selenium toxicity in root tissue was also expressed in their decreased volume and dry matter (Tab. 1). Root yield was differentiated with regard to various selenium levels as well as medium reaction. The plants studied in the basic environment where biomass dropped by 57–88% demonstrated the highest sensitivity to selenium.

Table 1; Tabela 1

Root yield and physiological indicators of experimental plant species
Plon i wskaźniki fizjologiczne korzeni badanych gatunków roślin

Differentiating factor Czynnik różnicujący		Root physiological indicators Fizjologiczne wskaźniki korzenia		
medium pH pH pożywki	Se concentration stężenie Se ($\mu mol \cdot dm^{-3}$)	root yield, g DM per pot; plon korzeni, g s.m. na wazon	root volume objętość korzeni (cm^3)	total adsorptive surface; całkowita powierzchnia adsorpcyjna (m^2)
Maize; Kukurydza				
4.5	0	0.67	10	0.43
	50	0.69	9.5	0.37
	100	0.36	2.5	0.09
5.8	0	0.97	22.5	0.93
	50	0.73	9.5	0.36
	100	0.31	3.5	0.13
7.5	0	0.66	14.5	0.52
	50	0.32	2.5	0.10
	100	0.16	1.5	0.06
Sunflower; Słonecznik				
4.5	0	0.90	14	0.76
	50	0.59	12	0.62
	100	0.36	10	0.47
5.8	0	1.04	15	0.87
	50	0.76	10	0.59
	100	0.52	8	0.36
7.5	0	1.08	13	0.79
	50	0.62	7	0.42
	100	0.17	2,5	0,16

Both plant species showed a fall total volume of roots as well as of active adsorptive surface, whereas active surface 1 cm^3 decreased only in the case of selenium activity in basic pH (Tab. 1, Figs. 1, 2). Selenium concentration in root tissues reflected pH influence on this element uptake by the root system. Selenium level in mg·kg^{-1} root dry matter ranged from 0.06 to 0.1 at pH 4.5 to 0.15–0.34 at pH 7.5 for maize plants, whereas for sunflower plants it ranged from 0.04–0.12 at pH 4.5 to 0.21–0.39 at pH 7.5 (Fig. 4).

Root as an organ of direct contact with soil solution is able to react to some changes in its composition the most quickly, thus the formation of roots physiological indicators can reflect plant sensitivity to the factors examined. Maize and sunflower roots proved to be extremely sensitive and reactive to each selenium concentration applied, irrespective of medium pH. Compared to the productivity indicators of shoots (present authors` unpublished results), roots reacted more clearly and quickly to selenium compounds introduction to a medium. As studies indicate [cite TERRY et al. 2000] selenium compounds in the form of selenite, are hardly able to translocate in a plant and get accumulated mainly in roots. That may be brought about by fast conversion of selenites into organic forms, like SeMet, which are retained in the root system and cause disturbances of its physiological functions [ARVY 1993].

Conclusions

1. Selenium presence in a medium causes a significant fall of root biomass.

2. Medium selenium at concentrations of 50 and 100 μmol·dm^{-3} caused disorders reflected in physiological indicator changes in maize and sunflower roots. Tolerance fixed with IT indicated higher sensitivity to selenium of roots of maize than those sunflower.

3. Hydrogen ions concentration in medium influenced selenium biological activity in plants. Toxic impact of selenium increases with its concentration and pH value in medium; it intensified with a longer exposure time. Selenium concentration in root tissues increased with increasing concentration of selenium and pH value in medium.

4. The highest drop of maize and sunflower root sorptive properties was recorded under the conditions of basic pH and medium concentration of 100 μmol Se·dm^{-3}.

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Key words: selenium, tolerance index, root crop, root adsorptive surface

Summary

In the experiment run in aquacultures, the influence of medium pH (4.5; 5.8; 7.5) on selenium toxicity (0; 50; 100 μmol Se·dm^{-3} medium) was examined in relation to two plant species roots i.e. maize (*Zea mays* L.) and sunflower (*Helianthus annuus* L.). Selenium was administered in the form of $Na_2SeO_3 \cdot 5\ H_2O$.

Selenium introduction into a medium caused biomass fall and morphological and physiological changes of the root system in the studied species. Medium reaction exerted a significant impact on the selenium toxicity. Selenium concentration in root biomass increased with selenium level and pH value of medium. At the basic environment (7.5 pH) the plants showed a lot higher sensitivity to selenium than at pH 4.5 and 5.8, as expressed in formation of root physiological parameters (IT, biomass crop, adsorptive properties of root system).

WRAŻLIWOŚĆ KORZENI NA SELEN W WARUNKACH ZRÓŻNICOWANEGO pH POŻYWKI

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Słowa kluczowe: selen, indeks tolerancji, plon korzeni, powierzchnia adsorpcyjna korzeni

Streszczenie

W doświadczeniu, prowadzonym w kulturach wodnych, badano wpływ pH pożywki (4,5; 5,8; 7,5) na toksyczność selenu (0; 50; 100 μmol Se·dm^{-3} pożywki) w stosunku do korzeni dwóch gatunków roślin: kukurydzy (*Zea mays* L.) i słonecznika (*Helianthus annuus* L.). Selen podawano w formie seleninu sodowego ($Na_2SeO_3 \cdot 5\ H_2O$).

Wprowadzenie selenu do pożywki u badanych gatunków powodowało spadek biomasy oraz zmiany morfologiczno-fizjologiczne systemu korzeniowego. Odczyn środowiska istotnie wpływał na toksyczność badanego pierwiastka. Stężenie

selenu w biomasie korzeni zwiększało się wraz ze zwiększeniem dawki Se oraz wzrostem pH środowiska odżywczego. W środowisku zasadowym (7,5 pH) rośliny charakteryzowały się dużo większą wrażliwością na selen niż przy pH 4,5 i 5,8, co wyraża kształtowanie parametrów fizjologicznych korzeni (IT, plon biomasy, właściwości adsorpcyjne systemu korzeniowego).

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