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DIFFERENCES IN CADMIUM AND LEAD ACCUMULATION BY LETTUCE (*Lactuca sativa* L.) DEPENDING ON THE CULTIVAR

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Abstract. A differentiated ability of heavy metals accumulation was found between different lettuce cultivars. In combinations with an addition of lead and cadmium grown in autumn, the least amount of lead was accumulated by Agora, Regina and Bona cvs, while the least amount of cadmium was found in Saba and Bona cvs. In spring, Syrena cv. accumulated the least amount of lead, while Marta cv. showed the least amount of cadmium.

Key words: cadmium, lead, lettuce, cultivars

INTRODUCTION

Vegetable plants grown in soils and substrates contaminated by heavy metals accumulate excessive amounts of these metals deteriorating the quality of vegetables. Many research works indicate that even when the content of heavy metals is within the natural limits, there can occur an excess of the admissible metal content in the edible parts of vegetables.

One of the methods limiting heavy metals content in vegetables is the selection of cultivars with a lesser ability of these metals accumulation.

The objective of the present work was to indicate the differences in cadmium and lead accumulation between lettuce cultivars grown in spring and in autumn, in substrates without any addition of these metals and in substrates with increasing doses of Cd and Pb.

MATERIAL AND METHODS

Pot experiments with lettuce were carried out in greenhouse in autumn of the years 1998–2000, and in spring in 1999–2001. In autumn, the following cultivars were grown: Agora, Bona, Królowa Majowych, Regina, Saba and Tola. In spring, the experimental cultivars included: Agora, Justyna, Marta and Syrena.

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Lettuce seedlings were prepared in greenhouse. Seeds were sown in boxes filled with peat and an addition of 7.0 g $CaCO_3$ (reagent) and 1.5 g of multicomponent fertilizer Fertisal Hydro per 1 dm^3 of peat. After 15–27 days, depending on the cultivar, year and growing season, the seedlings were planted into containers with previously prepared substrate. In each container of 6 dm^3 volume, 4 lettuce plants were grown. The substrate consisted of a mixture of mineral soil and peat in 1:1 proportion. The soil consisting of medium sand originated from Złotniki near Poznań and the peat came from Gryfice. On the basis of neutralization curve, the substrate was limed using 8 g $CaCO_3$ per 1 dm^3. After one week, macro- and micro-elements as well as cadmium and lead were jointly added. The substrate was enriched with 150 mg N, 75 mg P, 200 mg K and 97 mg Mg per 1 dm^3 of substrate as well as an addition of micro-elements in the form of Polichelate LS-7 in the amount of 100 $mg \cdot dm^{-3}$. Cadmium was applied in the form of $CdSO_4 \cdot 8H_2O$ in the doses: 0; 2; 5; 10 and 25 mg $Cd \cdot dm^{-3}$. Lead was used in the form of $(CH_3COOH)_2 \cdot 3\ H_2O$ in the doses of: 0; 10; 50; 100 and 150 mg $Pb \cdot dm^{-3}$.

Experimental combinations consisted of 4 replications. In the vegetation period, the plants were nourished a single time with 80 mg N, 40 mg P, 100 mg K and 50 mg $Mg \cdot dm^{-3}$ of substrate. Plants were harvested only once. Lettuce heads were disintegrated and dried in linen bags at 50°C. Dried plant material was homogenized and stored for chemical analysis. The weighed portion of plant material had the weight of 1.25 g. It was dry mineralized at 450°C and 5% NH_4NO_3 solution was added. Ash was dissolved in 10% HCl, transferred quantitatively into flasks of 25 cm^3 volume and supplemented with distilled water. Cd and Pb were determined directly in the solution by ASA method in AAS-3 apparatus (Zeiss Co.). The evaluation of precise determination was carried out using certified Cl-1 Cabbage Leaves material.

RESULTS

Lettuce grown in control combination. Results shown in figures 1 and 2 illustrate the Cd and Pb content levels in lettuce leaves grown in control combinations, i.e. in the substrate without any addition of cadmium and lead.

Table 1. The cadmium content in leaves of lettuce cultivars grown in autumn – mean values for years 1998–2000, mg kg^{-1} d.w.

Tabela 1. Zawartość kadmu w liściach odmian sałaty uprawianej jesienią – średnie dla lat 1998–2000, mg · kg^{-1} s.m.

Dose Cd Dawka Cd $mg \cdot dm^{-3}$	Cultivars – Odmiany						Mean Średnia
	Agora	Bona	Królowa Majowych	Regina	Saba	Tola	
0	1.16 a*	0.73 a	0.82 a	0.82 a	0.85 a	0.95 a	0.89 A*
2	8.72 bc	9.19 bc	13.64 cd	11.74 b-d	7.20 b	8.97 bc	9.91 B
5	21.67 ef	16.99 de	32.21 g	19.66 e	16.82 de	33.31 g	23.45 C
10	30.46 g	25.16 f	42.82 hi	41.30 h	20.82 ef	50.36 j	35.15 D
25	64.60 kl	50.06 j	63.74 kl	67.95 l	46.77 ij	61.98 k	59.18 E
Mean Średnia	25.32 B*	20.43 A	30.65 D	28.30 C	18.49 A	31.11 D	

*values followed by the same letters are not significantly different at α = 0.05
wartości oznaczone tą samą literą, nie różnią się statystycznie przy α = 0,05

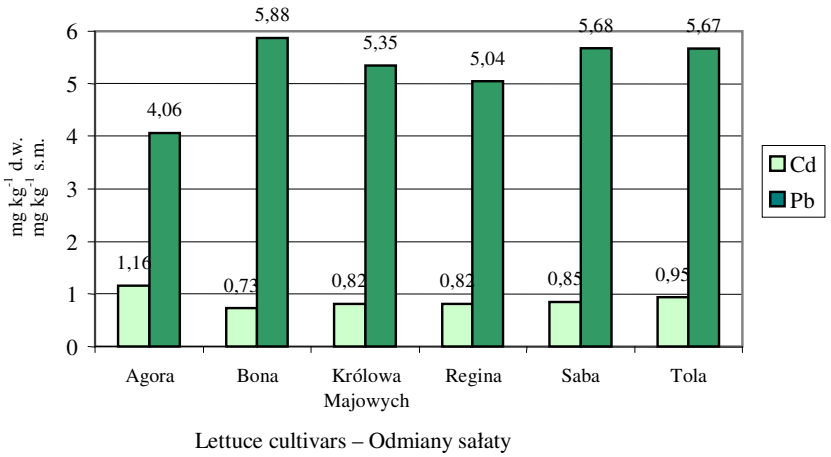

Fig. 1. The Cd and Pb content in leaves of lettuce in control combinations of autumn cultivation – mean values for years 1998–2000

Ryc. 1. Zawartość Cd i Pb w liściach sałaty w kombinacjach kontrolnych uprawy jesiennej – średnia dla lat 1998–2000

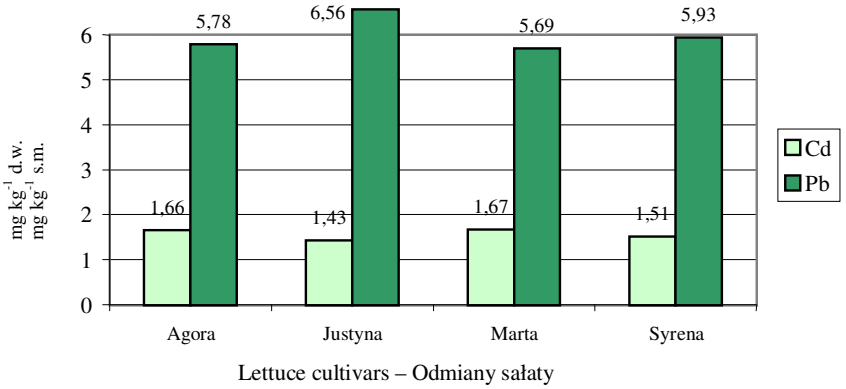

Fig. 2. The Cd and Pb content on leaves of lettuce in control combinations of spring cultivation – mean values for years 1999–2001

Ryc. 2. Zawartość Cd i Pb w liściach sałaty w kombinacjach kontrolnych uprawy wiosennej – średnia dla lat 1999–2001

Cadmium content in the leaves of all cultivars grown on autumn was similar. Lead content was more differentiated. Agora cv. was characterized by the least content of lead, while Bona cv. showed the highest accumulation of lead.

In the lettuce grown in spring, the contents of cadmium and lead in the leaves of the studied cultivars were similar. Agora cv. was grown both in spring and in autumn. This cultivar showed a lesser Cd and Pb accumulation when grown in autumn than when grown in spring.

Lettuce grown in all experimental combinations. *Autumn*. Increased Cd doses showed a corresponding increase of this metal in lettuce leaves (tab. 1). Differences in Cd content in plants caused by successive Cd doses were significant. Lettuce cultivars differed in their ability to accumulate Cd in leaves. Bona and Saba cvs. showed the least accumulation of heavy metals, while Króla Majowych and Tola cvs. demonstrated the highest level.

Increased doses of lead gave a corresponding increase of this metal in lettuce leaves (tab. 2). Differences in Pb content in the plants corresponding to each successive dose level were significant. Lettuce cultivars differed in their ability to accumulated lead in their leaves. The cultivars: Agora, Bona and Regina showed the least and similar accumulation ability. Królowa Majowych and Tola cvs. were characterized by a significantly higher amount of accumulated lead.

Table 2. The lead content in leaves of lettuce cultivars grown in autumn – mean values for years 1998–2000, mg · kg^{-1} d.w.

Tabela 2. Zawartość ołowiu w liściach odmian sałaty uprawianej jesienią – średnie dla lat 1998–2000, mg · kg^{-1} s.m.

Dose Pb Dawka Pb mg·dm^{-3}	Cultivars – Odmiany						Mean Średnia
	Agora	Bona	Królowa Majowych	Regina	Saba	Tola	
0	4.06 a*	5.88 b-e	5.35 bc	5.04 b	5.68 b-d	5.67 b-d	5.28 A*
10	6.25 c-e	6.17 c-e	6.18 c-e	5.85 b-e	6.39 de	6.64 e	6.24 B
50	8.10 f	9.85 gh	9.23 g	9.69 gh	9.95 gh	11.99 k	9.80 C
100	10.38 hi	10.93 ij	13.66 l	10.88 ij	12.17 k	12.36 k	11.73 D
150	14.07 l	11.80 k	17.99 n	11.49 jk	15.54 m	16.15 m	14.51 E
Mean Średnia	8.57 A*	8.93 A	10.48 C	8.59 A	9.95 B	10.56 C	

*values followed by the same letters are not significantly different at α = 0.05
wartości oznaczone tą samą literą, nie różnią się statystycznie przy α = 0,05

In autumn, Bona and Saba cvs. showed the least accumulation of cadmium, while Agora, Bona and Regina cvs. had the least content of lead.

Spring. Successive doses of cadmium in the substrate resulted in an increased content of this metal in the leaves of lettuce cultivars (tab. 3). The increased Cd content in the plants corresponding to each successive Cd dose was significantly higher. Lettuce cultivars differed in their ability of accumulating cadmium in their leaves. The least Cd accumulation was shown by Marta cv., while the highest Cd content was found in Justyna cv.

Table 3. The cadmium content in leaves of lettuce cultivars grown in spring – mean values for years 1999–2001, mg · kg^{-1} d.w.

Tabela 3. Zawartość kadmu w liściach odmian sałaty uprawianej wiosną – średnie dla lat 1999–2001, mg · kg^{-1} s.m.

Dose Cd Dawka Cd mg·dm^{-3}	Cultivars – Odmiany				Mean Średnia
	Agora	Justyna	Marta	Syrena	
0	1.66 a*	1.43 a	1.67 a	1.51 a	1.57 A*
2	17.84 b	17.78 b	15.86 b	16.63 b	17.03 B
5	33.90 c	34.63 c	29.80 c	33.99 c	33.08 C
10	53.44 ef	54.80 f	47.21 de	43.62 d	49.77 D
25	75.79 g	84.69 h	69.80 g	76.78 g	76.77 E
Mean Średnia	36.53 BC*	38.67 C	32.87 A	34.51 AB	

*values followed by the same letters are not significantly different at α = 0.05
wartości oznaczone tą samą literą, nie różnią się statystycznie przy α = 0,05

Table 4. The lead content in leaves of lettuce cultivars grown in spring – mean values for years 1999–2001, mg · kg^{-1} s.m.

Tabela 4. Zawartość ołowiu w liściach odmian sałaty uprawianej wiosną – średnie dla lat 1999–2001, mg · kg^{-1} s.m.

Dose Pb Dawka Pb mg·dm^{-3}	Cultivars – Odmiany				Mean Średnia
	Agora	Justyna	Marta	Syrena	
0	5.78 a*	6.56 ab	5.69 a	5.93 a	5.99 A*
10	7.19 b	8.41 c	7.38 b	7.18 b	7.54 B
50	9.58 de	9.05 cd	9.37 d	10.28 ef	9.57 C
100	11.79 g	10.94 fg	14.34 i	11.11 fg	12.05 D
150	15.83 j	13.91 i	19.31 k	12.65 h	15.42 E
Mean Średnia	10.03 B*	9.78 AB	11.22 C	9.43 A	

*values followed by the same letters are not significantly different at α = 0.05
wartości oznaczone tą samą literą, nie różnią się statystycznie przy α = 0,05

Increased lead doses in the substrate resulted in an increased content of this metal in the leaves of lettuce cultivars (tab. 4). The content of Pb in the leaves of each successive combination was higher than in the preceding one. The cultivars differed in their ability to accumulated lead in their leaves. The least amount of this metal was accumulated by Syrena cv. and the highest Pb amount was found in Marta cv. In spring, Marta cv. showed the least content of cadmium, while Syrena cv. was characterized by the least amount of lead.

DISCUSSION

The admissible Cd and Pb levels for lettuce are 0.2 mg Cd and 0.3 mg Pb·kg^{-1} fresh mass respectively [Journal of Law, D.U. 2003*]. It corresponds approximately to 2.0 mg Cd and 3.0 mg Pb in conversion to 1 kg of dry mass.

*This level is binding since the date of Poland's access to EU

The analysis of Cd content in lettuce grown in control combinations (without any addition of Cd and Pb) did not show any excess of the permissible Cd content in the leaves of the studied cultivars, either in spring or in autumn. The admissible Cd content for leaf vegetables (mentioned above), which is valid since the date of Poland's access to the European Union, has been fixed on a four-fold milder level. It seems that the admissible Cd content in leaf vegetable is too liberal.

All lettuce cultivars grown in spring and in autumn in substrate with an addition of 2 mg $Cd \cdot dm^{-3}$ (the smallest dose) were characterized by a higher Cd content than the admissible level. Analysis of Pb content in the leaves of lettuce cultivars grown in control combinations in spring and in autumn showed a higher value than the admissible one in spite of the natural Pb content in the substrate (3.22 mg $Pb \cdot dm^{-3}$ in mineral soil, and 0.67 mg $Pb \cdot dm^{-3}$ in peat). Lettuce grown in spring and in autumn in substrate with Pb addition, even in the smallest dose (10 $mg \cdot dm^{-3}$), showed also a higher lead content than the admissible one. Jurkowska et al [1999] reported that oil rape, spinach and garden beet grown in a soil with natural lead content (20 $mg \cdot kg^{-1}$) accumulated this metal in the edible parts in amounts which disqualify the vegetable for consumption. Gawęda [1996] investigated lead accumulation in two lettuce cultivars: Syrena and Debata. In control combinations, both cultivars showed the same content of lead. In combinations with an addition of lead, Debata cv. accumulated less lead. Gawęda [1998] reported that lettuce cultivars (Syrena and Ara) did not differ significantly in their ability of lead accumulation. Michalska [1996] compared two field-grown lettuce cultivars and found very high differences in cadmium and lead contents. The same author [Michalska 1997], in her comparison of 26 field-grown lettuce cultivars, confirmed the same regularity. Differences in cases of extreme Cd and Pb contents in the studied cultivars oscillated between about 40 mg and over 200 mg $Cd \cdot kg^{-1}$ d.m., and from 200 mg to over 1800 mg $Pb \cdot kg^{-1}$ d.m.

Crews and Davies [1985] found a small differentiation between six lettuce cultivars in reference to lead, but a high difference in reference to cadmium.

CONCLUSIONS

1. In control combinations, Agora cv. grown in autumn, in spite of a longer vegetation period, accumulated less cadmium and lead than when grown in spring. The same cultivar grown in autumn accumulated the least amount of lead, while Bona cv. accumulated the least amount of cadmium. In lettuce grown in spring, the content of both metals in the analysed lettuce leaves was similar.

2. In combinations with cadmium and lead doses grown in autumn, the least amount of lead was accumulated by Agora, Bona and Regina cvs., while the least amount of cadmium was shown by Bona and Saba cvs. In lettuce grown in spring, the least amount of lead was accumulated by Syrena cv. and the least amount of cadmium was found in Marta cv.

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RÓŻNICE ODMIANOWE W AKUMULACJI KADMU I OŁOWIU PRZEZ SAŁATĘ (*Lactuca sativa* L.)

Streszczenie. Między odmianami sałaty stwierdzono zróżnicowaną zdolność do akumulacji metali. W uprawie jesiennej, w kombinacjach z dodatkiem ołowiu i kadmu, najmniej ołowiu gromadziły odmiany Agora, Regina i Bona, a najmniej kadmu stwierdzono u odmian Saba i Bona. Wiosną, najmniej ołowiu gromadziła Syrena, a najmniej kadmu wykazała odmiana Marta.

Słowa kluczowe: kadm, ołów, sałata, odmiany

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