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EFFECT OF ORGANIC SUBSTANCE WITH DIVERSIFIED DECOMPOSITION DEGREE ON CADMIUM AND LEAD UPTAKE BY LETTUCE (*LACTUCA SATIVA* L.)

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ABSTRACT. Pot experiments with lettuce were carried out in the years 1999-2001. Substrates for the growing of these plants consisted of mineral soil (coarse sandy soil) and mixtures of this soil with 30% addition of brown coal, pine sawdust, wheat straw and pine bark. The substrates were supplemented with increasing doses of cadmium (0; 2.5; 10 $mg \cdot dm^{-3}$) and lead (0; 25; 100 $mg \cdot dm^{-3}$). After the termination of experiments, a great diversity in the amount of organic substance was found in the substrates. Except for the control, the greatest amount of organic substance was found in the substrates with addition of brown coal and the least amount was shown by the substrates with an addition of straw. In the successive years, the amount of organic substance was decreasing. Also the cadmium and lead content decreased in the leaves of lettuce.

Key words: mineral soil, brown coal, pine sawdust, wheat straw, pine bark, organic substance, lettuce, lead, cadmium

Introduction

In view of the practical impossibility to remove cadmium and lead from the soil and substrates, attempts are undertaken to mitigate the results of significant concentractions of these metals in the soil and substrates by the introduction of organic substances, loamy materials, aluminosilicates and by soil liming. The main objective of the experiments carried out for three years was the investigation of the effect of different types of organic substances with diversified decomposition degree on the uptake of cadmium and lead by lettuce.

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Material and methods

Pot experiments with lettuce "Marta" were carried out in the years 1999-2001 in Experimental Farms August Cieszkowski Agricultural University of Poznań: Experimental Station "Ogrody" in 1999, and Experimental Station "Marcelin" in 2000 and 2001. Pot experiments with lettuce were carried out in unheated greenhouse in the spring – summer seasons in three successive years: 1999, 2000 and 2001. Experimental factors were the following ones: increasing Cd doses (three doses 0; 2.5; 10 mg $Cd \cdot dm^{-3}$ of substrate) and Pb (three doses 0; 25; 100 mg $Pb \cdot dm^{-3}$); substrates consisting of mixture of loamy sand (LS: 83% of sand, 14% of silt, 3% of clay) with: brown coal, pine sawdust, wheat straw and pine bark; years of experiment (three years). Organic substance was added to mineral soil only in the first year of experiments in the amount of 30% of volume. Containers with the addition of organic substance in which vegetative experiments were performed in the second and third year were kept in greenhouse.

All substrates were supplemented (only in the first year) with calcium in the form of $CaCO_3$ (reagent pure for analyses) in the following doses in ($g \cdot dm^{-3}$): loamy sand (LS) 2.5; LS + brown coal 2.5; LS + pine sawdust 5.0; LS + wheat straw 2.5 LS + pine bark 5.0. $CaCO_3$ doses were determined on the basis of neutralization curves in order to obtain substrate pH in the interval between 6.5 and 7.0. Cadmium in the form of cadmium sulphate, and lead in the form of lead acetate, and macro- and micro-components were added in the same amount each year, one week before the plantation of lettuce seedlings. In the experiments macro-components were applied to obtain the following levels ($mg \cdot dm^{-3}$): in substrates for the growing of lettuce: 150 N – KNO_3; $Mg(NO_3)_2 \times 6H_2O$; 75 P – KH_2PO_4; 200 K – KH_2PO_4; KNO_3; 97 Mg – $Mg(NO_3)_2 \times 6H_2O$. Magnesium was not added to mineral soil with the addition of brown coal because this substrate contained a great amount of magnesium. Micro-components were added in the amount of 0.1 $g \cdot dm^{-3}$ to substrates for growing of lettuce in the form of Polichelate LS – 7 produced by Institute of Artificial Fertilizers in Puławy. All reagents were used in solutions.

In the years 1999-2001, three vegetations experiments were carried out. Each vegetation experiment consisted of 15 combinations. Each combination included 4 replications. The replications included 4 lettuce plants grown in polyethylene containers of 6 dm^3 capacity.

After harvest, lettuce leaves were dried and homogenized and subsequently, the air dry plant material in the amount of 2.5 g was transferred to porcelain crucibles and mineralized in combustion furnace LINN, Electro Therm, at 450°C. The content of cadmium and lead was determined by atomic absorption spectrophotometer AAS-3 (Zeiss Co.). Evaluation of the exactness and precision of determinations was carried out using certified plant material Cl–1 CABBAGE LEAVES.

Organic coal was determined by oxydometric method in a mixture of $K_2Cr_2O_7$ pure for analysis anhydride (2 $mol \cdot dm^{-3}$) and concentrated H_2SO_4.

Total nitrogen was determined by Kjeldahl´s method in Parnas-Wagner apparatus (**Lityński** et **al.** 1976).

Results and discussion

After the termination of experiments high diversity in amount of organic substance was found in the studied substrates (Table 1).

In all three years of studies, the greatest amount of organic substance was found in the substrates with an addition of brown coal. The content of organic substance, C:N proportion and the decrease of organic substance in the second and third year of studies expressed in percentages in relation to the first year in the substrates where lettuce was grow are show in table 1. Among substrates where organic substance was added, the smallest amount of it was found in the loamy sand with an addition of straw. It was also found that the amount of organic substance was decreasing in the successive years of studies. Substrates showed a very diversified decrease of organic substance. The greatest losses of organic substance in the second and third year of studies were found in the substrates with an addition of straw. In loamy sand, the decrease of organic substance was the smallest in comparison to other substrates. A greater loss of organic substance indicates a faster mineralization of the given type of organic substance.

According to **Mercik** et **al**. (1995), the humification coefficient of organic C introduced with organic fertilizers most frequently does not exceed 10% and they create comparatively few longlasting organic-mineral compounds. **Janssen** and **Noij** (1986) elaborated a simulation model for the calculation of the mineralization for a single application of organic fertilizers. The authors came to the conclusion that the time of total mineralization of organic substance expressed in years is 4-13 year for peat, 2.4 years for cow dung, 1.4 years for straw and 1.0 year for green fertilizers. These results indicate that the most longlasting action on the soil properties can be exerted by peat, and the same authors believe that brown coal can act still longer. As we can see, the speed of organic C mineralization depends also on the type of organic substance.

An analysis of C:N proportion in all substrates revealed that in the first year of studies, the most contracted proportion was shown by loamy sand and the widest one by the substrate with an addition of pine sawdust. In the second year of studies, it was found that C:N proportion kept contracting in all substrates. In the third year of experiments, the C:N proportion kept contracting in all substrates in comparison to the first and the second year.

The introduction of brown coal, pine sawdust, wheat straw and pine bark to loamy sand caused an increase of the amount of organic substance an a wide C:N proportion in the studied substrates. The amount of heavy metals in lettuce leaves (Fig. 1-10) was smaller in plants which were grown in substrates with added organic substance. The amount of cadmium and lead in the leaves of lettuce decreased in the successive years of studies. The most visible decrease of heavy metals was found in plants grown on substrates with an addition of brown coal. In all experiments, it was found that a 30% addition of brown coal to loamy sand exerted the greatest effect on the decrease of the amount of cadmium and lead in the edible parts of lettuce.

One of the methods limiting the uptake of Cd and Pb by plants is the addition of organic substance to the soil. This view is dominating in the literature (**Kabata-Pendias** 1993, **Tyksiński** et **al.** 2002). As reported by **Ciećko** et **al.** (1995), an increased content of organic substance in the soil limits the solubility of Cd and Pb reducing thereby the uptake of these metals by plants.

Table 1

Content of organic substance, C:N proportion, decrease of organic substance in all substrates after the termination of experiments with lettuce
Zawartość substancji organicznej, stosunek C:N, ubytek substancji organicznej we wszystkich podłożach po zakończeniu doświadczeń z sałatą

Substrate Podłoża	Doses Dawki ($mg \cdot dm^{-3}$)		Organic substance Substancja organiczna (%)	C:N Propor-tion Stosunek C:N	Organic substance Substancja organiczna (%)	C:N Propor-tion Stosunek C:N	*Decrease of organic substance Ubytek substancji organicznej (%)	Organic substance Substancja organiczna (%)	C:N Propor-tion Stosunek C:N	*Decrease of organic substance Ubytek substancji organicznej (%)
	Cd	Pb	I year of studies I rok badań		II year of studies II rok badań			III year of studies III rok badań		
Loamy sand (LS) Piasek słabo gliniasty (psg)	0	0	1.8	7.1	1.7	6.9	**5.6**	1.7	5.7	**5.6**
	2.5	25	1.8	4.0	1.7	5.0	**5.6**	1.7	5.6	**5.6**
	10	100	1.7	6.4	1.7	5.8	**0.0**	1.6	5.0	**5.9**
LS + Coal Psg + Węgiel	0	0	10.0	20.4	9.3	17.1	**7.0**	8.8	15.6	**12.0**
	2.5	25	10.1	20.0	9.1	14.7	**9.9**	8.9	14.3	**11.9**
	10	100	10.1	20.3	9.5	18.0	**5.9**	8.6	14.7	**14.9**
LS + Sawdust Psg + Trociny	0	0	6.3	27.5	5.8	12.2	**7.9**	5.6	9.1	**11.1**
	2.5	25	6.0	31.8	5.7	12.8	**5.0**	5.5	8.3	**8.3**
	10	100	6.1	25.8	5.5	11.4	**9.8**	5.3	7.2	**13.1**
LS + Straw Psg + Słoma	0	0	4.5	17.1	3.1	13.2	**31.1**	2.6	6.4	**42.2**
	2.5	25	4.7	12.9	3.2	10.7	**31.9**	2.5	6.8	**46.8**
	10	100	4.7	15.0	3.1	10.7	**34.0**	2.9	8.9	**38.3**
LS + Bark Psg + Kora	0	0	5.8	13.6	5.3	7.6	**8.6**	5.1	5.6	**12.1**
	2.5	25	5.8	10.7	5.2	7.2	**10.3**	5.1	5.7	**12.1**
	10	100	5.9	16.8	5.5	7.1	**6.8**	5.3	5.4	**10.2**

*Decrease of organic substance in relation to the first year.
*Ubytek substancji organicznej w stosunku do roku pierwszego.

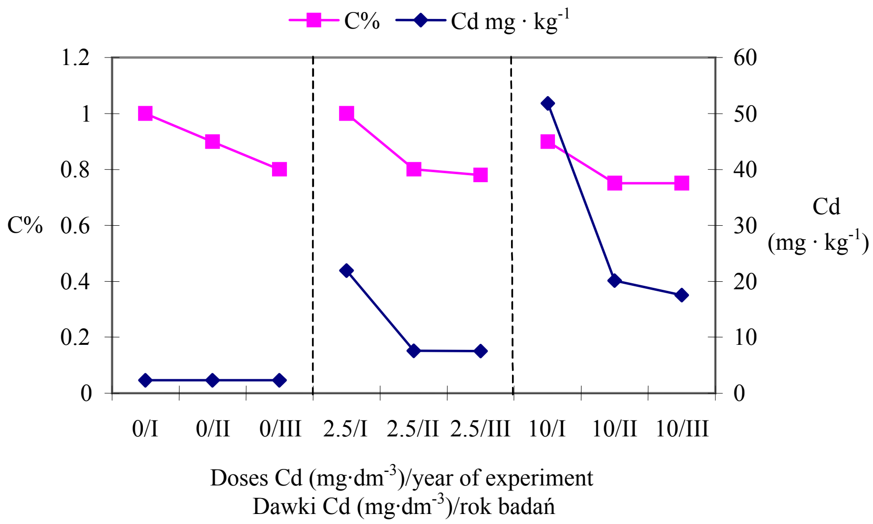

Fig. 1. Cadmium content in lettuce leaves depending on the dynamics of organic C content in loamy sand
Ryc. 1. Zawartość kadmu w liściach sałaty w zależności od dynamiki zawartości C organicznego w glebie mineralnej

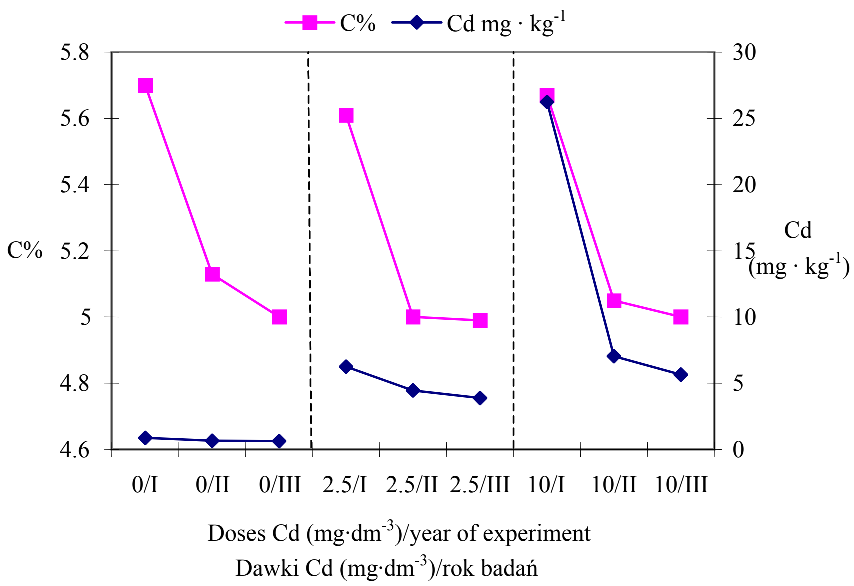

Fig. 2. Cadmium content in lettuce leaves depending on the dynamics of organic C content in substrates with an addition of brown coal
Ryc. 2. Zawartość kadmu w liściach sałaty w zależności od dynamiki zawartości C organicznego w podłożach z dodatkiem węgla brunatnego

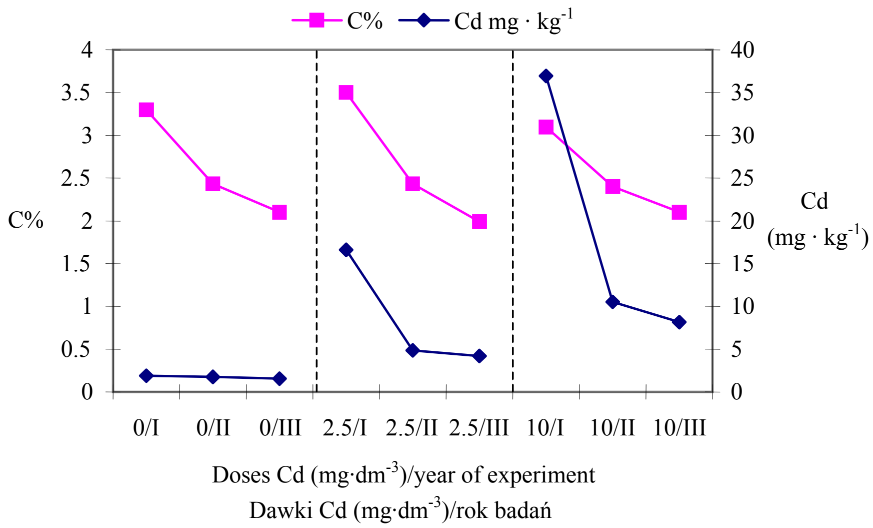

Fig. 3. Cadmium content in lettuce leaves depending on the dynamics of organic C content in substrates with an addition of pine sawdust
Ryc. 3. Zawartość kadmu w liściach sałaty w zależności od dynamiki zawartości C organicznego w podłożach z dodatkiem trocin sosnowych

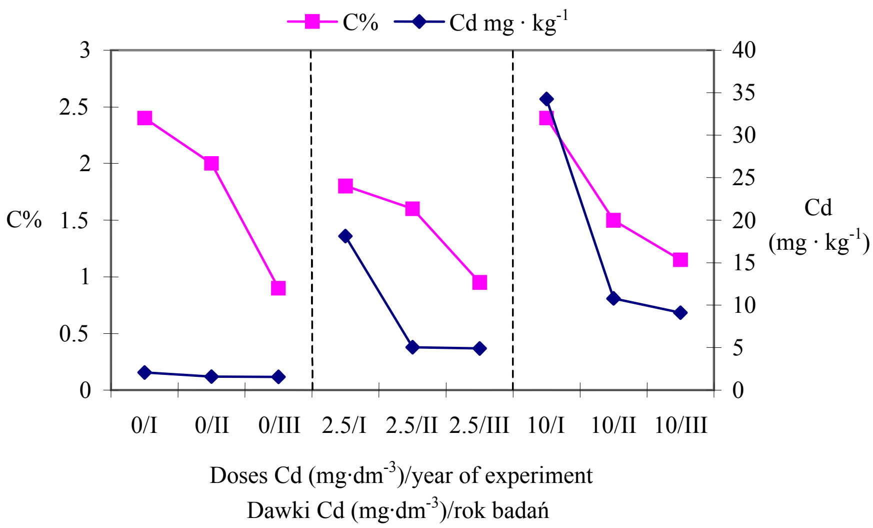

Fig. 4. Cadmium content in lettuce leaves depending on the dynamics of organic C content in substrates with an addition of wheat straw
Ryc. 4. Zawartość kadmu w liściach sałaty w zależności od dynamiki zawartości C organicznego w podłożach z dodatkiem słomy pszennej

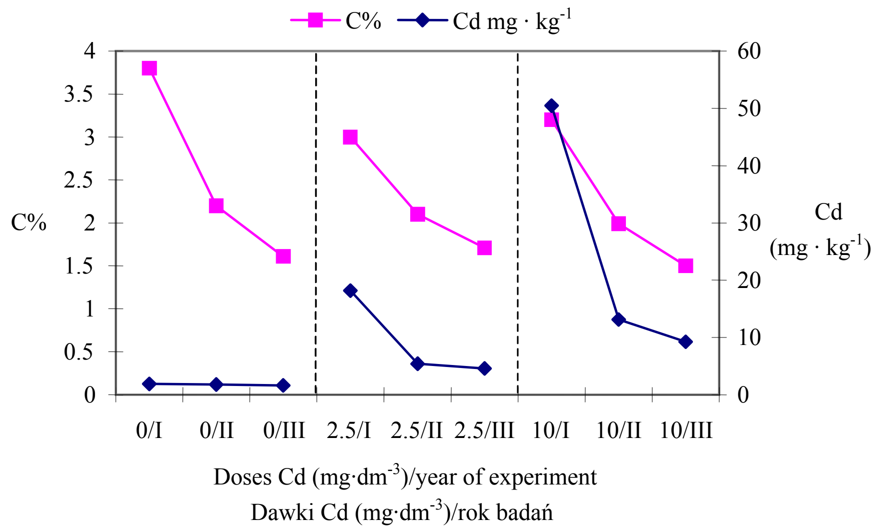

Fig. 5. Cadmium content in lettuce leaves depending on the dynamics of organic C content in substrates with an addition of pine bark
Ryc. 5. Zawartość kadmu w liściach sałaty w zależności od dynamiki zawartości C organicznego w podłożach z dodatkiem kory sosnowej

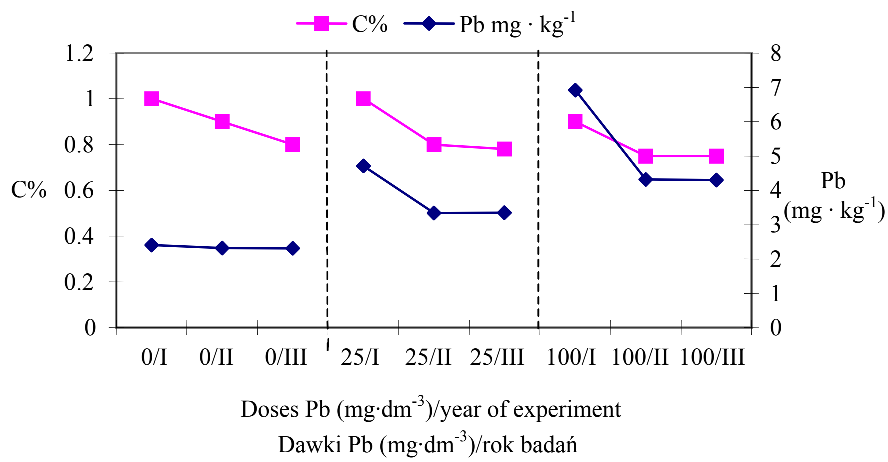

Fig. 6. Lead content in lettuce leaves depending on the dynamics of organic C content in loamy sand
Ryc. 6. Zawartość ołowiu w liściach sałaty w zależności od dynamiki zawartości C organicznego w glebie mineralnej

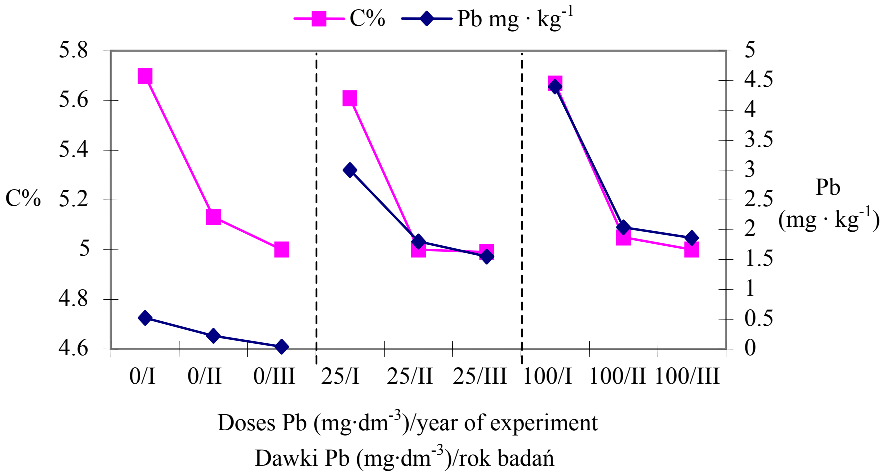

Fig. 7. Lead content in lettuce leaves depending on the dynamics of organic C content in substrates with an addition of brown coal
Ryc. 7. Zawartość ołowiu w liściach sałaty w zależności od dynamiki zawartości C organicznego w podłożach z dodatkiem węgla brunatnego

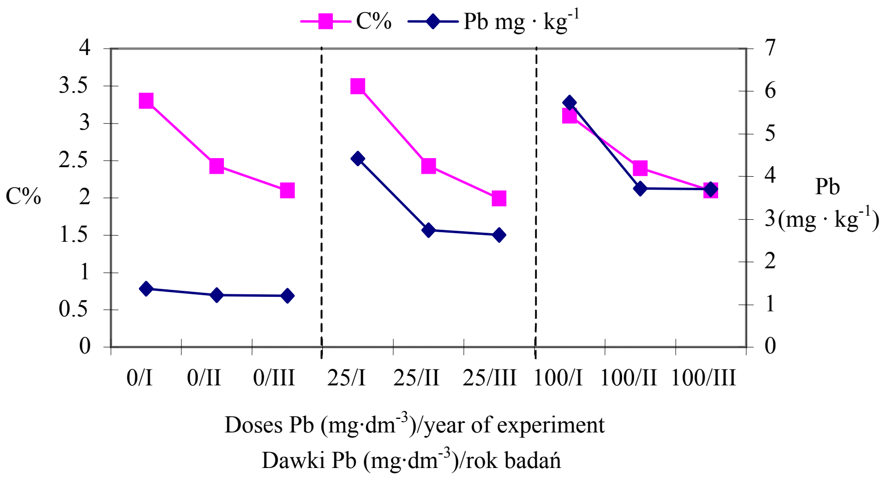

Fig. 8. Lead content in lettuce leaves depending on the dynamics of organic C content in substrates with an addition of pine sawdust
Ryc. 8. Zawartość ołowiu w liściach sałaty w zależności od dynamiki zawartości C organicznego w podłożach z dodatkiem trocin sosnowych

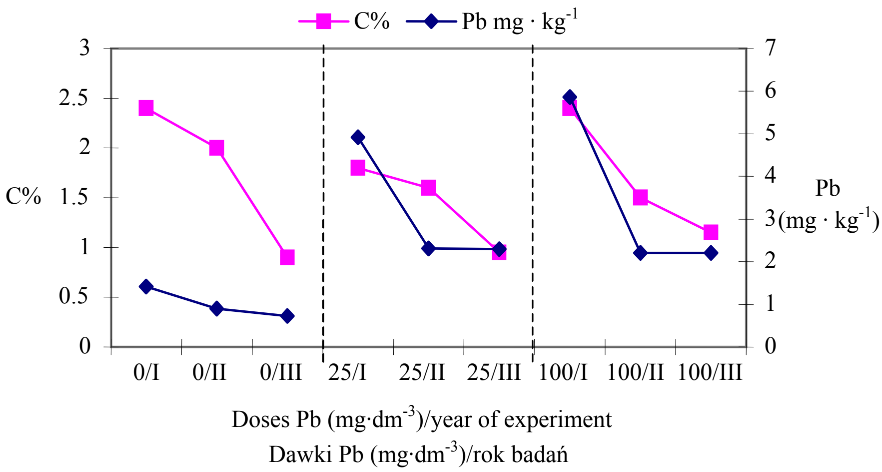

Fig. 9. Lead content in lettuce leaves depending on the dynamics of organic C content in substrates with an addition of wheat straw
Ryc. 9. Zawartość ołowiu w liściach sałaty w zależności od dynamiki zawartości C organicznego w podłożach z dodatkiem słomy pszennej

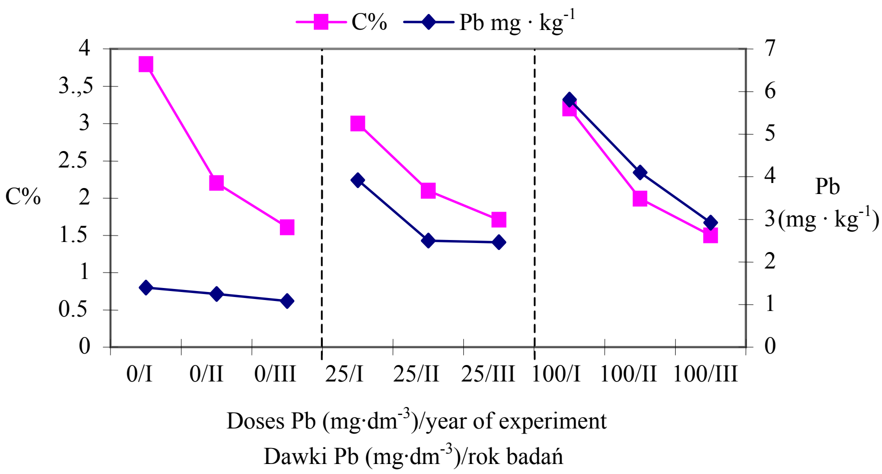

Fig. 10. Lead content in lettuce leaves depending on the dynamics of organic C content in substrates with an addition of pine bark
Ryc. 10. Zawartość ołowiu w liściach sałaty w zależności od dynamiki zawartości C organicznego w podłożach z dodatkiem kory sosnowej

Conclusions

1. The application of an addition of brown coal, pine sawdust, wheat straw and pine bark in the amount of 30% volumetric proportion to loamy sand caused a decrease of cadmium and lead content in the leaves of lettuce. In the successive years of studies, the content of cadmium and lead in the leaves of lettuce grown in the same substrates was decreasing.

2. Among all types of organic substances, a 30% addition of brown coal limited the plant uptake of cadmium and lead in the highest degree.

3. In the second and third years of studies, the C:N proportion kept contracting in all substrates where organic substance was added.

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WPŁYW SUBSTANCJI ORGANICZNEJ O ZRÓŻNICOWANYM STOPNIU ROZKŁADU NA POBIERANIE KADMU I OŁOWIU PRZEZ SAŁATĘ

S t r e s z c z e n i e

Doświadczenia wazonowe z sałatą przeprowadzono w latach 1999-2001. Podłoża do uprawy tych roślin stanowiły gleba mineralna (piasek słabo gliniasty) oraz mieszaniny tej gleby z 30% dodatkiem węgla brunatnego, trocin sosnowych, słomy pszennej i kory sosnowej. Do podłoży dodano wzrastające dawki kadmu (0; 2,5; 10 $mg \cdot dm^{-3}$) oraz ołowiu (0; 25; 100 $mg \cdot dm^{-3}$).

Po zakończeniu doświadczeń stwierdzono duże zróżnicowanie ilości substancji organicznej w badanych podłożach. Poza kontrolą najwięcej substancji organicznej było w podłożach z dodatkiem węgla brunatnego, a najmniej w podłożach z dodatkiem słomy. W kolejnych latach ilość substancji organicznej ulegała obniżeniu. Obniżeniu ulegała też zawartość kadmu i ołowiu w liściach sałaty. Dodatek węgla brunatnego w ilości 30% objętości najbardziej ograniczył pobieranie Cd i Pb przez sałatę.