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EFFECT OF LEAD ON THE GROWTH AND UPTAKE OF SOME NUTRIENTS BY LETTUCE AND SPINACH

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ABSTRACT

A greenhouse experiment was conducted at Soils Dept., Fac. Agric., Mansoura Univ. during 2000 / 2001 season to study the effect of different rates of lead added in form of lead sulphate ($PbSO_4$) at the rates of 0, 100, 200, 300 and 400 ppm Pb on the dry weight and chemical composition of lettuce *(Lactuca sativa)* and spinach *(Spinacia oleracea)*.

Results showed that dry matter yield of shoots and roots for both lettuce and spinach decreased by increasing Pb levels in the experimental soil.

With regard to the effect of lead levels on lead concentration and uptake by lettuce and spinach tissues, results showed that lead concentration and uptake increased with increasing lead levels in the experimental soil, and the concentration of Pb reached the toxic levels in the roots of the two plants. However, the concentrations and uptake of nitrogen, phosphorus and potassium by the plant tissues had a severely reduction with increasing lead levels in the experimental soil.

Keywords: Lead, growth, concentration, uptake, lettuce, spinach.

INRODUCTION

There no doubt that our knowledge has increased during the last decade concerning the danger of soil pollution especially by heavy metals on the environment.

The volume of heavy metals is increasing in the environment as a result of the discharge of metal- rich residues and the application of polluted production factors. Among these heavy metals, lead is shown to be very toxic for plants and animals. Torres, *et al.* (1996) recommended upper limits for total lead content in cultivated soils of 50-300 mg kg^{-1}.

Lead (Pb) is considered to be one of the heavy metals in agricultural environment. It can be easily absorbed and translocated to food crops in quantities that are not phytotoxic, yet may be harmful to human health (Chaney, 1980).

Lead and other toxic metals can be incorporated into soils by aerial deposition or as a consequence of sludge or city refuse applications. Although, soil lead presents low availability to plants, uptake and translocation may be enough to pose serious health risks to animals which feed on these plants (Kabata Pendias and Pendias, 1992).

The purpose of this study is to investigate the effect of different rates of lead on growth, yield and yield components of lettuce and spinach.

MATERIALS AND METHODS

Surface soil samples (0-30 cm) were collected from the Experimental Farm of the Faculty of Agriculture, Mansoura University, Egypt. The collected soil samples were air-dried, crushed to pass through a 2mm-sieve and

preserved for analysis. Some physical and chemical characteristics of the experimental soil are listed in Table 1. The soil analyses were determined as follows: Mechanical analysis was carried out using the international pipette method as described by Dewis and Freitas (1970); Saturation percentage was determined using the method of Richards (1954); Calcium carbonate was estimated gasometrical using Collin's calcimeter (Dewis and Freitas,1970); Organic matter content was determined by Walkley and Black method as described by Hesse (1971); Soil pH and EC were measured in the soil paste and soil paste extract, respectively (Jackson,1967). Available nitrogen was extracted by KCl 2 M and determined using the conventional method of Kjeldahl (Jackson,1967); Available phosphorus was extracted by $NaHCO_3$ 0.5 M, at pH 8.5 and determined colorimetrically according to Jackson (1967), available potassium was determined by extracting soil with 1.0 N ammonium acetate at pH 7 as described by Hesse (1971) and available Pb was extracted with 0.5 M HNO_3 and determined as described by Hesse (1971).

Table (1): Some physical and chemical characteristics of the xperimental soil.

Soil properties	Values
Sand, %	24.30
Silt, %	25.50
Clay, %	50.20
Soil texture	Clayey
Saturation percentage, %	67
Calcium carbonate, %	3.22
Organic matter, %	1.8
pH (soil paste)	7.6
EC ,dS/m	1.52
Available N , ppm	27
Available P , ppm	9.2
Available K , ppm	521
Available Pb , ppm	2.40

Plastic pots of 30-cm diameter and 40 cm depth were used. Each pot was filled with washed fine gravel up to 2 cm height from the bottom to improve aeration and irrigation processes. Each pot was filled with 8 kg air-dried soil. This investigation included two vegetable crops, lettuce (*Lactuca sativa L.*) and spinach (*Spinacia oleracea*), which have a strong ability to accumulate heavy metals (in particular), (Alloway, 1995).

The used experimental design was the randomized complete block design for both crops.

Lead was applied in 5 rates (0, 100, 200, 300 and 400 ppm) as lead sulphate ($PbSO_4$) and each rate was replicated 3 times, all of these treatments were added in the first irrigation which was 70% of the soil field capacity, after all pots were irrigated to reach 70% of the field capacity with which the lead treatments were applied, two lettuce (*Lactuca sativa L.*) seedlings and ten spinach (*Spinacia oleracea*) seeds were cultivated.

Spinach seedlings were thinned to five plants per pot. The assumed field capacity was readjusted each three days together with the irrigation water.

The two plants were fertilized with the recommended dose of the chemical fertilizers which are 40 kg N/fed and 24 kg P_2O_5/fed as ammonium sulphates (21%N) and superphosphate (15.5% P_2O_5) respectively, and the two plants were harvested after 90 days from cultivation.

After the plants were harvested, they were separated into shoots and roots and washed with tap water then distilled water. The different parts were oven dried at 70^0C until the constant weight; the dry weight was calculated in g/pot, and stored for chemical analysis. The ground plant material was digested by H_2SO_4–$HClO_4$ mixture. The concentration of Pb as ppm was determined according to Chapman and Pratt (1961), and the uptake of Pb by plants was calculated by multiplying the element concentration by dry weight of plants.

The statistical analysis of the obtained data was carried out according to the method described by Snedecor and Cochran (1967).

RESULTS AND DISCUSSIONS

1-Dry weight of plants:

The influence of increasing Pb levels in the experimental soil on the dry weight of both shoots and roots of lettuce and spinach are shown in Table 2.

Data show that dry matter yield of shoots and roots for both lettuce and spinach decreased highly significant with increasing Pb level in the experimental soil.

These results were similar with those obtained by Yang and Lea (1990) whom observed that application of 10 mg Pb/L, significantly inhibited lettuce cv. Grand rapid growth, solutions with 5 mg Pb/L decreased fresh weight by 35-40%. Also, Hassan (1994) reported that there was a general reduction in spinach dry weight by increasing Pb concentrations in the nutrient solution, the effect was more pronounced at the highest applied level.

Table (2): Effect of increasing lead levels in the experimental soil on dry weight (g/pot) of both shoots and roots of lettuce and spinach (mean values).

Pb levels (ppm)	Lettuce		Spinach	
	Shoots	Roots	Shoots	Roots
0	38.73	4.79	8.64	2.35
100	38..31	4.73	8.55	2.32
200	37.60	4.63	8.39	2.27
300	36.64	4.50	8.19	2.20
400	35.60	4.34	7.96	2.13
L.S.D at 0.05	0.06	0.01	0.02	0.01
L.S.D at 0.01	0.09	0.02	0.03	0.02

Regarding the reduction percentage in the dry matter of lettuce and spinach as indicated in Table 3, it was observed that the highest reduction was at the highest level of Pb (400 ppm). The roots of both crops were the

most affected plant part by Pb application. Hassan (1994) and Koul *et al.* (2001) obtained similar results.

Poskuta *et al.* (1987) and Becerril *et al.* (1988) found that lead has an inhibitory effect on photosynthesis process, others attributed this reduction to the ability of lead for inhibiting protein synthesis (Taiz and Zeiger, 1998), or to the ability of lead for inhibiting carbohydrate and sugar, and may cause some defects in activity of some enzymes (Kandil, 1995).

Table (3): Effect of lead levels in the experimental soil on reduction percentages of dry weight organs of lettuce and spinach.

Pb levels ppm	Lettuce		Spinach	
	Shoots	Roots	Shoots	Roots
0	--------	--------	--------	--------
100	1.08	1.25	1.04	1.28
200	2.92	3.34	2.89	3.40
300	5.40	6.05	5.21	6.38
400	8.08	9.39	7.87	9.36
Mean	3.50	4.01	3.40	4.08

2-Lead concentration and uptake:

Data in Table 4 show that increasing Pb level application increased high significantly the Pb concentration and uptake by both shoots and roots of lettuce and spinach. These results are in accordance with those reported by Judel and Stelte (1977) who reported that low levels of the highly soluble lead acetate increased plant lead content only slightly but 500 ppm Pb caused considerable increases in lead concentration and uptake by radish, carrot and spinach.

The data in Table 4 reveal that Pb concentrations in roots of lettuce and spinach were higher than that of shoots. These results are in a harmony with those reported by Tung and Temple (1996) who reported that soil Pb accumulated primarily in the roots when they investigated the detection of Pb in living or presented plant tissues. Also, Rooney *et al.* (1999) reported that lead concentrations in the roots were several magnitudes higher than those present in the leaves when they discussed the effect of Pb concentration in soil on Pb accumulation in barley, lettuce, ryegrass, radish and clover.

Table 4. Effect of lead levels in the experimental soil on lead concentration (ppm) and uptake (µg/pot) by both shoots and roots of lettuce and spinach.

Pb levels (ppm)	Lettuce				Spinach			
	Shoots		Roots		Shoots		Roots	
	ppm	µg/pot	ppm	µg/pot	ppm	µg/pot	ppm	µg/pot
0	17.78	688.61	30.22	144.75	16.15	139.53	25.83	60.70
100	44.70	1712.46	104.15	492.62	37.71	319.00	86.22	200.03
200	83.76	3149.38	198.51	919.10	69.80	585.62	163.31	370.71
300	177.07	6487.97	433.82	1952.19	136.22	1115.64	326.92	719.22
400	190.88	6795.32	486.50	2111.41	168.19	1338.79	420.46	895.57
L.S.D at 0.05	0.05	10.80	0.43	11.17	0.09	2.12	0.17	3.81
L.S.D at 0.01	0.07	15.72	0.63	16.25	0.14	3.08	0.25	5.55

As shown in Table 4, data show that lead concentration in roots of both lettuce and spinach reached to the toxic levels according to the data reported by Bowen (1979) and Kabata- Pendias and Pendias (1992).

3-Nitrogen concentration and uptake:

Data presented in Table 5 indicate that increasing Pb levels from 0 to 400 ppm gave a high significant decrease in N concentration and uptake by both shoots and roots of lettuce and spinach.

These results agree with those reported by Dahdoh *et al.* (1996) who found that increasing Pb levels from 0 to 50, 100 and 150 ppm Pb decreased N concentration in alfalfa (*Medicago sativa*) and rocket (*Eruca Sativa*) plants grown in calcareous soils.

However, Michalska and Asp (2001) reported that presence of lead in a water culture experiment did not affect the concentration of N and other macro- and micro nutrients uptaked by lettuce plant.

Table 5. Effect of lead in the experimental soil on nitrogen concentration (percentage) and uptake (mg/pot) by both shoots and roots of lettuce and spinach.

Pb levels (ppm)	Lettuce				Spinach			
	Shoots		Roots		Shoots		Roots	
	%	mg/pot	%	mg/pot	%	mg/pot	%	mg/pot
0	3.96	1533.70	2.77	132.68	3.61	311.90	2.35	55.22
100	3.89	1490.25	2.71	128.18	3.55	303.53	2.32	53.82
200	3.78	1421.28	2.61	120.84	3.44	288.61	2.23	50.62
300	3.64	1333.70	2.49	112.05	3.32	271.90	2.11	46.42
400	3.47	1235.32	2.34	101.55	3.17	252.33	2.00	42.60
L.S.D at 0.05	0.01	4.98	0.01	0.54	0.01	1.87	0.01	0.62
L.S.D at 0.01	0.02	7.24	0.02	0.78	0.02	2.73	0.02	0.90

4-Phosphorus concentration and uptake:

Data in Table 6 show the effect of Pb application on P concentration (%) and uptake by lettuce and spinach organs.

Table 6. Effect of lead in the experimental soil on phosphorus concentration (percentage) and uptake (mg/pot) by both shoots and roots of lettuce and spinach.

Pb levels (ppm)	Lettuce				Spinach			
	Shoots		Roots		Shoots		Roots	
	%	mg/pot	%	mg/pot	%	mg/pot	%	mg/pot
0	0.429	166.15	0.181	8.67	0.395	34.13	0.164	3.85
100	0.426	163.20	0.179	8.46	0.390	33.34	0.163	3.78
200	0.420	157.92	0.176	8.14	0.385	32.30	0.160	3.63
300	0.413	151.32	0.172	7.74	0.379	31.05	0.156	3.43
400	0.403	143.46	0.166	7.20	0.371	29.53	0.151	3.22
L.S.D at 0.05	0.001	0.65	0.0006	0.03	0.003	0.31	0.001	0.06
L.S.D at 0.01	0.002	0.94	0.0009	0.04	0.004	0.46	0.002	0.09

Data clearly show that there was a highly significant reduction in P concentration and uptake by lettuce and spinach organs, due to increasing Pb level in the experimental soil from 0 to 100, 200,300 and 400 ppm. Gaweda and Capecka (1995) reported similar results when they investigated in a pot experiment, the effect of substrate pH on the accumulation of Pb, which applied at rates of 0,300 or 600 mg Pb/ dm^3 in radish and spinach. Dahdoh *et al.* (1996) agreed with this opinion. However, Stoyanov *et al.* (1980) did not agree with this opinion as they indicated that applied Pb increased accumulation of P in roots, stems and leaves of maize grown in a nutrient solution for 25 days.

5- Potassium concentration and uptake:

There is a high significant reduction in K concentration and uptake by both shoots and roots of lettuce and spinach as shown in Table 7. These results are in agreement with those reported by Foroughi *et al.* (1975) and Gaweda and Capecka (1995). However, Stoyanov *et al.* (1980) disagree with this result, where they reported that applied Pb increased the accumulation of K in roots, stems and leaves of maize plants grown in a nutrient solution. Also, Dahdoh *et al.* (1996) reviewed that increasing Pb application increased K concentrations in alfalfa (*Medicago sativa*) and rocket (*Eruca sativa*) plants when they discussed the effect of organic matter (Peat moss) on Pb absorption.

Table 7. Effect of lead in the experimental soil on potassium concentration (percentage) and uptake (mg/pot) by both shoots and roots of lettuce and spinach.

Pb levels (ppm)	Lettuce				Spinach			
	Shoots		Roots		Shoots		Roots	
	%	mg/pot	%	mg/pot	%	mg/pot	%	mg/pot
0	4.31	1669.26	1.90	91.01	3.72	321.40	1.61	37.83
100	4.23	1620.51	1.85	87.50	3.65	312.08	1.58	36.65
200	4.09	1537.84	1.77	81.95	3.53	296.17	1.51	34.27
300	3.91	1432.63	1.67	75.15	3.38	276.82	1.43	31.46
400	3.70	1317.20	1.55	67.27	3.19	253.92	1.34	28.54
L.S.D at 0.05	0.01	7.92	0.005	0.35	0.01	2.20	0.01	0.61
L.S.D at 0.01	0.02	11.53	0.007	0.50	0.02	3.21	0.02	0.90

Thus, it can be concluded that increasing Pb levels from 0 to 400 ppm caused a highly significant reduction in the dry matter yield of shoots and roots of lettuce and spinach plants. Also, Pb concentration and uptake by these plants were increased significantly with increasing Pb levels, and the concentration of Pb reached to the toxic levels in the studied two plant roots.

The concentration and uptake of N, P, and K were decreased significantly with increasing Pb levels.

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تأثير الرصاص على النمو ومحتوى بعض العناصر الغذائية لنباتات الخس والسبانخ

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أقيمت تجربة أصص بقسم الأراضي- كلية الزراعة- جامعة المنصورة- مصر ، خلال الموسم الزراعي ٢٠٠٠ /٢٠٠١ وذلك لدراسة تأثير إضافة الرصاص للتربة (في صورة كبريتات رصاص($PbSO_4$) بتركيزات صفر ،١٠٠، ٢٠٠ ،٣٠٠ و ٤٠٠ جزء/ مليون على الوزن الجاف والتركيب العنصري لكل من نباتي الخس والسبانخ.

أوضحت النتائج أنه حدث انخفاض معنوي في الوزن الجاف لكل من الجذور والسيقان في نباتي الخس والسبانخ وذلك عند زيادة مستويات الرصاص المضافة للتربة. أما بخصوص تأثير مستويات الرصاص على تركيز وامتصاص الرصاص في نباتي الخس والسبانخ فقد أوضحت النتائج أن هناك زيادة معنوية في تركيز وامتصاص الرصاص في أنسجة كل من النباتين. وقد حدث انخفاض معنوي في تركيز وامتصاص عناصر النيتروجين والفسفور والبوتاسيوم في كل من النباتين بتأثير زيادة تركيز الرصاص في التربة.

وقد اوضحت النتائج أن تركيز الرصاص قد وصل إلى حد السمية في جذور كل من نباتي الخس والسبانخ.