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EFFECT OF LEAD ON THE ACCUMULATION OF SOME METALS IN LEAVES OF *ZEA MAYS* L.

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The correlation between the concentration of lead (10^{-2} M - 10^{-6} M) in external medium and accumulation of some metals in leaves of *Zea mays* L. was investigated. The experiments were carried out on 8 day old maize plants (*Zea mays* L. var. K33xFa). The accumulation of metals in the leaves of maize was measured by emission spectroscopy using ICP-AES spectrometer and IY50P which simultaneously carries out the multielements solution analysis. High accumulation of lead was found in the leave tissues of plants growing in a medium containing 10^{-3} M and higher concentration of $PbCl_2$. On the other hand, lead ions at different concentrations (10^{-2} M - 10^{-6} M) decrease the uptake and accumulation of some examined metals in plant leaves.

INTRODUCTION

Heavy metals like Pb, Cd, Zn, Cu are common pollutants resulting from various agricultural and industrial activities. Lead has a relatively greater mobility than other heavy metals in the surrounding soil and in the plants and is very easily absorbed by plants though it has a toxic influence on the plant growth and on the some metabolic processes (Balsberg-Pahlsson, 1989). Pb influences respiration, as well as activity some enzymes in plant tissue and inhibits photosynthesis and synthesis of chlorophyll as well as transpiration (Burzyński, 1985, 1990; Clijster & Van Assche, 1985; Poskuta, Parys & Romanowska, 1987; Poskuta, Parys, Romanowska, Gajdziś-Gujdan & Wróblewska, 1988; Symeonidis & Karataglis, 1992). It has been found that lead acts on the structure and function of protoplasmic membranes, membrane permeability, as well as on ionic transport and ionic pumps localised in the plasmalemma. Especially, H^+ proton pump is sensitivity to stress (Pazurkiewicz-Kocot & Stolarek, 1991; Morse & Spanswick, 1984; Śpiewla, Godzik & Jaśkowska, 1983). Lead affects the uptake and distribution of nutrient elements in plants (Burzyński, 1987, 1988; Khan & Khan, 1983; Trivedi & Erdei, 1992). However, the uptake of lead may be affected by other elements (John & Van Laerhoven, 1972).

The aim of this work was to examine Pb accumulation in leaves of maize in the presence of 14 individual metals (Zn, Cd, Co, Ni, Mn, Fe, Cr, Al, Cu, Ba, Mg, Ca, Na, K) in the external medium.

MATERIALS AND METHODS

Plant material

The experiments were carried out on 8 day old maize plants (*Zea mays* L. var K33xFa). Seeds of *Zea mays* L. were cultivated for 4 days in darkness at 27°C on moist filter paper. Individual seedlings were transferred to an aerated Hoagland's solution, pH=6.5 (Hoagland, 1948) containing the macro- and microelements (Zn, Cd, Co, Ni, Mn, Fe, Cr, Al, Cu, Ba, Mg, Ca, Na, K) and cultivated in green house under 12h photoperiod at 25°C and an irradiance of ca. 100 W/m^2. Lead was added (as $PbCl_2$) to the nutrient solution on the second day of incubation at final concentrations of 10^{-2} M, 10^{-3} M, 10^{-4} M, 10^{-5} M and 10^{-6} M. The seedlings were exposed to the solution containing $PbCl_2$ about 72h before the chemical analysis.

Reagents and apparatus

The following reagents were used in the experiment: redistilled water, concentrated nitric acid and hydrogen peroxide solution. All chemicals were of analytical quality. The standard solution of Zn, Pb, Cd, Co, Ni, Mn, Fe, Cr, Al, Cu, Ba, Mg, Ca, Na, K metals used in this work were 1 mg/ml (Merck).

The concentration of lead ions and other elements in the leaves of maize was measured by emission spectroscopy with excitation by an argon inductively coupled plasma technique (ICP-AES), simultaneous ICP spectrometer JY5OP (JOBIN-YVON) at a frequency 40.68 MHz, power 1.0 kW, torch quartz (demountable), plasma gas 13.0 l/min, auxiliary gas 0.0 l/min, sheath gas 0.2 l/min (for

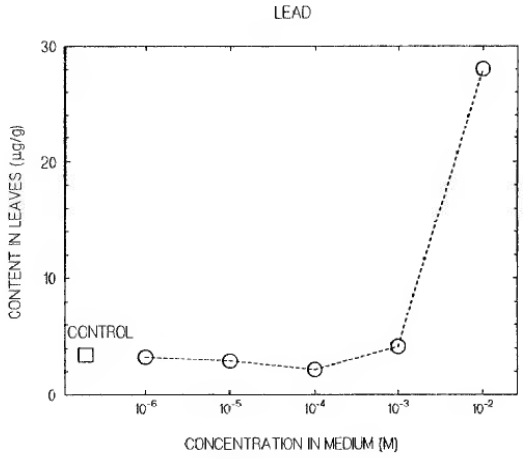

Fig. 1. The relationship between the leaf content of Pb (µg/g dry weight) and of Pb concentration (M) in external medium (the values in the figure represent the averages obtained from 3 measurements, the estimated standard error is of about 8%).

alkaline metals 0.75 l/min), carrier gas 0.3 l/min, nebulizer concentric Meinhard, nebulizer pressure 3.25 bar, spray chamber glass (according to Scott), sample rate 1 ml/min, holographic grating 3600 grooves/mm, wavelength range polychromator 165-770 nm, integration time 10 s, analytical line:

Zn — 213.856 nm; Pb — 220.353 nm; Cd — 226.502 nm; Co — 228.616 nm; Ni — 231.604 nm; Mn — 257.610 nm; Fe — 259.940 nm; Cr — 267.716 nm; Al — 308.215 nm; Cu — 324.754 nm; Ba — 233.527 nm; Mg — 279.553 nm; Ca — 317.933 nm; Na — 589.592 nm; K — 766.490 nm.

The emmision spectrometry with an excitation in the inductively coupled plasma (ICP-AES) is perfectly suited to the direct multielemental analysis of solutions. The method can be applied to the simultaneous determination of elements both in macroamounts and in trace analysis for the samples in solution (up to several millilitres).

Preparation of samples

Application of the ICP-AES technique in the analysis of materials originating from plants requires first mineralization of the sample which corresponds to the decomposition of the organic matrix. Depending on the type of the plant material and the analytical method applied several mineralization technique can be adopted. Here the plant tissue was dried at 105°C to constant mass and mineralized by using microwave techniques. In this work we applied a pressureless mineralization of the sample using microwave mineralizer MAXI-DIGEST MX 350 made by Prolabo Rhone-Poulence (France). Each sample of ca. 1 g dry matter was treated with 10 ml of concentrated nitric acid and left for 24 hours. Next the samples were mineralized by gradually raising the power and adding HNO_3 and H_2O_2 until complete mineralization was achieved (i. e. the solution was free of sediment). After mineralization the samples were diluted with redistilled water to a volume of 25 ml. The dissolved samples were introduced through a teflon connector on a peristaltic pump into a nebulizer. After pulverization with a carrier gas the sample was delivered to the ICP burner and analyzed.

RESULTS AND DISCUSSION

The correlation between the concentration of lead ions in the external medium and the accumulation of some metals in the leaves of the maize is

Tab. 1. Effect of lead on the accumulation of some metals in leaves of *Zea mays* L. (the values in the table are from 3 measurements, the estimated standard error is about 8%).

Metal contents µg/g dry weight	Control	10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}
K	18035.3	18717.3	22010.9	19221.9	22715.7	19770.8
Pb	1822.72	2311.47	1849.66	2085.58	2007.01	2107.72
Mg	1469.69	1898.79	1235.5	1341.69	1415.85	1494.57
Na	736.76	870.46	795.35	515.15	664.14	647.99
Zn	138.53	173.19	139.1	98	106.55	101.38
Fe	267.00	219.65	192.37	180.3	189.02	186.39
Al	102.26	198.67	55.3	52.28	58.93	96.15
Cu	24.83	27.68	25.93	21.72	20.58	20.38
Mn	27.05	30.13	23.53	27.72	26.02	28.25
Cr	13.55	10.1	8.43	6.57	7.77	7.14
Ni	7.75	11.82	3	2.35	4.85	2.4
Ba	2.76	2.93	2.44	1.96	1.82	2.05
Pb	2.42	3.25	2.92	2.15	4.95	28.05
Cd	0.81	0.72	0.48	0.58	0.55	1.11
Co	0.19	0.14	0.15	0.12	0.18	0.21

summarized (Tab.1 and Fig.2). The dependence between lead content in leaves and lead concentration in the external medium is shown in Fig.1. Our results indicate the strong accumulation of this metal in the tissues of plants grown in a medium containing 10^{-3} M and higher concentration of $PbCl_2$ (Fig.1). On the other hand lead ions affect the uptake and accumulation of the nutrient elements in plant leaves. This causes a decrease of the concentration of some elements in plant tissues. For the concentrations of the nutrient solution of 10^{-5} M Pb and higher we observed significant decrease of accumulation of the following metals: Fe, Zn, Al and Ni. The accumulation of the other metals such as Cu, Cr and Na were only slightly reduced in the presence of the Pb solutions. For the lowest concentration of Pb (10^{-6} M) we did not observe any significant influence on the accumulation of Zn, Ni, Cu, Cr and Na. For the other metals, however, the observed fluctuations of the metal contents were at the level of the experimental errors, for the whole range of the solutions of Pb used (Tab.1, Fig.2).

The toxic effect of lead on plants is reflected mainly in the form of the growth inhibition and the influence on some metabolic processes (Balsberg-Pahlsson, 1989: Burzyński, 1985, 1990; Kacabova & Natr, 1986; Symeonides & Karataglis, 1992). One of the effects of the extensive absorption of lead by plants is the uptake disturbance of the indispensable macro- and microelements in plants. Some authors have already shown decreases in the accumulation of necessary cations (K^+, Ca^{2+}, Mg^{2+}), some anions (phosphate, nitrates) and microelements such as Fe, Mn and Zn that was induced by lead ions present in soil or growth medium (Burzyński, 1987, 1988; John & Laerhoven, 1972; Trivedi & Erdei, 1992). Nevertheless, a number of reports indicate that the lead ions either do not have any influence on the uptake of cations or anions (Broyer, Johnson & Paul, 1972), or stimulate their absorption (Khan & Khan, 1983). It is possible that the primary influence of heavy metals on the plant cell depends on its interaction with the plasmalemma. The accumulation effect of the metal ions can be explained as a primary influence of the Pb ions on the protoplasmic membranes and, or on metabolic cellprocesses. Possibily Pb changes the permeability coefficient of plasmatic membranes for some ions and therefore it affects the ion transport in plant cells. Blockade of transport of the ions, is

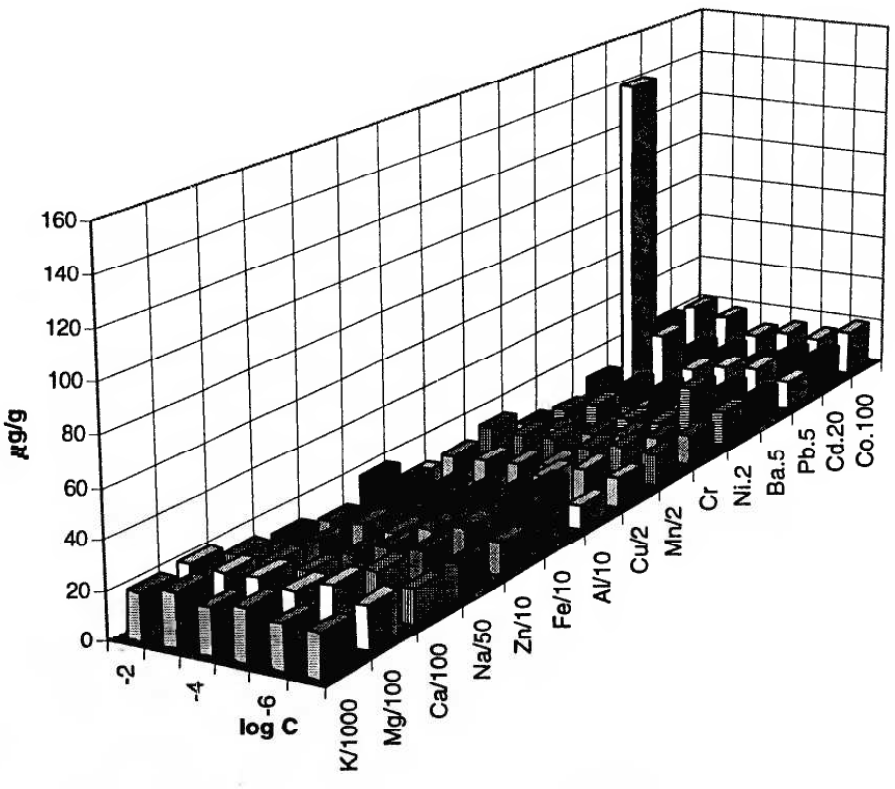

Fig. 2. The accumulation of some metals in leaves of plants (*Zea mays* L.) cultivated on Hoagland's solution at presence of lead ions at different concentrations (10^{-2} M - 10^{-6} M), (the values in the figure represent the averages obtained from 3 measurements, the estimated standard error is of about 8%).

probably one of the first observed symptoms of Pb toxic effects on plants.

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