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Characterization of the stimulating effect of low-dose stressors in maize seedlings

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ABSTRACT The effect of some more or less harmful compounds like Cd, Pb, Ni, Ti salts and DCMU at low concentrations on the development of chloroplasts in maize seedlings has been investigated. Stimulation of chlorophyll (Chl) synthesis, photosynthetic activity and increased amount of photosystem I and light-harvesting complex II (LHCII) was observed during the treatment, while chlorophyll a/b ratios did not change considerably except in DCMU treated plants. Electron micrographs showed only sligth differences in the morphology of chloroplast lamellar system. It is assumed that these low-dose stressors generate non-specific alarm reactions in plants, which may involve changes of the hormonal balance.

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KEY WORDS

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Toxic effects of some chemical stressors like heavy metals and herbicides have been thoroughly investigated at relatively high concentrations (~10^{-5}-10^{-3} M). Nevertheless, these compounds applied at low concentrations (~10^{-8} M to 10^{-6} M) may have a beneficial effect on plants. Acceleration of plant growth (Wójcik and Tukendorf 1999) and stimulation of metabolic activity (Krupa et al. 1993; Prasad et al. 2001) were the most frequently observed effects. To examine this stimulating effect we chose developing maize plants, which proved to be a sensitive model system in terms of chlorophyll synthesis and photosynthetic processes.

Materials and Methods

Maize (*Zea mays* L. var. Mvsc 429) seedlings were grown in Hoagland solution supplied with microelements up to three weeks in 14/10 hours light/dark period at 24/18°C illuminated at photon flux density of 80 μmol m^{-2} s^{-1}. Treatment was carried out with $Cd(NO_3)_2$ (5.10^{-8} M), $Pb(NO_3)_2$, $NiSO_4$ and DCMU (10^{-7} M), and $TiCl_3$ (10^{-6} M) in nutrient solution on every second day. Chl content and Chl a/b ratios of leaves were determined according to Porra et al. (1989). Isolation and solubilization of thylakoids and separation of CPCs was carried out as in Sárvári and Nyitrai (1994). Samples for electron microscopy were prepared according to Böddi et al. (1997). Photosynthetic activity ($^{14}CO_2$ fixation) of leaves was measured as described by Láng et al. (1985).

Results and Discussion

Growth parameters as the length, fresh and dry weight of roots and shoots were stimulated by Pb, Ni and Ti treatment at low concentration, but they were retarded in Cd and DCMU treated plants. All the low-dose stressors facilitated considerably the Chl synthesis at different stages of leaf development (Table 1). Chl a/b ratios of treated leaves showed a small decrease, while after DCMU treatment the decrease was about 25 to 30%. Thylakoids of Cd, Pb, Ni and Ti treated plants contained higher amount of LHCII and bands belonging to PSI particles. Bands containing PSIICA and PSIICC showed a mild decrease, while decreased amount of PSI and more LHCII was found in DCMU treated thylakoids (Table 2).

Electron microscopy of maize leaves did not show significant differences in the chloroplast lamellar systems between control and treated plants except a slight increase in the proportion of grana after DCMU treatment. Photosynthetic activities were higher (120-130%) in every treatment compared to the control ones. Many experimental data are available to demonstrate that cytokinins cause an increase in Chl accumulation, synthesis of some proteins such as small subunit of RUBISCO, apoprotein of LHCII (Flores and Tobin 1986). They facilitate stabilization of LHCII and LHCI and increase the photosynthetic activity (Nyitrai 1996). General features of the stimulating effect of these low-dose stressors showed many similarities to the above mentioned effects of cytokinins. We hypothesize that cytokinins take part in the mediation of the effect of low-dose stressors used in our experiments, *e.g.*, they may be components of signal transduction pathways from the environment to metabolic targets.

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Table 1. Chl content (μg Chl/g.fr.w) of control (Ctr) and treated first leaves of maize seedlings in the course of development. Standard deviations are within 10%.

	8 day		11 day		14 day		21 day	
	Chl	%	Chl	%	Chl	%	Chl	%
Ctr	1307	100	1675	100	1807	100	1665	100
Cd	1628	125	2064	123	2167	120	2003	120
Pb	1624	124	1841	110	2383	132	1993	120
Ni	1576	121	2261	135	2201	122	2047	123
Ti	1819	139	1934	115	2332	129	2162	130
DCMU	1485	114	2788	166	2225	123	1706	102

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Table 2. Relative distribution of CPCs of control (Ctr) and hydroponically treated two-week old first leaves of maize thylakoids. Absolute amount of Chl (µg Chl/g.fr.w) in brackets.

	Ctr	Cd	Pb	Ni	Ti	DCMU
PSI	39.1 (707)	42.5 (921)	41.5(1001)	42.3 (931)	40.5 (944)	31.3 (696)
PSIICC	7.5 (136)	4.7 (101)	5.1 (122)	4.8 (106)	4.8 (112)	6.5 (145)
PSIICA	8.2 (148)	6.8 (147)	6.2 (148)	5.7 (125)	6.5 (152)	6.8 (151)
LHCII	38.9 (703)	41.1 (895)	41.1 (979)	42.2 (929)	42.2 (984)	47.2(1050)
FP	6.3 (113)	4.7 (103)	5.6 (133)	5.0 (110)	6.0 (140)	8.2 (183)

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