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BRIEF COMMUNICATIONS

Changes in the rooting and growth of willows and poplars induced by cadmium

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Abstract

Growth parameters of six fast growing trees showed that the roots responded to Cd treatment more sensitively than the shoots. Cd-treatment suppressed rooting and root growth (length and biomass production) as well as its development in all tested species. Root systems of *Salix cinerea, Salix alba*, and *Populus* cv. Robusta were more tolerant to Cd stress than the root system of the other studied species. Shoot growth parameters of *Salix* species were significantly reduced unlike *Populus* species, which were not affected by Cd treatment.

Additional key words: Cd uptake and accumulation, dry mass, fast growing trees, root elongation.

Cadmium belongs to the most dangerous environmental pollutants as it has toxic and mutagenic effects on both, the plants and animals. Generally, Cd in plants reduces growth, both in roots and in shoots and causes leaf rolling and chlorosis (*e.g.* Sanita di Toppi and Gabbrielli 1999). Barceló and Poschenrieder (1999) summarized the main morphological and structural effects of Cd on roots as follows: decrease of root elongation, root tip damage, collapsing of root hairs or decrease of their number, decrease of root biomass, increase or decrease of lateral root formation, etc. The fast growing trees may be interesting for phytoextraction for their massive root system penetrating deeply into the soil, perennial character, long life span, high evapotranspiration, quick regeneration of removed above-ground parts, easy vegetative reproduction, and large biomass production (Stomp *et al.* 1993). The aim of this paper was screening of six clones of fast growing trees grown under Cd stress. Root and shoot growth parameters were measured and Cd accumulation of roots and shoots was established.

Four willow species – *Salix viminalis* L., *Salix alba* L. clone 21, *Salix purpurea* L. and *Salix cinerea* L., and two poplar species – *Populus* × *euroamericana* cv. Gigant and *Populus* × *euroamericana* cv. Robusta (later only *P.* Gigant and *P.* Robusta) were used for the studies. These clones were selected according to their tolerance on metal contaminated areas. Stem cuttings (18 cm long) were grown in solution containing 10^{-5} M $Cd(NO_3)_2$ and 10^{-4} M $Ca(NO_3)_2$, and the control variant in solution containing only 10^{-4} M $Ca(NO_3)_2$ (Greger and Landberg 1999). The cuttings were grown in the cultivation box under controlled conditions (12-h photoperiod, irradiance of 100 μmol m^{-2} s^{-1}, day/night temperature of 25 °C and relative humidity of 60 - 70 %). The solutions were changed twice a week. Twenty one-day-old plants washed in distilled water were used for growth analyses –

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Abbreviations: d.m. - dry mass; FAAS - flame atomic absorption spectrometry.
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Table 1. Growth parameters and Cd accumulation in studied *Salix* and *Populus* roots growing in control conditions and influenced by Cd (* - statistically significant difference at $P = 0.05$; ** - statistically significant difference at $P = 0.01$).

Plant species	Cumulative length [m] control	Cd	Number control	Cd	Dry mass [g seedling^{-1}] control	Cd	Cd accumulation [mg kg^{-1}(d.m.)] Cd
S. viminalis	1.581±0.08	0.096±0.020**	21.1±1.56	16.9±2.72*	0.058±0.0030	0.0170±0.0010**	4658.2
S. alba	1.774±0.08	0.596±0.070*	45.0±2.82	40.6±4.11	0.022±0.0020	0.0082±0.0010**	4135.7
S. purpurea	1.263±0.13	0.107±0.010**	15.0±2.75	16.0±2.80	0.033±0.0030	0.0090±0.0020**	2561.0
S. cinerea	0.876±0.07	0.175±0.009**	17.9±2.38	32.8±4.02**	0.022±0.0020	0.0070±0.0010**	2307.0
P. Robusta	0.429±0.05	0.035±0.010**	6.7±0.33	2.7±1.20*	0.011±0.0007	0.0050±0.0020*	5014.3
P. Gigant	0.246±0.05	0.001±0.001**	4.0±0.15	0.2±0.00*	0.004±0.0008	0.0002±0.0001**	no roots

Table 2. Growth parameters and Cd accumulation in studied *Salix* and *Populus* shoots growing in control conditions and influenced by Cd (* - statistically significant difference at $P = 0.05$; ** - statistically significant difference at $P = 0.01$).

Plant species	Cumulative length [m] control	Cd	Number control	Cd	Dry mass [g seedling^{-1}] control	Cd	Cd accumulation [mg kg^{-1}(d.m.)] Cd
S. viminalis	0.443±0.040	0.315±0.020**	39.0±0.52	4.5±0.45	0.558±0.052	0.343±0.023**	3.08
S. alba	0.206±0.009	0.140±0.010*	3.8±0.58	2.2±0.20*	0.137±0.011	0.168±0.011	24.45
S. purpurea	0.348±0.040	0.245±0.003*	2.7±0.26	2.6±0.37	0.311±0.022	0.232±0.041	62.11
S. cinerea	0.132±0.010	0.086±0.010*	2.0±0.02	2.1±0.12	0.159±0.018	0.112±0.012	9.44
P. Robusta	0.077±0.010	0.075±0.010	1.7±0.33	1.3±0.33	0.195±0.015	0.262±0.074	29.15
P. Gigant	0.086±0.010	0.082±0.005	1.5±0.28	1.0±0.00	0.156±0.015	0.215±0.009	2.02

cumulative length, number and dry mass of adventitious roots and shoots (newly growing parts without the original cuttings). Dried powdered samples were digested with HNO_3, HF and H_3BO_3 and flame atomic absorption spectrometer (FAAS; *Perkin Elmer 1100*) was used for determination of Cd content. To evaluate the significance of obtained data *Excel 2000* was used.

Growth parameter estimation showed that roots responded to Cd treatment more sensitively than shoots. Cd-treatment suppressed rooting and root growth (length and biomass production) as well as its development in all tested species. Roots of *S. alba* were more tolerant than other species. There was found 66 % reduction of root length there. Roots of *P.* Gigant showed the strongest inhibition of growth (99.7 %). Reduction of root length in other tested species ranged from 80 to 94 %. In most studied species the number of roots either decreased or was not influenced. Increased root number was found only in *S. cinerea*. The root dry mass was significantly reduced in all studied species. The lowest reduction was observed in *P.* Robusta and *S. alba*. The most sensitive clone was *P.* Gigant again (Table 1). The cumulative length of shoots significantly decreased in all studied *Salix* species. The reduction of shoot length ranged from 29 % in *S. viminalis* to 35 % in *S. cinerea*. Shoot dry mass was not negatively influenced except for *S. viminalis*. Neither cumulative length nor dry mass of studied *Populus* species was affected. Cadmium had no impact on the number of shoots in all clones except for *S. alba* 21 (Table 2). The analyses of Cd content in roots, cuttings and shoots showed that Cd ions were accumulated mainly in the roots. Relatively higher accumulation in the shoots was found in *S. purpurea*, *S. alba* and *P.* Robusta in comparison to *S. cinerea*, *S. viminalis* and *P.* Gigant (Tables 1, 2).

Inhibition of root growth we observed can be the result of Cd interference with cell division and/or with cell elongation (Hagemeyer and Breckle 1996). Increased root number found in *S. cinerea* could be probably explained as a compensation of root growth inhibition caused by Cd stress. Observed decrease of shoot length and subsequently not significant differences in dry mass between control and Cd-treated plants could be explained by impact of Cd on water balance. The latest experiments indicated that toxic metals caused the impairment of water transport into root cells as well as through the root (Poschenrieder and Barceló 1999) and thus negatively influenced the water balance in the shoots. On the other hand, the shoot dry mass was negatively influenced in *S. viminalis*, what might be a result of significant reduction of leaf area in Cd treated plants (unpublished data).

In conclusion, root systems of *S. cinerea* and *S. alba* were more tolerant to Cd stress than other four studied species. Shoot growth parameters of *Salix* species were significantly reduced unlike *Populus* species, which were not affected. Cadmium content in different plant organs were analysed because of potential use of studied species for phytoextraction of Cd from contaminated substrates. Cadmium content in plant parts showed remarkable interspecific differences. In the shoots these differences were within the order of magnitude. Even greater difference was found when the ratio of Cd content in shoot and root was evaluated. This parameter ranged from 40 to 1500 times higher values in roots compared with shoots. These findings demonstrated the possibility of selection of fast growing trees utilizable in phytoremediation.

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