HEAVY METAL STRESS REDUCTION IN SUNFLOWER BY BIOCOMPOST APPLICATION TO CONTAMINATED SOIL

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Abstract: Growth chamber pot experiment was set up to study how biowaste compost can reduce the metal mobility in a contaminated soil. The contaminated fulvisol (Cd-10.7; Cu-332; Pb-792, Zn-1906 mg kg^{-1} in aqua regia extract) originating from Gyöngyösoroszi was mixed with 10% (m m^{-1}) of biowaste compost. After 5 weeks of plant growth the metal concentrations were determined in mobile fractions of contaminated soil, and in plant organs of sunflower (*Helianthus annuus* L. cv. NK Neoma). It was found that biowaste compost application significantly reduced the "mobile" and "water soluble" Cd concentrations in soil by 29 and 45%. In case of Cu and Pb the "plant available" concentrations were reduced by 11-11%, while in "mobile" fraction 28 and 25% reduction was detected. The zinc content in "plant available", "mobile" and "water soluble" fractions of contaminated soil were reduced by 16, 20, and 40% respectively. In shoots of sunflower grown in biowaste compost stabilized soil 25% less Cd and 35% less Zn was found. Since the heavy metal stress was considerable reduced, shoot yield was 2.8 times higher in stabilized than in not stabilized soil.

Keywords: heavy metal, stress reduction, sunflower, biowaste compost, contaminated soil, pot experiment

Introduction

During the last decades as a consequence of mining, metal processing, industrialization, traffic, burning of fossil fuels, disposal of wastes, etc. soil and water resources were contaminated with toxic metals all over the world. This becomes of environmental concern when metals (i.e. Pb, Cd, Zn, Cu, Cr, Ni, Hg) in soils and waters enters to the food chain, and begins to affect human health (Simon, 2005).

Phytostabilization is a new promising strategy to handle polluted soils. During phytostabilization the pollutants are first stabilized with amendments and additives (e.g. liming agents, aluminosilicates, phosphates, iron and manganese oxides, coal fly ashes and organic materials) to reduce their solubility and mobility (Berti and Cunningham, 2000; Friesl et al., 2006; Simon et al., 2006). Polluted areas are then covered with plants to prevent contamination of groundwater, air or neighbouring uncontaminated areas. Plant roots physically stabilize the soil, prevent erosion and deflation, and can minimize the leaching of contaminants to groundwater. Organic amendments such us composts, sludges, manures, biosolids, and peat benefit plant growth by increasing soil moisture holding capacity, improving soil texture, and providing plant nutrients such as nitrogen and phosphorus (Prasanna et al., 2008). Organic matter often has high cation exchange capacity and forms strong complexes with soil Zn, Cu and Pb, which can reduce metal stress to plants (Berti and Cunningham, 2000). Phosphates present in biosolids (sewage sludge) can strongly bind Pb, reducing its phytoavailability (Kádár and Morvai, 2008).

Biowaste is collected separately in city Nyíregyháza (Eastern Hungary) at households located in suburbs. Litter from gardens; leaves, mowed grass, branches and organic waste from household (except scraps of food) can be collected in selective containers. The biowaste is composted in piles at the dumping-ground of city, and is used to landscape, or is passed to resident population for ornamental or indoor plant growing. In

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our preliminary experiment biowaste compost (thereafter biocompost) was found to be not contaminated with metals (data not shown).

North from the village Gyöngyösoroszi (located in Mátra Mountains, North Hungary) a sphalerite and galenite mine had been operating till 1986. Careless handling of mine spoil caused serious metal pollution of the local environment including soil in floodplain of Toka creek (Simon, 2005; Simon et al., 2006).

The objectives of our work were to study how biocompost can reduce the mobility of metals (Cd, Cu, Mn, Pb, Zn) and sulphur in contaminated soil, and how influence the reduced metal and sulphur-stress the growth of sunflower plants.

Materials and methods

The fulvisol originated from experimental plots (with EOV coordinates X: 275.330; Y: 713.980) of the Research Institute of Soil Science and Agricultural Chemistry located in the floodplain of the Toka creek near Gyöngyösoroszi. Average samples for soil analysis and pot experiment were collected at the end of March 2008. Analysis of this soil at SGS Hungária Ltd. revealed that this fulvisol (clayey loam with pH_{KCl} 6.43 and 3.6% humus content) is contaminated with heavy metals, and its sulphate concentration is as high as 4565 mg kg^{-1}. Air dried and sieved (<2mm) soil was mixed with 10% (m m^{-1}) of air dried and sieved (<5mm) biocompost (originating from dumping-ground of Nyíregyháza).

Growth chamber pot experiment was set up between June-July 2008 at the College of Nyíregyháza with sunflower (*Helianthus annuus* L. cv. NK Neoma). Three plants were grown in plastic pots with 1.5 kg of soil with 3 replications. Light (350 μmol m^{-2} s^{-1} for 10 hours daily), temperature (23±4°C), and humidity (40~50 %) were controlled. After 5 weeks of plant growth the metal and sulphur concentrations were determined in plant organs of sunflower by ICP-OES technique, as described in Simon (2005). “Total”, “plant available”, “mobile” and “water soluble” metal and sulphur concentrations were determined in aqua regia (according to Hungarian standard MSZ 21470-50:1998), in Lakanen-Erviö (according to Hungarian standard MSZ 20135:1999), in acetate buffer (pH 4.5, according to Hungarian standard MSZ 21978-9:1998), and in distilled water extracts (according to Hungarian standard MSZ 21978-9:1998), respectively. Fresh and dry weights (after drying at 70°C for 10 hours) of plants were determined at the end of pot experiment.

Processing of the experimental data was done with Excel XP software. Statistical analysis was made with SPSS 14.0 software, using Student’s t-test.

Results and discussion

Table 1 demonstrates the metal and sulphur concentrations in various fractions of contaminated soil. The fulvisol from Gyöngyösoroszi is contaminated with Cd, Cu, Mn, Pb, Zn and S. The aqua regia extraction characterise the “total” metal concentration in soil. Metals in Lakanen-Erviö extract are moderately bound to soil particles and can be “plant available”, while metals in acetate buffer are “mobile”, and can be taken up directly by plants. “Water soluble” metals are the most mobile in soil, and can be taken up easily by plants. The biocompost application significantly reduced the „total” concentration" of Cu, Zn and S in soil, while the concentration of other metals was also lower in treated than in unamended soil. This could be attributed to direct dilution effect of 10% biocompost, but change in solubility of metals and sulphur in consequence of biocompost application was also supposed.

Table 1. "Total" (aqua regia extraction), "available" (Lakanen-Erviö extraction), „mobile" (acetate buffer extraction) and „water soluble" (distilled water extraction) heavy metal and sulphur concentrations in contaminated soil treated with biocompost (pot experiment, Nyíregyháza Hungary, 2008)

Treatments	**Cd**	**Cu**	**Hg**	**Mn**	**Pb**	**S**	**Zn**	**pH**
				„Total" (mg kg^{-1})				
Contaminated soil (1)	10.7	332	1.12	1328	792	5819	1906	n.d.
1+10% biocompost	9.71	287*	0.52	1236	719	5036*	1715*	n.d.
				„Plant available" (mg kg^{-1})				
Contaminated soil (1)	6,64	162	u.d.l.	n.d.	309	3770	821	n.d.
1+10% biocompost	6,24*	145*	u.d.l.	n.d.	274*	3156*	739*	n.d.
				„Mobile" (µg dm^{-3})				
Contaminated soil (1)	196	452	u.d.l.	n.d.	193	378	32948	4.52
1+10% biocompost	140*	328*	u.d.l.	n.d.	145*	299*	26545*	4.58*
				„Water soluble" (µg dm^{-3})				
Contaminated soil (1)	14,1	124	u.d.l.	n.d.	14,5	304	1824	5.99
1+10% biocompost	7,78*	160*	u.d.l.	n.d.	8,4	324	1097*	6.33

Student's t-test, data are means of 3 replications. Statistically significant at * $P<0.05$ level.
u.d.l. = under detection limit, n.d. = not detected

It was found that biocompost application significantly reduced the "mobile" and "water soluble" Cd concentrations in soil by 29 and 45%. In case of Cu and Pb the "plant available" concentrations were reduced by 11-11%, while in "mobile" fraction 28 and 25% reduction was detected. The zinc content in "plant available", "mobile" and "water soluble" fractions of contaminated soil were reduced by 16, 20, and 40% respectively. Our results are in agreement with Friesl et al. (2006) who found in 1M NH_4NO_3 extract a 26% reduction for Cd and 25% reduction for Zn concentration in a contaminated soil incubated for 1 month with 2% (m m^{-1}) biocompost.

Table 2 shows the heavy metal and sulphur concentrations in sunflower plant organs at the end of the pot experiment. It was found that biocompost application significantly reduced the Cd, Zn and S accumulation in shoots, while Cu and Mn contents were higher. In shoots of sunflower 25% less Cd, 35% less Zn, and 40% less S was found.

Table 2. Heavy metal and sulphur concentrations in sunflower plant organs grown in contaminated soil stabilized with biocompost (end of the pot experiment, Nyíregyháza Hungary, 2008)

Treatments	**Cd**	**Cu**	**Hg**	**Mn**	**Pb**	**S**	**Zn**
				(mg kg^{-1})			
				Roots			
Contaminated soil (1)	30.5	105	0.24	29.7	43.6	8390	772
1+10% biocompost	27.4	138	0.25	34.9	46.7	7706	1370*
				Shoots			
Contaminated soil (1)	8.03	13.6	u.d.l.	32.8	1.02	10071	901
1+10% biocompost	5.99*	18.3*	u.d.l.	57.5*	1.19	6038*	586*

Student's t-test, data are means of 3 replications. Statistically significant at * $P<0.05$ level.
u.d.l. = under detection limit, n.d. = not detected

Figure 1 presents the effects of biocompost on the yield of sunflower grown in metal and sulphur contaminated soil. Biocompost application significantly enhanced the fresh weight of roots and shoots by 625% or 283%, respectively. Dry weights were 3.8 and 2.8 times higher. Plants grown in biocompost-amended soils had healthy whitish roots and green shoots, while plants grown in contaminated soil had brownish stunted roots, and chlorotic leaves with necrotic spots.

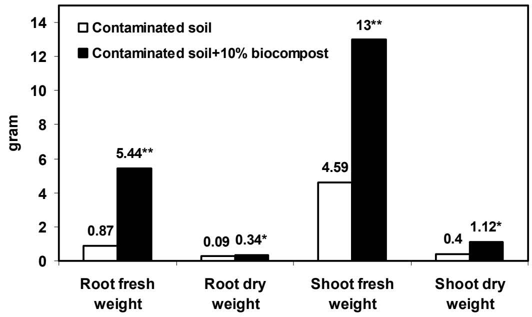

Figure 1. Yield of sunflower grown in heavy metal and sulphur contaminated soil treated with biocompost (pot experiment, Nyíregyháza Hungary, 2008). Student's t-test. Statistically significant at * P<0.05; ** P<0.01 level. Each value represents the mean of 3 replications.

Conclusions

Biocompost application considerably reduced the mobility of heavy metals and sulphur in a mine spoil contaminated soil. Presumably the organic substances formed during decomposition of biocompost have reduced the mobility and phytoavailability of toxic metals in soil. Reduced heavy metal stress resulted in better yield of sunflower plants.

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