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STUDIES ON PLANT GROWTH AND METAL BIOACCUMULATION IN CROPS ON FLY ASH DISPOSAL SITE

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Abstract. The fly ash contains average amounts of heavy metals: chromium (85 mg/kg dry matter (DM)), copper (62–67 mg/kg DM), nickel (50 mg/kg DM), lead (12–14 mg/kg DM), zinc (5–85 mg/kg DM) and iron (4.600–4.700 mg/kg DM). The municipal sludge compost added as fertiliser contains sufficient quantities of nutrients, which is enough material to increase the degree of plants germination and subsequent coverage of soils in common barley crop *(Hordeum vulgare*). Three experimental variants have been used in barley crop: fly ash (variant I), fly ash together with 50 t/ha compost (variant II) and fly ash with 150 t/ha compost (variant III). The addition of compost did not reduce the accumulation of chromium in barley straw but reduced its accumulation in grains. In the case of iron, the addition of compost has reduced the accumulation, both in grain and straw. The addition of 150 t/ha compost reduced heavy metals bioaccumulation of grain, and straw, each with 70%. The implementation of a strategy to cover the fly ash deposits with a vegetable coating of common barley crops can be easily and efficiently done through the use of fertilisers as sewage sludge compost and vegetable scraps from a vineyard.

Keywords: fly ash deposit, compost, barley crop, vegetation strategy.

AIMS AND BACKGROUND

This study shows how *Hordeum vulgare* grass species, forming a layer of vegetation, develops and capitalises on the environmental conditions of fly ash deposits untreated and treated with organic fertilisers, such as compost of vegetable scraps resulting from vineyard culture and the degree of the heavy metal accumulation such as Cr, Cu, Fe and Zn in straw and grains.

Fly ash is part of the by-products resulted from coal combustion in thermal power plants. The fly ash represents 70–75% as fine particles below 10 μm (Ref. 1). Fly ash deposits containing millions of tons of free inorganic nutrients are without vegetation to restrict erosion due to deflation, changes in precipitation and tempera-

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ture control in agricultural areas adjacent. In particular, open fly ash deposits may gradually release in decades the included constituents, such as toxic heavy metals (Cd, Cr, Cu and Zn) (Refs 2–4). These deposits are generally devoid of vegetation, with an aspect of desert area and potential to spread the material in the form of fine particles in the atmosphere and/or soil, washing/stripping it in the rainfall, etc. The annual amount of fly ash produced in the world is estimated to 500 million t, of which 95 million t are produced in the EU countries. Countries generating the largest quantities of fly ash around the world are the USA, China and India with over 100 million t/year each[5]. There is a need for strategies of vegetation cover in these areas for economic, environmental, and aesthetic reasons[4,6–8].

Natural changes of the upper layers of soil, such as their enrichment in humic materials from alternate vegetative cycle, even in the case of very poor vegetation, may change the characteristics of fly ash[9]. To adopt the most efficient re-vegetation method in the affected area, preliminary study plots located on the surface of studied ash deposits are needed. In some cases vegetation strategy research aims to choose the plant species to convert deposits into a pleasant landscape as well in a new habitat for various species of wild animals in the future ecosystem. The British research experience noted that some of the most tolerant plants are grasses[3,6,8,10].

EXPERIMENTAL

The study was carried out in pots. Pots are equipped with equal amounts of fly ash, 5.5 kg/pot. The study was performed on an experimental block consisting of 9 pots (3 replicates for each experimental variant). The experimental variants of the study were as follows: fly ash variant with no organic fertiliser added, as control (variant I), fly ash variant fertilised with organic fertiliser, compost at 50 kg/ha (variant II) and also fly ash variant fertilised with organic fertiliser, compost at 150 kg/ha (variant III). The *Hordeum vulgare* plant species was seeded in March 2010. Compost used for fertilisation is achieved through the process of fermentation of municipal sludge with chopped vegetable scraps from a vineyard and has the following characteristics: N_{total} – 17.072 mg/kg DM, P_2O_5 – 2.306 mg/kg DM, K_2O – 28.667 mg/kg DM, 110 mg Cu/kg DM, Pb – 62 mg/kg DM, Zn – 487 mg Zn/kg DM.

Soil sample analysis was done to determine the metal concentrations according to the following method: the heavy metals were extracted from the soil samples (1 g) by heating with aqua regia (10 ml) for 2 h, at reflux. After interrupting the heat, the system was left in stand-by for 16 h. Then the samples were diluted in a flask with deionised water to exactly 50 ml. Plant tissues were thoroughly rinsed of fly ash with deionised water to remove any soil particles attached to plant surfaces. The plant tissues (about 5 g) were dried (105°C) to a constant weight. Plant samples with precise weight were then brought to 550°C; to the residual materials 5 ml of concentrated hydrochloric acid were added, samples were maintained for 30 min on the dry sand bath. The dry residue was taken up with 10 ml hydrochloric acid 1:1 solution. After filtering those in a paper filter with small porosity were taken to a calibrated flask (100 ml). Plant and soil extracts analysis was done using a spectrophotometer, Varian Spectra AAS.

In Table 1 are presented the concentrations of metals in fly ash pot experimental variants.

Table 1. Concentrations of heavy metals in fly ash pot experimental variants

No	Experimental variant	Contents of heavy metals (mg/kg DM)					
		Cr	Cu	Fe	Ni	Pb	Zn
1	fly ash (variant I)	94.5	67.1	4843.1	37.3	9.8	69.3
2	fly ash/compost 50 kg/ha (variant II)	94.6	67.2	4835.1	38.1	7.8	74.6
3	fly ash/compost 150 kg/ha (variant III)	83.6	61.5	4725.3	48.3	13.0	84.5

The amount of Cr, Cu and Ni in topsoil in pots is included in the alert threshold values, for less sensitive soil and the amount of Pb and Zn is in the range of concentrations for normal soils, according to the Romanian rule.

RESULTS AND DISCUSSION

Plants grown on fly ash layer are poorly developed, leaves are suffering and fructification is reduced. The compost added as fertiliser resulting in increased seed germination rate of the *Hordeum vulgare* after planting. The addition of compost in a quantity of 50 to/ha increased the germination rate and degree of coverage with sown grass species with 30–34%. Increasing the amount of fertiliser to 150 t/ha, the germination rate, and the degree of vegetation cover became 43%. The plants have normal appearance, but the fructification is reduced.

Table 2 shows the heavy metal bioaccumulation in the aerial part of plant, straw and grain of the cultivated *Hordeum vulgare* in all the experimental variants.

The amount of chromium, copper and iron accumulated in the straw is higher than that accumulated in grains in all studied cases. Addition of compost reduces the accumulation of metals both in straw and grain. Reduction efficiency is dependent on plant parts, straw or grain, as well as on the amount of compost added. Table 3 shows the degree of metal accumulation in *Hordeum vulgare* harvest straw and grain from compost fertilised experimental variants versus unfertilised fly ash (%). For example, the maximum amount of compost used as fertiliser reduces the accumulation of chromium in grain by 67% but only at insignificant level in straw. In the case of iron, the addition of compost reduces the accumulation both of grain and straw, with 70% (Table 3).

Table 2. Heavy metal bioaccumulation in the aerial part of plant, straw and grain of the cultivated *Hordeum vulgare* in all the experimental variants

No	Experimental variant	Aerial parts of the plant	Contents of heavy metals (mg/kg DM)					
			Cr	Cu	Fe	Ni	Pb	Zn
1	fly ash	straw	7.19	5.60	1042.0	bdl	bdl	37.5
		grains	6.91	2.53	299.2	bdl	bdl	37.2
2	fly ash/ compost – 50 kg/ha	straw	7.38	4.13	791.9	bdl	bdl	60.8
		grains	4.86	4.25	178.6	bdl	bdl	46,8
3	fly ash/ compost – 150 kg/ha	straw	6.28	5.48	323.3	bdl	bdl	38.7
		grains	2.28	2.77	89.7	bdl	bdl	35.9

bdl – below the detection limit.

Table 3. Degree of metal accumulation in *Hordeum vulgare* harvest, straw and grain from compost-fertilised experimental variants versus unfertilised fly ash (%)

No	Experimental variant	Aerial parts of the plant	Degree of metal accumulation in harvest from fertilised variants versus unfertilised fly ash (%)		
			Cr	Cu	Fe
1	fly ash/ compost – 50 kg/ha	straw	–	26.0	24.0
		grains	30.0	–	40.0
2	fly ash/ compost – 150 kg/ha	straw	13.0	5.0	70.0
		grains	57.0	–	70.0

Furthermore, bioaccumulation of Cu and Zn in straw and grain is not affected in the studied experimental variants by the presence of the fertiliser. Note that the species of grasses grown on the experimental variants does not accumulate lead and nickel at the detection levels. An implementation strategy to cover with vegetation the fly ash deposits with *Hordeum vulgare* grasses can be done quickly and effectively, using fertilisers based on municipal sewage sludge compost mixed with vegetable scraps. Besides the effect of providing some nutrient in poor ash layers, compost may act by reducing the bioaccumulation of heavy metals, especially in grains.

CONCLUSIONS

Fly ash contains amounts of Cr, Cu, and Ni in the range threshold alert values for less sensitive soil. The added compost provides enough nutritional material to raise the germination degree and, in time, increases the coverage degree for *Hordeum vulgare* crops. In all the three experimental variants, *Hordeum* spp. crops present amounts of chromium, copper and iron accumulated in the straw higher than those accumulated in grains. The addition of compost did not reduce the accumulation of Cr in straw, but it reduced the accumulation in grains up to 67%.

In the case of iron, the addition of compost reduces the bioaccumulation both of grains and straw. An addition of compost 150 t/ha reduced the accumulation in straw, respectively grains, by 70%. Addition of compost did not change the bioaccumulation of Cu and Zn in grains or straw.

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