ESP fly ash application effects on plant biomass and bioconcentration of micronutrients in nursery seedlings of *Populus deltoides*

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Abstract
Fly ash mixed with soil on a w/w basis at concentrations of 0, 5, 10, 20 and 30 per cent was used for growing nursery seedlings of *Populus deltoides* to see the effect of fly ash application on biomass production and bioconcentration of Fe, Mn and Zn in stems and leaves. Fly ash application @ 20 % (w/w) fly ash was found to be optimum for preparing potting mix for *Populus deltoides.* Biomass accumulation in the stems and roots increased with increase in the rate of fly ash application up to 20 per cent whereas the biomass accumulation in leaves as well as total biomass accumulation in the *Populus* saplings increased with fly ash application up to a level of 10 per cent only. Bio concentration of micronutrients Fe, Mn and Zn in stem and leaves of *Populus deltoides* displayed higher values up to 10 per cent level of fly ash application, and thereafter declined by a magnitude of 78, 71 and 62 per cent respectively. Fly ash when added to the soil at an optimum level of 20 % benefits biomass production and increase in plant growth which in turn attains significance from the point of view of eco-friendly disposal of fly ash.

Key Words
Bioconcentration factor, biomass accumulation, metal uptake.

Introduction
Fly ash is a repository of nutrients which can benefit plant growth and increase biomass production. Fly ash has been reported to contain low amounts of C and N, medium amounts of available K and high concentration of available P (Sharma and Kalra 2006). Species belonging to genus *Populus* have a good capability of accumulating metals in the aerial portions due to their fast growth, more water usage and extensive root system (Vose *et al.* 2000; McLinn *et al.* 2001). Organisms achieve a chemical equilibrium with respect to a particular medium or route of exposure (Mountouris *et al.* 2002). Distribution of any element in environment is dependent on continous exchange between air, water, soil/sediment and biota (Agoramoorthy *et al.* 2008). Based on these two assumptions, bioaccumulation of elements can be quantified using a bioconcentration factor. Bioconcentration Factor (BCF) provides an index of the ability of the plant to accumulate a particular element with respect to its concentration in the soil (McGarth and Zhao 2003). In the present study, fly ash was used as a soil ameliorant for nursery seedlings of *Populus deltoides* to see its effect on biomass production and bioconcentration of Fe, Mn and Zn in stems and leaves.

Materials and methods
Electrostatic precipitator (ESP) fly ash collected from Guru Gobind Singh Thermal Power Plant, Ropar, Punjab in Northern India was air-dried prior to analysis. Soil from Thapar Technology Campus, Patiala, Punjab was collected from 0-30 cm depth and spread on polythene sheets, air-dried and sieved through a 2 mm sieve for chemical analysis. The pH of fly ash and soil used in the study was 5.28 and 7.63 and electrical conductivity was 50×10^{-3} and 59×10^{-3} dS/m respectively. The chemical properties of ESP fly ash and soil used in the study are listed in Table 1. Fly ash was mixed with soil on a w/w basis at concentrations of 0, 5, 10, 20 and 30%. The different fly ash-soil mixtures were placed in polythene bags perforated at the bottom. Shoot cuttings for the nursery trial were taken from full grown trees of *Populus deltoides* and were further segregated for uniform diameter (0.8 cm) and length (15 cm). The cuttings were washed and treated with IBA (4000 ppm) before being planted into the bags with 20 replications per treatment. The bags were placed in a screen house and weeding was carried out regularly. The nursery was grown for a period of four months. After four months the plants of *Populus deltoides* were gently uprooted and washed with water to remove any adhering soil particles. Thereafter the plants were dried with blotting sheets and weighed for fresh weight. The plants were then kept overnight in an oven at 65 ºC and weighed again for dry weight. To measure the bioconcentration of Fe, Mn and Zn in stems and leaves, the dried leaves and stems were ground

followed by sieving with a 0.2 mm sieve to obtain a fine powder and analyzed for Fe, Mn and Zn using atomic absorption spectrophotometer (Page *et al.* 1982). Bioconcentration factor for Fe, Mn and Zn was calculated in stems as $BCF_S = C_{stem}/C_{soil}$ and leaves $BCF_L = C_{leaf}/C_{soil}$ where C is the concentration of a particular metal in ppm.

Table 1. Chemical characterization of ESP fly ash and soil used in nursery trial.

Property	ESP fly ash	Soil	Property	ESP fly ash	Soil
pH	5.82	7.63	Zn (ppm)	210	35.1
EC ($x10^{-3}$ dS/m)	50	59	Mn (ppm)	530	338
N (%)	0.20	0.41	Mo (ppm)	4.4	3.2
P (%)	0.224	0.03	As (ppm)	6.7	3.9
K (%)	0.0043	0.002	Se (ppm)	4.2	2.4
S (%)	0.069	1.11	Pb (ppm)	28.5	21.7
Ca (%)	0.024	0.04	Ni (ppm)	25.3	25.2
Mg (%)	0.187	0.15	Cd (ppm)	<0.009	<0.009
Na (%)	0.0018	0.003	Cr (ppm)	49.4	35.9
Fe (%)	0.219	0.18	Co (ppm)	15.1	11.5
Cu (ppm)	19.9	<0.025			

Results and discussion

Biomass accumulation in the stems and roots increased with increase in the rate of fly ash application up to 20 per cent level of fly ash application, whereas the biomass accumulation in leaves as well as total biomass accumulation in the *Populus* saplings increased with fly ash application up to a level of 10 per cent only (Figure 1). Fly ash concentration in the potting mixture accounted for up to 69, 62 and 89 per cent of the variation in biomass accumulation in the stems, leaves and roots respectively when biomass accumulation was fitted as a quadratic function of fly ash concentration (Figure 1). Overall, the concentration of fly ash in the potting mixture accounted for 93 per cent of the variation in total biomass accumulation when biomass accumulation was fitted as a quadratic function of fly ash concentration (Figure 2). Biomass production in *Populus* is benefited as a result of amelioration with fly ash since combination of surface soil layer and a layer of fly ash underneath can provide a substrate capable of supporting plant growth (Bi *et al.* 2003).

The content of Fe, Mn and Zn in the soil increased substantially from 2180 to 7175, 310 to 555 and 25 to 55.3 ppm respectively with fly ash application up to 30 % (Table 2). In other words, soil was enriched in Fe, Mn and Zn by up to 229, 79 and 121 per cent respectively with fly ash application @ 30 per cent. Bioconcentration of iron, manganese and zinc in stem and leaf without any fly ash application, as measured by bio-concentration factor was 0.52 and 0.62; 0.09 and 0.09; and, 2.69 and 1.31, in the same order. This indicates that the stem and leaves were relatively impoverished in iron and manganese and relatively abundant in zinc as compared to the soil matrix.

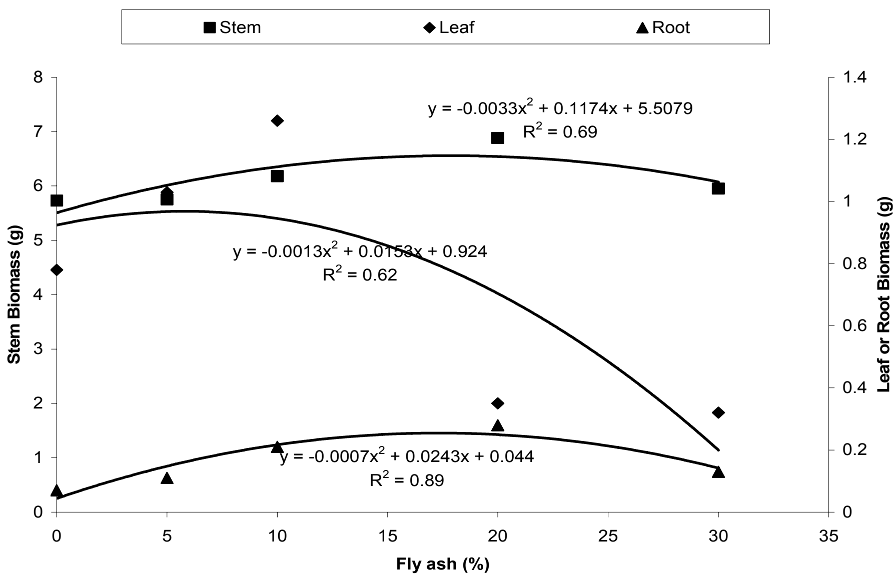

Figure 1. Biomass accumulation in various plant parts of nursery seedlings of Populus deltoides as a function of fly ash addition.

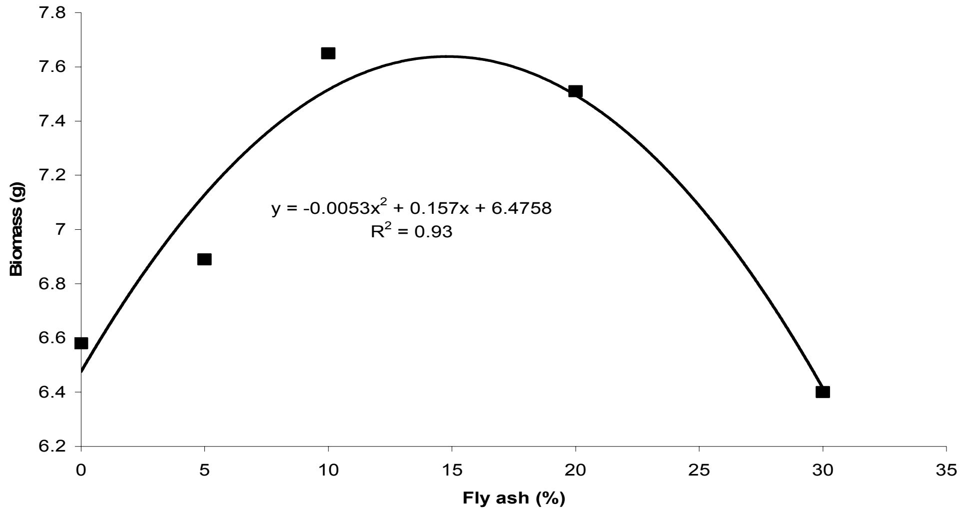

Figure 2. Total biomass accumulation in nursery seedling of Populus deltoides as function of fly as concentration.

A reduced bioconcentration factor of nutrients is attributed to an increased metal concentration in soil (Unnisa *et al.* 2008). Bioconcentration in the stem and leaves of *Populus* was least for manganese and maximum for zinc. Bienfait *et al.* (1982) have reported highest bioconcentration factor for Fe in both stem and leaves with a reasoning that if the pH of soil ranges from 6.74 to 6.92, as was their case, the reduction of ferric to ferrous iron is stimulated leading to iron accumulation in plant parts. The different behaviour in the bioconcentration of different micronutrients in this study is attributed to a greater soil pH (7.63). Considerable proportion of nutrient elements in soil are remobilised according to pH and are potentially available for plant uptake and incorporation in soil solution (Riba *et al.* 2002).

Table 2. Micronutrients Fe, Mn and Zn in fly ash amended soil used in nursery trial of *Populus deltoides.*

Fly ash added	Micro nutrient content (ppm)		
	Fe	Mn	Zn
0	2180	310	25
5	3500	475	34.6
10	5795	520	43.1
20	6040	540	48.3
30	7175	555	55.3

Bio concentration of micronutrients Fe, Mn and Zn in stem and leaves of *Populus deltoides* displayed higher values up to 10 per cent level of fly ash application, and thereafter declined (Figure 2).The bioconcentration factor of iron, manganese and zinc averaged for the stems and leaves, decreased by a magnitude of 78, 71 and 62 per cent when the level of fly ash incorporation was increased from 10 to 20 per cent. This could be attributed to a decrease in plant uptake of iron, manganese and zinc by a magnitude of 76, 71 and 51 per cent respectively when the level of fly ash incorporation was increased from 10 to 20 per cent. A clear relationship does not always exist between the nutrient elements (such as Fe, Mn and Zn in this study) of the soil or soil solution and their uptake by plants since it depends upon each step of uptake pathway and pH of soil (Kallis *et al.*2007).

Conclusions

Increased biomass accumulation was observed up to 10-20 per cent level of fly ash application in various plant parts of *Populus*. Fly ash concentration in the potting mixture accounted for up to 69, 62, 89 and 93 per cent of the variation in biomass accumulation in the stems, leaves, roots and on whole plant basis respectively. Fly ash application up to 30 per cent enriched the soil in Fe, Mn and Zn but simultaneously led to a relative impoverishment of the stem and leaves in Fe and Mn and a relative enrichment in Zn as compared to the soil matrix. Thus *Populus* cultivation may be explored as an environmentally sound and cost effective technology for proper disposal and utilization of solid wastes such as fly ash.

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