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EFFECT OF FLY ASH APPLICATION ON SOME SOIL PHYSICAL PROPERTIES AND MICROBIAL ACTIVITIES

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A b s t r a c t. Electrostatic precipitator (ESP) fly ash obtained from a thermal power plant was mixed with a slightly alkaline soil on w/w basis for use as a potting mixture for poplar nursery and investigated for its influence on microbial activity and physical properties. Application of fly ash as an amendment @ 10% was found to be optimum for bacterial population, soil dehydrogenase activity and microbial biomass. Water holding capacity of fly ash amended soil increased and bulk density decreased as result of fly ash addition as compared to unamended soil. The suitability of fly ash to be used as a soil ameliorant in nursery plantations attains significance from the point of view of eco-friendly disposal of fly ash.

K e y w o r d s: soil microbial diversity, soil texture, soil structure, soil aggregation, nutrient availability, soil physical environment

INTRODUCTION

Fly ash has been reported to be a repository of nutrients which helps in reclamation of alkaline and saline soils and also improves soil properties for plant growth (Kesh *et al.* 2003). Fly ash application can alter the water holding capacity (Pathan *et al.* 2003) and available water content of soils (Adriano and Weber, 2001) . Presence of organic matter in soil has an additive effect as it reduces the concentration of toxic metals through sorption, lowers the C/N ratio and provides organic compounds, which promote microbial proliferation and diversity (Wong and Wong 1986, Pitchel and Hayes 1990). Increased microbial activity was reported for ash-amended soils containing sewage sludge (Pitchel 1990, Pitchel and Hayes 1990). Fly ash-sludge mixtures containing 10% ash had positive effect on soil micro-organisms in terms of enzyme activity, N and P cycling and reducing the availability of heavy metals (Lai *et al.* 1999). Microbial biomass is commonly used to characterize the microbiological status of soil (Nanniperi *et al.* 1990) and to study the effect of soil management practices (Perrott *et al.* 1992). Soil microbial biomass is a sound indicator of soil health since it regulates nutrient cycling and acts as a highly labile source of plant available nutrients (Jenkinson and Ladd 1981).

The objective of the present investigation was to evaluate the effect of fly ash addition on some soil physical properties and microbial activities when it is disposed off by soil application as an amendment.

MATERIALS AND METHODS

Electrostatic precipitator (ESP) fly ash in bulk was collected using random sampling procedure from a fly ash dump near Guru Gobind Singh Thermal Power Plant (GGSTPP), Ropar, Punjab in Northern India and air-dried. Soil was also collected in bulk using random sampling procedure from a field in Thapar Technology Campus, Patiala, Punjab, India, from 0-30 cm depth, analysed and used in the present study. The fly ash and soil were analysed for basic physico chemical characteristics such as pH and electrical conductivity using 1:2 fly ash/soil –water suspension, water holding capacity using Keen's boxes (Black 1965) and bulk density using core sampler (Black, 1965). Fly ash was found to be acidic with pH 5.82, electrical conductivity of 0.05 dS m^{-1}, water holding capacity of 73 % and bulk density of 0.36 Mg m^{-3}. The soil was slightly alkaline with pH of 7.6, electrical conductivity of 0.06 dS m^{-1}, water holding capacity of 33.6 % and bulk density of 1.24 Mg m^{-3}. The texture of the soil determined using hydrometer method (Bouyoucos 1962) was found to be loamy sand. Fly ash was mixed with soil on a w/w basis at concentrations of 0, 5, 10, 20 and 30% and used for growing stem cuttings of *Populus deltoides* for a period of four months in polythene bags (0.8 cm diameter and 15 cm length) perforated at the bottom in a net house. There were 20 replications for each treatment. After four months, the soil from each bag was analysed for bulk density (Black 1965), water holding capacity (w/w) (Black 1965), bacterial count (Cappuccino and Sherman 1987), dehydrogenase activity (Cassida 1977) and microbial biomass (Vance *et al.* 1987). The mean values of the soil physical and microbiological parameters in each of the treatments were compared using regression analysis with respect to the rates of fly ash application. Fly ash addition to soil also modifies bulk density, soil porosity, surface encrustation, saturated hydraulic conductivity, pH and electrical conductivity of soil (El-seewi *et al* 1980, Hartmann *et al.* 2009). Several workers have reported a direct influence of microbial activity on soil physical properties thereby providing an early sign of improvement or warning of soil degradation (Doran and Parkin 1994, Sparling 1997). Micro-organisms invariably adapt to the stresses of the soil.

RESULTS

Mean bulk density of soil in the treatments receiving no fly ash application was 1.24 Mg m^{-3} which decreased linearly with fly ash addition (R^2 = 0.99) (Fig. 1a) to a level of 1.10 Mg m^{-3} in the treatments receiving 30% fly ash. Mean water holding capacity (w/w) of soil in the treatments receiving no fly ash application was 39.8 % which increased linearly (R^2 = 0.97) (Figure 1b) with fly ash addition to a level of 61.3 % when fly ash application rate was increased to 30%.

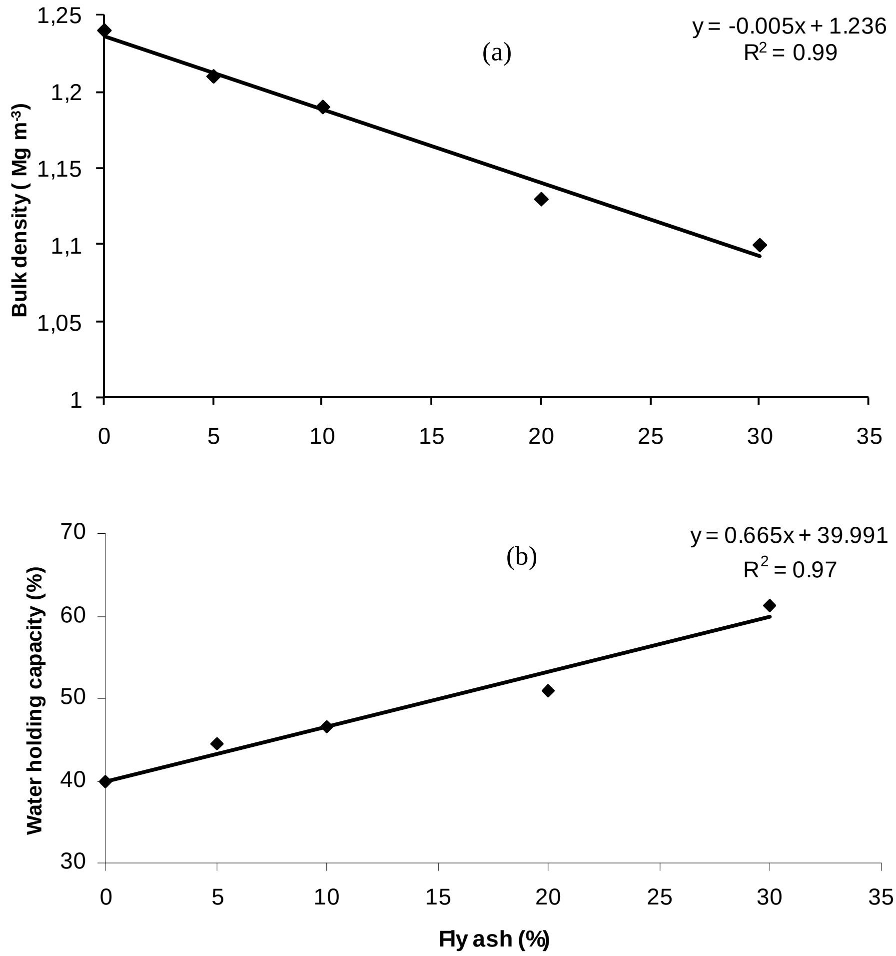

Fig. 1. Effect of fly ash addition on (a) soil bulk density and (b) water holding capacity

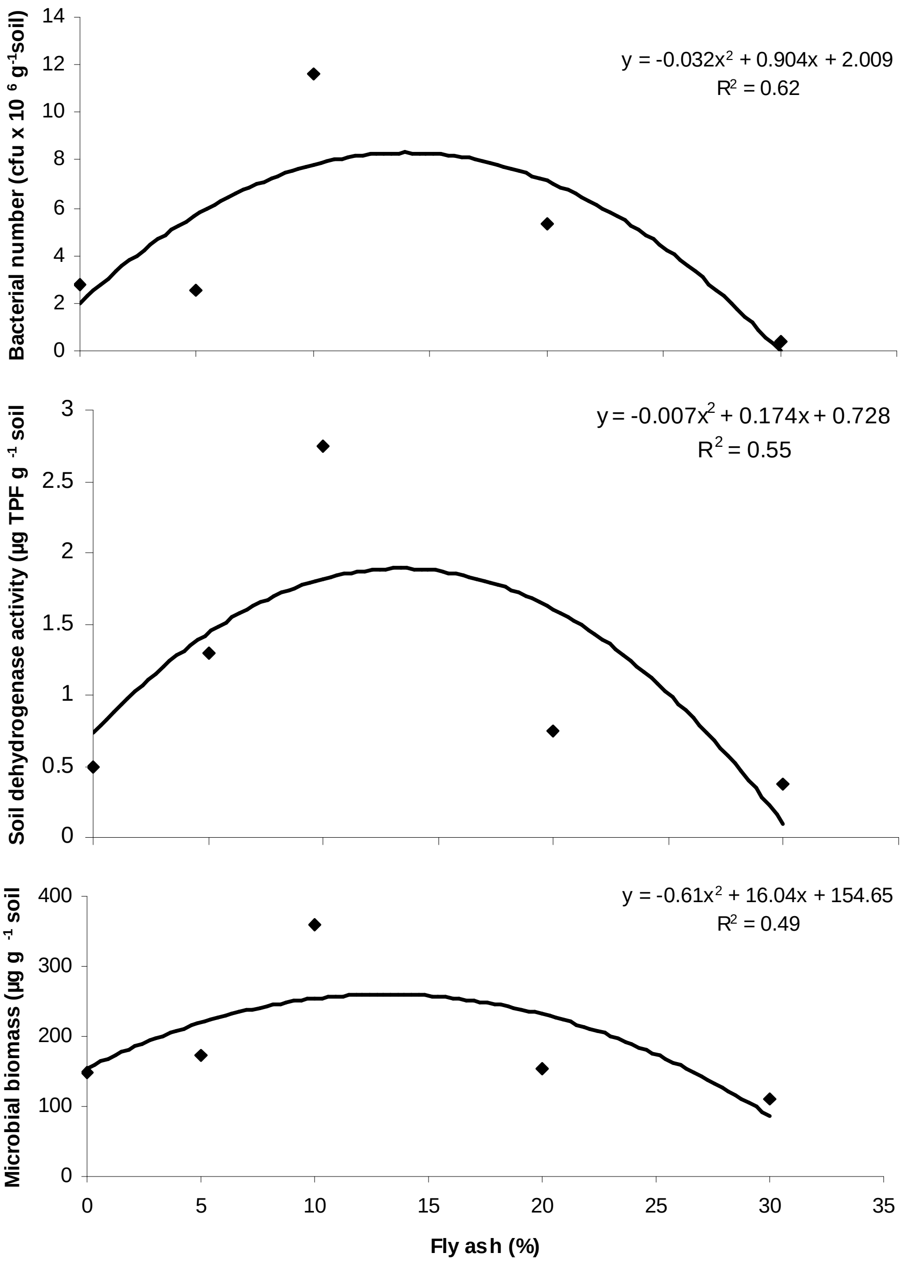

Fig. 2. Effect of fly ash addition on number of bacteria, dehydrogenase activity and microbial biomass in soil

The bacterial number, soil dehydrogenase activity (SDA) and microbial biomass responded in a parabolic manner to increasing levels of fly ash addition (Fig. 2) (R^2 = 0.62, 0.54 and 0.49 respectively). The mean number of soil bacteria in the treatments receiving no fly ash application was $2.75 \cdot 10^6$ cfu g^{-1} soil which increased to $11.6 \cdot 10^6$ cfu g^{-1}soil at 10% level of fly ash amendment and finally decreased to 0.43 cfu g^{-1}soil at 30% level of fly ash amendment. Similarly, SDA increased from a level of 0.5 µg TPFg^{-1} soil day^{-1} in the treatment receiving no fly ash application to a peak value of 2.75 µg TPFg^{-1} soil day^{-1} in response to 10 percent level of fly ash amendment and finally decreased to 0.37 µg TPFg^{-1} soil day^{-1} as the level of fly ash was increased to 30%. In case of soil microbial biomass, an increase of 143% was observed from 148 µg g^{-1} soil in the treatment receiving no fly ash application to 359.3 µg g^{-1} soil in soil amended with 10% fly ash. As the rate of fly ash application was increased to 30%, the soil microbial biomass decreased to 110.7 µg TPFg^{-1} soil day^{-1}.

DISCUSSION

Bulk density decreased linearly with increasing fly ash addition. Decrease in bulk density with increasing fly ash addition has also been reported in other studies (Chang *et al.* 1977, Chang *et al.* 1989) and leads to improved soil porosity, better workability, easier root penetration and increased moisture retention capacity of the soil (Page *et al.* 1979). As expected, water holding capacity of the soil increased linearly with fly ash addition. Addition of fly ash decreases bulk density and improves water holding capacity due to dominance of silt-sized particles in fly ash (Campbell *et al.* 1983). Sale *et al.* (1996) have also reported that fly ash is composed predominantly of silt-sized particles and when added to a soil high in clay, the soil texture and other associated physical characteristics, such as bulk density, can be altered to be more desirable for plant growth. For a fine textured soil such as clay, addition of fly ash will increase the soil bulk density whereas for a coarse textured soil such as the sandy loam soil used in the present study, addition of fly ash is expected to reduce the bulk density. Fly ash addition to the soil also promotes soil aggregation (Sale *et al.*1996). Due to the fine nature of fly ash, it improves the water holding capacity of sandy soils and removes the compaction of clay soils (Sharma and Kalra, 2006). Further beneficial effects are envisaged with plant growth in the fly ash amended soils due to the nutritional advantage to be gained from association with plant roots and exudates in addition to amelioration of the soil physical environment. Nutrient enrichment of soil due to fly ash amendment up to a certain level would be expected to stimulate root growth and excretion of root exudates in the soil. This has a cyclic effect; the addition of exudates and root biomass not only ameliorates the soil physical conditions further, but also brings the added nutrients into the biological nutrient cycle, making the soil resurgent and verdant.

This is evident as the number of bacteria increased markedly up to $11.6 \cdot 10^6$ cfu g^{-1} soil with 10% fly ash addition. Rippon and Wood (1975) attributed the increased microbial population with fly ash addition to the release of nutrients from fly ash with time. Surridge *et* al. (2009) have reported that fly ash addition has a liming effect on the soil leading to increased mobility of calcium and hydroxide ions, ultimately causing an increase in bacterial species richness. However, fly ash also has a high content of toxic heavy metals (Page *et al.* 1979) which can hinder normal microbial metabolic processes when added in the soil at higher concentrations. Application of fly ash, particularly unweathered one, shows a tendency of accumulating elements like B, Mo, Se and Al (Sharma and Kalra, 2006). Soil dehydrogenase activity and microbial biomass were greatest at 10% level of fly ash amendment since fly ash amendment at moderate levels provides nutrients to the micro-organisms for carrying out various metabolic activities without any adverse effect (Wong and Wong 1986, Saffigna *et al.* 1989). The rhizosphere of plants creates a more aerobic environment in soil that stimulates microbial activity which enhances oxidation of organic chemical residues (Anderson *et al.*1993, Schnoor *et al.* 1995, Narayanan *et al.* 1998, Jones *et al.* 2004, Kirk *et al.* 2005). When fly ash is added at levels more than 10%, a decline in microbial activity was observed. This could have been due to a decrease in substrate availability associated with accumulation of persistent lignite-derived organic carbon compounds (Rumpel *et al.* 1998). Gaind and Gaur (2004) found that *Azotobacter chroococcum*, *Azospirillum brasilense* and *Bacillus circulans* showed their maximum viability in fly ash alone whereas *Pseudomonas striata* proliferated most in soil-fly ash (1:1) combination. Schutter and Fuhrmann (2001) have indicated that fly ash amendment may benefit fungi and gram-negative bacteria relative to other components of the soil microbial community. On the whole, the effects of the level of fly ash application on soil aggregation coupled with the influence of the growing plants effects on soil microbial diversity could be favourable for plant growth and soil resurgence.

CONCLUSIONS

1. Fly ash application led to a linear decrease in soil bulk density and a linear increase in soil water holding capacity.
2. Fly ash application at 10% level was found to be optimum for soil microbiological parameters such as number of bacteria, dehydrogenase activity and microbial biomass.

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WPŁYW ZASTOSOWANIA POPIOŁU LOTNEGO NA NIEKTÓRE WŁAŚCIWOŚCI FIZYCZNE GLEBY ORAZ NA AKTYWNOŚĆ MIKROORGANIZMÓW

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Streszczenie. Lotny pył otrzymany z filtrów elektrostatycznych (ESP) w elektrowni cieplnej zmieszano z wysoce zasadową glebą w stosunku wagowym i zastosowano jako mieszankę wazonową w szkółce topoli w celu zbadania jego wpływu na aktywność mikrobiologiczną oraz właściwości fizyczne gleby. Stwierdzono, że dodatek 10% pyłu lotnego jest optymalny w odniesieniu do liczebności bakterii, aktywności dehydrogenaz w glebie oraz biomasy mikroorganizmów. Pojemność wodna gleby nawożonej pyłem lotnym wzrosła, a zmalała jej gęstość objętościowa w porównaniu do gleby bez dodatku pyłu lotnego. Przydatność pyłów lotnych stosowanych jako środek ulepszający glebę w plantacjach szkółkarskich ma znaczenie z punktu widzenia zagospodarowania takich pyłów w sposób przyjazny dla środowiska naturalnego.

Słowa kluczowe: różnorodność mikrobiologiczna gleby, tekstura gleby, struktura gleby, agregacja gleby, dostępność składników pokarmowych, fizyczne środowisko glebowe