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Coal fly ash amendment in acidic field: Effect on soil microbial activity and onion yield

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ABSTRACT

Beneficial soil microorganisms are directly or indirectly involved in promoting plant growth and yield. The ameliorating effect of fly ash (FA) with reference to the microbial density and activity is sparsely studied in acidic soil under field conditions. Hence, an experiment was conducted to assess the population dynamics of beneficial microorganisms at different levels of FA (25 Mg/ha, 50 Mg/ha, 100 Mg/ha and control with no fly ash) by using onion (*Allium cepa* L.) crop. It was observed that population density of phosphorus solubilising bacteria (PSB) (1.33×10^6 cfu/100 g soil), *Actinomycetes* (3.11×10^5 cfu/100 g soil) and arbuscular mycorrhizal fungi (AM fungi) were maximum at 50 Mg/ha FA. However, the density of *Azotobacter* (6.27×10^4 cfu/100 g soil) was highest at 25 Mg/ha. AM fungi root colonization and soil microbial activity were significantly highest at 50 Mg/ha dose of FA in comparison to control. FA amendment significantly improved the physico-chemical properties of soil. Cation exchange capacity (CEC), water holding capacity (WHC), available P and available K were optimum at 50 Mg/ha. Heavy metal content in FA amended soil was found to be reduced with respect to the control. Although, Hg and As were present in the experimental FA, they were found to be absent in FA amended soil. Highest onion yield was obtained at 50 Mg/ha dose of FA which showed an increase of 31.91% over control. Pearson correlation analysis exhibited significant correlation between pH, WHC, P and Ca with crop yield, microbial density and activity. Therefore, 50 Mg/ha dose of FA may be considered as a suitable dose for amendment in onion cultivation in terms of sustainable management of biological and physico-chemical health of acidic soil as well as safe FA utilization practice.

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1. Introduction

Fly ash (FA) is of grave environmental concern worldwide due to its increasing accumulation over the years, followed by air-water pollution and land degradation. FA can be utilized as an alternative to other industry resources, processes, or applications. These include mainly in sectors viz. construction, reclamation, mine filling, agriculture, etc. Due to its excellent soil ameliorating properties, FA has a vast potential of utilization in agriculture, forestry and wasteland reclamation wherein it can be utilized gainfully in bulk (Parab et al., 2012; Ram and Masto, 2014). The use of FA for soil amelioration has been advocated for the last three decades in different types of soils due to its favorable physico-chemical properties including appreciable amounts of K, Ca, Mg, S and P, (Pandey et al., 2010a; Ram and Masto, 2010). Previous studies have demonstrated the potential of FA in the improvement of crop yield of wheat (*Triticum aestivum*), rice (*Oryza sativa*), maize (*Zea mays*), mung (*Vigna unguiculata*), eggplant (*Solanum melongena*), onion (*Alium cepa*) and chickpea (*Cicer arietinum*) cultivated on different types of soils (Rizvi and Khan, 2009; Pandey et al., 2010b; Arivazhagan et al., 2011; Singh et al., 2012; Parab et al., 2013a,b).

Soil acidity causes a detrimental effect to both plants and soil organisms (Runge and Rode, 1991). The activities of beneficial soil microorganisms generally get reduced under acidic conditions that result into low availability of macronutrients viz. N and P and high availability of toxic heavy metal Al. Liming is well known treatment for acidic soil but it depletes natural resources. Application of FA in acidic soil is well studied by earlier researchers wherein it was reported to be beneficial in improving physico-chemical and biological properties of acidic soil (Rautaray et al., 2003; Basu et al., 2009).

Beneficial microorganisms are one of the most integral parts of soil system which maintain the soil health and quality to make it dynamic for nutrient turn over and sustainability of cropping systems (Mishra et al., 2011; Ahemad and Kibert, 2014). A wide range of microorganisms is involved in various biotic activities such as organic matter decomposition, nitrogen fixation,

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solubilisation of micro and macro nutrients, maintenance of soil structure, soil borne disease suppression, plant growth promotion, siderophore production and release of hormones (Mishra et al., 2008). Among them, plant growth promoting microorganisms viz. *Azotobacter chroococcum*, PSB, AM fungi and *Actinomycetes* play vital role in agriculture by mediating plant growth by alteration of whole microbial community in rhizosphere niche through the production of various substances (Mishra et al., 2009). Hence, it is imperative to evaluate the potential impact of FA on the plant growth promoting microorganisms (*A. chroococcum*, PSB, AM fungi and *Actinomycetes*) if it has to be considered for soil amendment in acidic soil.

Previous studies depicted that application of unweathered FA to soils severely inhibited microbial respiration, enzymatic activity and soil N cycling processes (Pichtel, 1990; Pichtel and Hayes, 1990). This limitation of microbial activities was due to some factors such as lack of substrate C, adequate N supply, pH, salinity, toxicity of B, the excess concentration of soluble salts and trace elements (Pandey et al., 2010a). Mixed application of farm yard manure (FYM) and FA proved to be beneficial in augmenting proliferation and activity of microorganisms in acidic soil (Lal et al., 1996). Generally, on FA amendment in soil, microbial diversity increases as ash weathers and nutrients accumulate (Sims et al., 1995). Parab et al. (2013b) reported that mycorrhizal dependency in onion varies with FA amendment. Further, most of the studies reported that lower level of the FA amendment improves the microbial population but it decreases with higher levels (Pandey et al., 2010a). On the other hand, increased microbial activity at low levels of FA might help to reduce its detrimental effects on soil since most of the bacterial strain either enhance mobility of required micronutrient or immobilized toxic elements (Tiwari et al., 2008).

In view of the above observations, it is essential to study the effect of different concentrations of FA on soil microbial community in order to identify its optimal level for soil amendment vis a vis crop yield. Hence, the present study aimed to evaluate the effect of different doses of FA on the density and activity of plant growth promoting microorganisms, physico-chemical properties of soil and yield of onion under field conditions.

2. Materials and methods

2.1. Experimental site and treatments

The field study was conducted during January 2013–May 2013 on Agrifound light Red variety of onion (*Allium cepa* L.) at Panvel, Maharashtra, India at latitude 18°58′60N, longitude 73°5′60E and at the altitude 27 m above the mean sea level. The onion seedlings were procured from National Horticultural Research and Development Foundation, Nashik, India. The experimental area is characterized as tropical with a mean annual precipitation of about 3267 mm, most of the rain falling between June and October. During the study, maximum temperature ranged from 29.4 °C to 34.3 °C, the minimum temperature was in between 17.7 °C and 24.4 °C and average humidity was 27%.

FA was procured from Nashik Thermal Power Station, Nashik (M.S.) India and amended in soil at the rate of 25 Mg/ha, 50 Mg/ha and 100 Mg/ha properly as per the treatment wherein control was without FA. The study was conducted in randomized block design with total 4 treatments in triplicates. Plots of 2 m × 1.8 m dimension were prepared after that air dried FA was properly mixed as per the treatments. To separate each plot a strip of 30 cm was left on all the sides to avoid the exchange of soil nutrients and microbes between the experimental plots. FYM as a source of organic fertilizer was added at the rate of 10 t/ha whereas the recommended dose of chemical fertilizers were mixed as NPK (100:40:40) to all the treatments through urea, diammonium phosphate (DAP) and muriate of potash. Further, 50% dose of chemical fertilizers was mixed as basal dose while the remaining 50% was added as top dose after 45 days of transplantation. Onion saplings of 4 weeks from the nursery were transplanted at the spacing of 15 cm × 20 cm. Irrigation was done at regular interval, to maintain the optimum moisture level (water holding capacity 0.44 ml g^{-1} of soil) in each plot. Depending upon the intensity of weed, manual weeding was done time to time.

2.2. Soil sampling and analysis

Soil samples were collected randomly in zigzag manner from 15 to 20 spots (10–15 cm depth) from each replicates after the harvesting of crop and mixed thoroughly to make a homogenized three subsamples. For physico-chemical analysis soil samples were passed through 2 mm sieve after air drying in the shade. The samples for microbial analysis were stored at 4 ± 1 °C and 1 g of soil sample was used for serial dilutions in each case. Analytical reagent grade chemicals were used in present study.

The pH and electrical conductivity (EC) of amended and unamended soil samples and FA were measured in the suspension of 2:5 (w/v) with the help of pH meter (Equip-Tronics, Model EQ-621) and conductivity meter (Equip-Tronics, Model EQ-664), respectively. Water holding capacity (WHC) was measured by the method of Black (1965). Organic carbon (OC), available nitrogen (N) and phosphorus (P) in pre and post soil samples were estimated by Walkley and Black (1934), Kjeldahl and Olsen's method, respectively. Available potassium (K), calcium (Ca) and magnesium (Mg) were determined by ammonium acetate extraction (1:5 w/v) method (Hanway and Heidal, 1952) whereas analysis of cation exchange capacity (CEC) was performed by sodium-ammonium acetate extraction method (Maiti, 2003). Ammonium acetate of analytical grade from Merck was used for extraction. Available concentrations of lead (Pb), nickel (Ni), aluminium (Al), silica (Si), arsenic (As) and chromium (Cr) in control as well as in FA amended soil was determined by using Atomic Absorption Spectrophotometer (AA 7000, SHIMADZU, Japan) after extraction in diethylene triamine penta acetic acid (DTPA) in 1:2 w/v ratio to samples (Lindsay and Norvell, 1978). DTPA was procured from Sigma–Aldrich.

The *A. chroococcum* and phosphorus solubilising microorganism (PSB) were isolated from rhizospheric soil of control as well as FA amended treatments by plate dilution method on sterile Jensen's and Pikovaskaya's agar plates, respectively. The plates were incubated at 28–30 °C for *A. chroococcum* and at 30–32 °C for PSB up to 48–72 h and colony count was recorded. In case of PSB, colonies showing clear zones around them were counted. For the enumeration of actinomycetes soil samples were serially diluted up to 10^{-5} dilution and 0.1 ml of the soil suspension from 10^{-3} to 10^{-5} dilution was cultured on sterile starch casein agar plates. The plates were incubated at 27–28 °C for 48–96 h and observed continuously for growth. Data of microbial density are expressed as log number of colony forming units (CFUs/g) of dry soil. All the media were procured from Himedia. Wet sieving and decanting method of Gerdemann and Nicolson (1963) was used for determination of spore density of AM fungi. The AM colonization in root was determined as per Giovannetti and Mosse (1980) after clearing and staining roots with 0.05% trypan blue (Phillips and Hayman, 1970). Soil microbial activity was estimated by CO_2 evolution method (Anderson, 1982).

2.3. Estimation of yield

Onion bulbs were harvested after 105 days of transplantation on attaining 75% neck fall of the crop and stored in properly leveled

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