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Macronutrient availability and microbial population in fly ash amended alluvial soil

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ABSTRACT

Investigation into the effect of fly ash with three organic manures *viz.*, farm yard manure (FYM), green leaf manures (GLM) and humic acid (HA) and inorganic fertilizers on macronutrient availability and microbial population was studied. Rice *(ADT 49)* was selected to raise field study. Fly ash generated from Mettur Thermal Power Station was selected for the study and examined for its physical and chemical properties. Analysis of fly ash revealed that it is neutral to alkaline (pH 8.1) in reaction. The results confirmed that fly ash contains all the essential elements required for the plant growth as that of soil except organic carbon and nitrogen. It was observed that fly ash (@ 20 t ha^{-1} + GLM (@ 6.25 t ha^{-1} with RDF (150:50:50) increased the NPK availability in soil. Application of fly ash @ 20 t ha^{-1} + GLM @ 6.25 t ha-1 + RDF recorded the highest soil available N (183 kg ha^{-1}), P (25.6 kg ha^{-1}), K (313 kg ha^{-1}). The treatment which received fly ash + GLM with RDF (150:50:50) recorded the highest grain (5.49 t ha^{-1}) and straw yield (6.59 t ha^{-1}). Combining GLM and FYM with fly ash influenced more microbial populations than fly ash alone. Fly ash application did not influence the population of fungi and actinobacteria while bacterial population showed a marked level of increase. Thus the integrated effect of fly ash, manures and fertilizer was well pronounced in enhancing the macronutrient availability, microbial population and rice productivity.

Key words : *Fly ash, FYM, GLM, HA, Macronutrient and microbial population*

Introduction

Nutrition of crops has been more important than "nutrition of soils". To maintain high response of crops to applied fertilizer, equal importance has to be given to soil health management practices and efforts have to be made to create awareness of soil health among the farming community, so that soils (natural resource) in good condition could be transferred to the next generation (Doran, 2002; Trivedi *et al.*, 2016; Fr¹c *et al.*, 2018). For this purpose fertility restorer inputs like available fly ash, gypsum, formulated compost, FYM, city waste and other agro-industrial waste, have to be recycled in soil through integrated nutrient management approach (Malik and Thapliyal, 2009; Ahmaruzzaman, 2010). The basic concept of integrated plant nutrient management helps to maintain soil fertility for sustainable crop production through optimizing all potential sources of plant nutrients (Parab *et al.*, 2012).

Coal is a predominant source of global energy. In India it is a major source of electrical energy for 120 coal based thermal power plants, which produce 175 million tonnes per year fly ash (Adriano *et al.*, 1980; Xu *et al.*, 2017; Chen *et al.*, 2020). Fly ash is the noncombustible mineral matter in coal which is thermally altered as it cycles through the combustion process. About 40,000 ha of land are required

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for the construction of ash ponds for dumping 175 million tonnes of fly ash (Bajpai *et al.*, 2020; Yousuf *et al.*, 2020). Indian coals, though low in sulfur, contain higher amount of ash (about 35-45 %), hence the fly ash is generated in huge quantities from the thermal power plants.

Fly-ash has great potentiality in agriculture due to its efficacy in modification of soil health and crop performance (Sahu *et al.*, 2017; PAUL, 2020). The high concentration of nutrient elements (P, K, Na, Zn, Ca, Mg and Fe) in fly-ash increases the yield of many agricultural crops. But compared to other sectors, the use of fly-ash in agriculture is limited (Karwal and Kaushik, 2020; Rao *et al.*, 2020).

Poor nutritional status is a major cause determinant of crop productivity of a soil (Manik *et al.*, 2019; Shah and Wu, 2019). Many waste materials containing essential plant nutrients are available in huge quantities which when applied at appropriate rates can enhance the nutrient status as well as other soil properties (Basu *et al.*, 2009; Singh *et al.*, 2010). Yields of several crops were required to increase addition of fly ash which alleviates nutrient deficiencies in plants although the response varied from soil to soil (Usmani *et al.*, 2019). Thus, the use of fly ash in agriculture provides a feasible method to improve the soil environment and enhance the crop productivity and also for its safe disposal.

Rice is the staple food of majority of the population in the world. In south India, rice is the major food grain, which is cultivated under wet conditions (Shrestha *et al.*, 2017; Goswami *et al.*, 2020). Recent high yielding rice varieties remove huge quantity of nutrients and hence to sustain rice productivity, these nutrients are to be replaced through fertilizers (Cuong *et al.*, 2017; Gaspar *et al.*, 2017). High cost of fertilizers will increase the cost of production and also unaffordable for the resource poor farmers (Chaudhari *et al.*, 2018). Utilization of fly ash in rice farming as a source of nutrient will help to sustain rice productivity and also reduce the cost of cultivation. However, a proper management strategy has to be developed to abate the land pollution from the dumping of fly ash.

Hence the present investigation has been envisaged to find out the feasibility of using fly ash along with organic manures in agriculture for sustaining the soil fertility and crop yield. The literature relevant to the characterization of fly ash, manures, fertilizers and its effect on soil properties, nutrient uptake and yield of crops are reviewed in this chapter.

Materials and Methods

Rice Field Experiment

Field experiment was conducted using fly ash collected from Mettur Thermal Power Station with Rice (ADT 49) in KVK Field No.9E, Tirur, Tamil Nadu. Since rice crop is extensively cultivated in this zone it was selected as test crop.

Basic Properties of Fly Ash, Manures and Soil Used for the Field Experiments

The fly ash sample collected from the Mettur Thermal Power station of Tamil Nadu, composite surface soil collected for incubation study from field No. 9E and also the initial soil samples of field experiment plots were analysed for physical, physico-chemical and chemical properties.

Characterization of Fly Ash

The fly ash sample collected from Mettur Thermal Power station of Tamil Nadu where coal is used as a fuel for power generation are neutral in soil reaction and non saline. Particle size analysis evinced its texture as silt loam. The physical properties *viz.*, bulk density, particle density, porosity and water holding capacity were 1.24 (Mg m^{-3}), 1.99 (Mg m^{-3}), 42 per cent and 33 per cent respectively. With reference to the CEC, fly ash recorded 2.1 c mol (p+) kg-1 and organic carbon was found to be low (0.01%).

Characteristics of Fly Ash used for the Field Experiment

The fly ash were analysed chemically for the total N, P, K, micronutrients and heavy metal content. The total N content of the fly ash was found to be very low (0.04%). With regard to the total P content, fly ash recorded (0.22%) and the total K was comparatively high among three macro nutrients. The total K content of the fly ash was 0.51%. The analytical results of DTPA extractable micronutrients *viz.*, Zn, Fe, Cu and Mn were 6.8, 17.0, 1.5 and 1.3 mg kg^{-1} respectively. Regarding the total heavy metals, the content of Cr was 41 mg kg^{-1}, Pb 2.6 mg kg^{-1} and 4.1 mg kg^{-1} Cd.

Characteristics of Soil used for the Field Experiment

The composite soil collected from field No.9E of KVK Farm, Tirur for conducting incubation and field studies was slightly alkaline in reaction and non saline. The textural analysis revealed that it is silty clay loam in nature. The physical properties *viz.,* bulk density, particle density, porosity and water holding capacity were 1.35 (Mg m^{-3}), 2.64 (Mg m^{-3}), 47.3 per cent and 40.1 per cent respectively. The organic carbon status was medium and the exchange reactions of soil in respect of cations were 13.4 cmol (p+) kg^{-1}. The available nutrient status of soil in respect of N, P and K showed high K, medium P and low N.

Nutrient Composition of the Manures used

Among the manures used for both the incubation and field experiment, FYM contained 0.97 per cent N, 0.58 per cent P and 0.72 per cent K, GLM contained 2.76 per cent N, 0.28 per cent P and 4.6 per cent K, humic acid contained 3.5 per cent N, 1.5 per cent P and 2.1 per cent K.

Nutrients Availability in the Post Harvest Soil

Available Nitrogen

The available N content of the post harvest soil ranged from 154 to 189 kg ha^{-1}. Among the different manurial treatments, fly ash + GLM showed its superiority by registering a mean available N content of 183 kg $ha^{-1.}$ Among the different fertilizer combinations, the plot that received the RDF treatment showed the highest available N content of 178 kg ha^{-1}, the 50% K received plot recorded 177 kg ha^{-1} followed by the treatment of RDF without K (176 kg ha^{-1}). The fly ash + FYM treated plots were on par with fly ash + GLM plots. The treatments of RDF without Fe, without Zn and without Zn and Fe recorded available N of 174, 173 and 170 kg ha^{-1} respectively. The fertilizers along with manures showed a significant variation in available N status. The highest available N of 189 kg ha^{-1} was recorded in fly ash + GLM and RDF treated plot whereas in the fly ash alone treated plot the available N was only 154 kg ha^{-1}. The lowest N content was recorded in the fly ash alone with no fertilizer treated plots. Application of fly ash + GLM with RDF and 50% K are on par with each other. The conjoint application of fly ash, manures and fertilizers displayed the effect was statistically significant.

Availability of N in the post harvest soil remained unaffected as compared to the initial level. Among the treatments, the highest available N was observed in the fly ash + GLM treatment followed by fly ash + FYM treatments. As fly ash contains very little amount of N (0.04%), it is not sufficient enough to increase the available N in the post harvest soil (Lukashe *et al.*, 2019). Hence the available N was low in fly ash alone treated plots. Addition of fly ash with GLM markedly increased the available N content of the soil because, GLM being a rich source of N could supply the required quantity of N (Lim *et al.*, 2017; Sahu *et al.*, 2017). Thus, addition of fly ash along with organic manures did not affect the N status of the soil.

The available N content ranged from 168 to 178 kg ha-1 in different levels of fertilizer treatments. Regarding the interaction of fly ash and manures with different levels of fertilizers, fly ash + GLM with RDF showed an increased available N in soil. The highest N was registered in the RDF treated plots which might be due to the balanced supply of nutrients.

Available Phosphorus

The available P content of the post harvest soil ranged from 21.7 to 26.2 kg ha^{-1}. The different manurial treatments recorded a significant variation in the available P status of the soil. The highest mean available P status of 25.6 kg ha^{-1} was registered in the fly ash + GLM treatment followed by fly ash + FYM (24.8 kg ha^{-1}), fly ash + HA (24.2 kg ha^{-1}) and the least was recorded in fly ash alone treated plot (23 kg ha^{-1}). The RDF treated plot showed the highest available P status of 25.1 kg ha^{-1} whereas control showed a low P status of 23.6 kg ha^{-1}. The treatments which received RDF without K and RDF with 50% K showed a similar result on available P of 24.7 and 24.8 kg ha^{-1} respectively. Application of fertilizers without Fe, without Zn and without Fe and Zn recorded 24.4, 24.2 and 24 kg ha^{-1} respectively. The RDF without K treated plots was on par with RDF with 50% K. Among the interaction of fly ash and manures with fertilizers, fly ash + GLM with RDF showed highest available P of 26.2 kg ha^{-1}. In the manure and fertilizer interaction, fly ash + GLM with RDF excluding K and fly ash + GLM with RDF 50% K are on par with each other. The interaction of manures with varied levels of fertilizers showed a significant variation in terms of available P.

The available P content ranged between 21.7 and 26.2 kg ha^{-1} in the different manure treated plots. Among the manures, GLM in addition with fly ash performed better than others. The highest available P was recorded in the fly ash + GLM treated plots followed by fly ash + FYM. Seshadri *et al.* (2013) reported that addition of fly ash with manures showed a positive result in P adsorption and enhanced the P retention capacity of the soil. With respect to the varied levels of fertilizers, the P availability varied significantly among the treatments but it was in small units only (Kalra *et al.*, 1998; Gupta *et al.*, 2002). Interaction of fertilizers with fly ash and manures increased the P levels in soil (Wong and Wong, 1989; Lee *et al.*, 2006). Combination of fly ash + GLM with RDF recorded the highest P content in soil.

Selvakumari *et al.* (2000) reported that combined application of fly ash and organics had marked influence on P availability. The synergistic effect of combined addition and the contribution of P from the organic sources might have resulted in the marked enhancement of P availability in the soils. Green manure significantly improved the soil available P status than control. Trivedi *et al.* (2016) stated that the decomposition products of added plant material being dominantly anionic in character compete with PO_4 anion in polar adsorption increases the soil available P. The hydroxyl acids liberated during the decomposition of organic manures also chelate Fe and Al and prevent them from reacting with PO_4 to form insoluble precipitates.

Available Potassium

The available K status was assessed using neutral N NH_4OAc and the available status of K ranged from 289 to 328 kg ha^{-1} among the manurial treatments. The status of available K was the lowest in fly ash alone treatment and the highest in fly ash + GLM treated plot. With regard to the fertilizer treatment, RDF registered the highest available K status of 313 kg ha^{-1} followed by RDF without K (310 kg ha^{-1}), RDF with 50% K (312 kg ha^{-1}), RDF without Fe (309 kg ha^{-1}), RDF without Zn (308 kg ha^{-1}) and RDF without Fe and Zn (306 kg ha^{-1}). The RDF excluding Fe and excluding Zn was on par with each other. The application of fly ash + FYM with RDF and fly ash + FYM with 50 % K were on par and fly ash + FYM excluding Fe and fly ash + FYM excluding Zn were on par with each other. The interaction effect of manures with fertilizers was statistically significant.

The available K content of the soil ranged from 289 to 328 kg ha^{-1}. Application of fly ash with FYM, GLM and HA increased the available K in soil. However, the highest available K content of 322 kg ha-1 was recorded in the fly ash + GLM treatment. Similar results on the phenomenal enhancement of available K was reported by Mittra *et al.* (2003). Application of fly ash + GLM with RDF significantly increased the K content in the soil which, clearly indicated the release of K from fly ash to the soil on action of different manures. Similar findings were reported by Selvakumari *et al.* (2000).

Effect of Fly Ash, Manures and Fertilizers on Biological Properties of the Post Harvest Soil

Bacterial Population

The microbial populations were estimated in the post harvest soil by using the serial dilution technique. The bacterial population of manurial treatments secured in the range of 14.4 to 18.35 (g-1 of dry soil). The treatment effect of fly ash + GLM has revealed the highest bacterial population of 18.13 (g^{-1} of dry soil) followed by fly ash + FYM (17.66 (g^{-1} of dry soil). The population of fly ash alone treatment has secured the lowest level of 14.56 (g^{-1} of dry soil). On account of varied levels of fertilizers, there was an increase in bacterial population and the population changes among the different levels of fertilizers were in small units. The interaction of fly ash + GLM with RDF showed highest number of bacterial population after the harvest of the crop. In the fly ash + GLM treatment RDF excluding K and RDF with 50% K are on par with each other. The interaction among the varied fertilizers level and fly ash - manures were found to be significant.

The population of fungi was progressively increased with the application of fly ash and manures. The range of fungi was from 6.48 to 8.28 (g^{-1} of dry soil). The highest mean fungal population was observed in the fly ash + GLM treated plots 8.34 (g^{-1} of dry soil) followed by fly ash + FYM (7.91 (g^{-1} of dry soil). The effect of fly ash alone treated plots registered the least level of fungi as 6.59 (g^{-1} of dry soil). With regard to the varied levels of fertilizers, the effect of change in population of fungi was varied significantly. The interaction effect of fly ash and manures and its interaction with the fertilizers showed a significant increase in the fungi population. The highest fungal population was noticed in the fly ash + GLM with RDF treated soils and the lowest were seen in fly ash alone without fertilizer treatment.

The combination of adding fly ash and manures increased the Actinomycetes population significantly. Among the other manurial effect with fly ash, fly ash + GLM recorded the highest number of

5.31 (g^{-1} of dry soil) followed by fly ash + FYM (4.63 (g^{-1} of dry soil). The least population of 3.61 (g^{-1} of dry soil) was observed in the fly ash alone treated plots. The variation among the manurial treatments was significant. The effect of varied levels of fertilizers over the actinomycetes population was not significantly increased. The interaction of fly ash and manures with the combination of varied levels of fertilizers was statistically significant.

Soil microbiological properties including microbial biomass, microbial diversity, microbial activity and enzyme activity are important soil quality indicators and often used to assess extent of soil pollution due to heavy metal contamination (Yang *et al.*, 2006) (Banerjee *et al.*, 2020). In this study, application of fly ash along with different organic manures produced a significant result regarding microbial population. Among the different manures used, GLM performed well in improving the microbial population (Zhou *et al.*, 2020). Because during the decomposition of fresh GLM, the activity of the microbes enhanced which in turn increased the microbial population (Barros *et al.*, 2020). FYM also registered a significant result in the microbial population. The effect of HA addition also revealed a positive result in microbial population.

Varshney *et al.* (2020) recorded that application of fly ash did not cause any negative effect on the microbial communities and improved the population of fungi including arbuscular mychorrhizal fungi and gram negative bacteria.

Under submerged conditions, the population of bacteria, actinomycetes and phosphobacteria were relatively higher in alluvial soil. This might be due to the relatively higher native fertility as well as the fertility built up due to continuous addition of fly ash and manures over four crop seasons in alluvial soil (Hu *et al.*, 2021). However, there was a relatively less fungal population in alluvial soil which might be due to its high pH (8.0). Similar results were reported by Basker *et al.* (2000).

Conclusion

Though fly ash in itself is not a source of soil microbes, its beneficial effect on the physico-chemical properties of soils has improved microbiological activity. The results drawn from the field study indicated that the fly ash had not produced any adverse/ toxic effect on microbial population. The results generated from this study showed that fly ash could be a source of nutrient especially in soils low in fertility.

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