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Fly ash—a potential source of soil amendment and a component of integrated plant nutrient supply system

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Abstract

In sub-tropical climate the high rainfall and high temperature is responsible for low soil productivity due to losses of bases and low organic matter content in soil. In acid lateritic soil low availability of P and high content of Al and Fe posses nutritional imbalance which is generally corrected by lime materials. Alkaline fly ash can be used in such problematic soil as an amended material and also it acts as source of plant nutrition for crop production. An attempt was made to develop an integrated plant nutrient supply system utilizing the fly ash along with other organic wastes like paper factory sludge, farm yard manure, crop residue and chemical fertilizers for rice–peanut cropping system. Direct and residual effects of fly ash were assessed based on crop yield, nutrient uptake and changes in soil characteristics. The application 10 t ha^{-1} of fly ash in combination with organic sources and chemical fertilizer increased the grain yield and nutrient uptake of rice, and pod yield of peanut compared to chemical fertilizers alone. The heavy metal contents in plant and soil system was analyzed and found to remain below the permissible level. The results indicated that fly ash could be applied safely to tropical agro eco-systems for retaining productivity of acid lateritic soil.

Keywords: Fly ash; Integrated plant nutrient supply system; Heavy metal content

1. Introduction

In intensively cropped tropical soil, indiscriminate use of chemical fertilizers has resulted in low organic matter content and imbalance in nutrient supply by depletion of essential micronutrients. Moreover in acidic soil, such problems are aggravated due to fixation of phosphorus by iron and aluminium, besides less availability of micro-nutrient like molybdenum. This has resulted in low and inconsistent production of crop yield in rice based cropping systems. This calls for development of an integrated nutrient management system by supplying organic and inorganic sources of fertilizers and for improving physical and chemical properties of soil. One of the possible ways of enhancing productivity of acid lateritic soil is use of alkaline fly ash and other industrial wastes in combinations with organic matter and chemical fertilizers which would act as a soil amendment and source of nutrient. Any increase in soil pH and thereby reduction in soil acidity will improve availability of nutrient particularly phosphorus.

Fly ash, a finely divided residue resulting from the combustion of bituminous coal of thermal power plant is regarded as an amorphous ferro-alumino, silicate mineral containing all of the essential elements that occurs naturally in soil except humus and nitrogen [9]. It has a pH of 8.5 [2] and has certain physical and chemical properties that might be useful to neutralize soil acidity [1,8] and improve crop production [7]. Since it is composed of mostly silt size particles, addition of fly ash to sandy soils would permanently alter soil texture, increase microporosity and improve water retention capacity [3].

Organic materials like farm yard manure, crop residues and paper factory sludge are commonly used for enrichment of soil. These materials are readily available from animal

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and crop production system and as industrial waste. Paper factory sludge is a rich source of carbon with active silicic acid [6] and improves soil organic matter contents, water holding capacity, soil structure and bulk density [10]. Different organic materials with varying C/N ratio and biochemical compositions release nutrients at different rates and in varying quantities. It is also known that chemical fertilizer and organic materials are not substitute for each others; rather their role is complementary. Therefore, the application of chemical fertilizer, industrial waste and agricultural animal waste together may bring changes in the decomposition process of organic materials and hence are likely to alter the nutrient release pattern of the soil.

In general, organic sources of fertilizers applied to one crop meet a part of the requirement of the succeeding crop. The present investigation was, therefore, conducted to study the direct and residual effect of fly ash and other sources of fertilizers applied alone or in an integrated manner on crop productivity, restoration of soil fertility and nutrient status in plant in rice–peanut cropping sequence.

2. Materials and methods

The investigation was carried out at the experimental farm of the Agricultural and Food Engineering Department, Indian Institute of Technology, Kharagpur, India. The climate of this region was warm and humid with average annual rainfall ranging from 1300 to 1600 mm, most of which received during wet season of June to October. The soil of the experimental site was acid lateritic, sandy clay loam (Haplustalf) with pH 5.4, CEC 8.4 c mole kg^{-1}, organic carbon 3.8 g/kg and total N, P, K 0.045, 0.036, 0.066%, respectively. The available nutrients of different elements are presented in Table 1a.

Field experiment was conducted with rice (*Oryza sativa*) variety IR36 during the wet season (July, 3–November, 5) followed by peanut (*Arachis hypogaea*) variety JL24 during dry season (February, 4–May, 29). Rice was transplanted in puddled soil by using 25 days old seedling raised in nursery bed. The seed rate used in nursery bed was 50 kg ha^{-1}. The crop was irrigated as and when required to maintain a shallow level of submergence (5 ± 2 cm) throughout the crop growth period. There was no incidence of pest and diseases to rice. The peanut seed (kernel) was sown by seed drill at 90 kg ha^{-1}. The crop was irrigated to maintain 75% available moisture in soil. For control of tikka disease fungicide (Dithane M-45) was applied as per recommended dose.

Two sets of experiment were conducted and the experimental design was randomized complete block with three replications. The size of each plot was 8.4 m × 4.0 m. For rice the recommended dose of N: P_2O_5: K_2O at 90: 60: 40 kg ha^{-1}, respectively, were applied in different treatment combinations except two treatments where fly ash (FA) was applied alone at 10 t ha^{-1} and an absolute control

Table 1a
Selected properties of soil

Parameter	
Texture	Sandy silt loam
Bulk density (g/cm^3)	1.64
Field capacity (%) at 33 K Pa	14.83
Permanent wilting point (%) at 15 K Pa	5.72
pH (soil:water, 1:2.5)	5.40
CEC (c mole $kg^{-1)}$	8.40
Organic carbon (g/kg)	3.80
Total nitrogen (g/kg)	0.0045
Total phosphorus (g/kg)	0.0036
Total potash (g/kg)	0.0066
Total sulphur (g/kg)	0.0003
Total calcium (g/kg)	0.0045
Total magnesium (g/kg)	0.0039
Total iron (g/kg)	0.0087
Total boron (mg/kg)	0.50
Available nitrogen (mg/kg)	77.0
Available phosphorus (mg/kg)	13.0
Available potassium (mg/kg)	78.0
Available calcium (mg/kg)	242.0
Available magnesium (mg/kg)	51.0
Available sulphur (mg/kg)	20.0
Available iron (mg/kg)	52.0
Available manganese (mg/kg)	7.0
Available zinc (mg/kg)	0.84
Available copper (mg/kg)	1.19

treatment where nothing was applied. After harvest of wet season rice the residual effect of these fertilizer treatments was studied on the subsequent dry season peanut crop. Besides residual fertility the crop also received a uniform dose of N: P_2O_5: K_2O supplied at 30: 60: 40 kg ha^{-1}, respectively, through chemical fertilizer in all treatment except absolute control. Industrial wastes, viz. FA, paper factory sludge (PFS), organic manure like farm yard manure (FYM), crop residue (CR), lime (L) as soil amendment and chemical fertilizer were used in different combinations. The physical and chemical properties of the industrial waste materials and FYM are presented in Table 1b.

Fly ash was applied at 10 t ha^{-1} and organic materials such as FYM or PFS or CR were applied in quantity to supply 30 kg N ha^{-1} and lime at 2 t ha^{-1}. In another set of experiment fly ash was applied at 5 t and 10 t ha^{-1} in combined treatments. Fly ash and organic materials FYM and PFS were broadcasted and incorporated into the soil. Crop residue was applied after chopping by mechanical shredder. Fly ash, different organic wastes, lime and entire dose of chemical fertilizer P and K and half dose of N fertilizer were applied as basal at the time of sowing, the remaining half of N chemical fertilizer was top dressed by broadcasting in standing crop after 45 days of plantation. The chemical fertilizer N, P, K were supplied through urea, single super phosphate and muriate of potash.

Periodic observations on plant growth and yield of rice and peanut were recorded. The nutrient uptake for N, P, K, Ca, Mg, Fe, Mn, Zn, Cu and Co were calculated at harvest of the crop. Besides accumulation of heavy metals (As, Cd, Ni