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Short communication

Coal fly ash and farmyard manure amendments in dry-land paddy agriculture field: Effect on N-dynamics and paddy productivity

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ABSTRACT

A field study was conducted at a dry-land agricultural farm during paddy crop season to assess the effect of fly ash (FA) and farmyard manure (FYM) amendments on the dynamics of inorganic-N (NH_4^+ and NO_3^-), N-mineralization and nitrification rates and paddy yields. Four treatments, each consisted of three replicates, were established in completely randomized block design. The treatments were: control, 50 t ha^{-1} FA, 50 t ha^{-1} FYM, and FA + FYM (each 50 t ha^{-1}). The variations in soil physico-chemical properties due to treatments were statistically significant. Across different treatments, FA + FYM treated plot had significantly higher organic-C, total-N, total-P, water-holding capacity, but lower bulk density compared to control plot. The effect of various amendments and months was significant for soil inorganic-N (NH_4^+ and NO_3^-) concentrations, soil moisture (SM) content, N-mineralization and nitrification rates. Across various amendments and sampling months, inorganic-N, SM, N-mineralization and nitrification rates were greatest in FA + FYM treated plot in August month. An exponential positive relationship existed between gravimetric SM content and N-mineralization ($R^2 = 0.865$) and nitrification ($R^2 = 0.633$) rates. The SM content was negatively correlated with NH_4^+ ($R^2 = 0.841$) and NO_3^- ($R^2 = 0.920$). The various selected paddy agronomic parameters and yields differed significantly due to treatments. The most effective treatment noted for paddy grain yield was the combination of FA + FYM (92% increase over control) followed by FYM and FA. Significant correlation was noted among soil physico-chemical properties (except soil pH) and paddy productivity. The results suggested that FA and FYM amendments enhance the rates of N-transformation processes, plant available-N and paddy productivity. Thus, FA and FYM can be used as potential amendments to enrich soil productivity and crop yields for dry tropical nutrient poor soils.

1. Introduction

The generation of plant available-N pools (NH_4^+ and NO_3^-) in soil, mediated by N-mineralization and nitrification process, governs the supply of inorganic-N to plants (Singh and Kashyap, 2006; Singh et al., 2010). Thus, the rate of plant available-N supply may be a crucial factor for paddy crop productivity. The N-mineralization and nitrification in soils could be influenced by selective factors such as organic matter contents, soil pH, gravimetric moisture content, etc. An insight into the dynamics of N-mineralization and nitrification processes in fly ash (FA) and farmyard manure (FYM) amended agriculture soil will provide knowledge on improving paddy crop management. Nevertheless, research evidences regarding the role of FA and FYM applications on soil N-dynamics and paddy crop productivity are scanty for the dry-land rice agriculture.

Intensive agriculture and decreasing inputs of organic materials have led to severe degradation of soil fertility and productivity, particularly in rice agriculture (Kachroo and Dixit, 2005). Apart from plant residues, FA can be also considered as a potential source of soil amendments for paddy agriculture production (Pandey and Singh, 2010). However, information regarding the effects of FA amendments in paddy agro-ecosystem on microbial soil N-transformations (N-mineralization and nitrification) is still limited (Schutter and Fuhrmann, 2001).

FA, a by-product of the coal-burning industry, has already been recognized as a potential soil amendment for increasing the availability of mineral nutrients for plant growth (Mittra et al., 2005; Lee et al., 2007; Pandey and Singh, 2010). It has also been suggested that the application of FA from 10 to 80 t ha^{-1} did not show toxicity effects to the rice plants and increased the yields of paddy (Sikka and Kansal, 1995; Lee et al., 2006). Kuba et al. (2008) in a field experiment, a recultivation trial on an alpine ski-run, demonstrated that up to 16% ash admixture to organic wastes was beneficial to improve the product quality. In combination with various organic manures, FA can enhance soil microbial activities and plant productivity (Jala and Goel, 2006; Pandey et al., 2009). Recently, Insam et al. (2009) and Bougnom et al. (2010) reported that the use of wood ash, compost and sludge, or a combination of them, can change

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plant growth, soil microbial communities and properties related to soil N-dynamics. Several studies also indicated that the addition of FA to soils affect microbial activities (Wong and Wong, 1986), N-transformations (Cerevelli et al., 1986), physico-chemical characteristics of soil under rain-fed agriculture (Singh et al., 1997). FA in combination with other organic amendments improves physical, chemical and microbial processes related to N-dynamics of paddy soils (Pandey and Singh, 2010).

Keeping in view the importance of the FA and FYM amendments on the improvement of various soil properties, an experiment on rain-fed rice field was conducted with the following objectives: (i) to study the comparative effect of FA and FYM applications on the soil physico-chemical properties, paddy yield and dynamics of soil N-mineralization and nitrification rates, (ii) to examine relationships between gravimetric SM and inorganic-N, N-mineralization and nitrification rates, and (iii) to analyse the correlations between amended soil properties themselves and with paddy crop productivity. We hypothesized that soil N-mineralization and nitrification processes and rice productivity would be mainly regulated by the FA and FYM induced variations in soil characteristics.

2. Materials and methods

2.1. Experimental site and climate

The experiment was conducted at agriculture farm (lat. 26°52′21″N; long. 80°57′20″E; 110 m msl) of the Department of Environmental Science, Babasaheb Bhimrao Ambedkar (Central) University, Lucknow, Uttar Pradesh, India. The climate of study region was warm (with a rise in temperature up to a level of 45 °C or more) and humid with average annual rainfall ranging from 900 to 1100 mm, most of which received during wet season of late June–October. However, from last few years it is highly erratic and unpredictable, at times causing drought spells of varying degrees and durations. The soil of the experimental site is slightly alkaline, sandy loam, nutrient poor with moderate water holding capacity (Singh et al., 2010).

2.2. Experimental design and paddy crop cultivation

Field experiment was conducted during August 4–November 29, 2009, with a high-yielding rice (*Oryza sativa*) variety HUBR 2-1 (Malviya Basmati Dhan 1) suitable for cultivation in dry tropical region of eastern India. The dry-land rice variety was provided by Department of Genetics and Plant Breeding, Institute of Agriculture Sciences, Banaras Hindu University, Varanasi. HUBR 2-1 is semi-dwarf, with stiff stems, has fairly strong tillering ability (350–400 effective tillers m^{-2}) and is tolerant of blast, bacterial leaf blight, and stem borer. Its grain is long, slender, and aromatic, with 20–21% amylose and yield is about 4–5 t ha^{-1} (Singh et al., 2006).

The paddy agriculture field and experimental plots were prepared on June 25, 2009. The detailed methodologies adopted for the preparation of experimental plots of present study are according to our earlier investigation which was conducted in the same area during July 2008–October 2008 (Singh et al., 2010). The experimental plots (each measure 5 m × 3 m dimensions) were arranged in a completely randomized block design with three replicates. To separate each plot a strip of 30 cm was left to avoid the exchange of soil nutrients and microbes between the experimental plots. The various treatments applied in the present study were (i) control (without any amendments), (ii) fly ash (FA) (50 t ha^{-1}), (iii) farmyard manure (FYM) (50 t ha^{-1}), and (iv) FA + FYM (for this combination each amendment was applied 50 t ha^{-1}). A blanket application of NPK fertilizer (150:80:40 kg ha^{-1}) was also applied as a basal dose. Half of the recommended dose of N was applied respectively, during seed sowing (August 4, 2009) and panicle initiation (October 10, 2009). For the present experiment coal FA was obtained from National Thermal Power Corporation (NTPC) Plant, Unchahar, Raibarelly, Uttar Pradesh and FYM were provided by the Department of Applied Plant Science, Babasaheb Bhimrao Ambedkar (Central) University, Lucknow. FA and FYM amendments were incorporated in the experimental plots on July 31, 2009 as described by Schutter and Fuhrmann (2001). The detailed information about the contents of various toxic elements (heavy metals), macro- and micronutrients of FA used in the present study have already been described in previous investigations by Dwivedi et al. (2007), Kumar et al. (2008) and Tripathi et al. (2008). Sowing of paddy seeds, maintenance of experimental plots, measurements of selected plant growth variables, crop harvesting (on November 29, 2009) and estimation of paddy crop yield was made according to our previous experiment from rain-fed saline rice agro-ecosystem (Singh et al., 2010).

2.3. Soil sampling and analyses

From each experimental plot soil samples were collected monthly during the crop cycle from August 2009 to November 2009 from the 0–15 cm depth 20 days after the application of treatments. From each experimental plot, 10–15 soil cores (2.5 cm diameter) were sampled randomly, and combined to the level of one composite sample after thoroughly mixing by hand. In laboratory, the composite soil samples (field-moist condition) were sieved through a 2-mm mesh screen, divided into two equal parts and stored at 4 °C till further analysis. One part (in triplicate) was used for analysis of physico-chemical soil properties (analysed only once during the study period at the beginning of the study period) and the second part (in triplicate) was used for the determination of inorganic-N (NH_4^+ and NO_3^-), N-mineralization and nitrification rates. FA and FYM were analysed according to Kalra and Maynard (1991). Metals, macro- and micronutrients were analysed as described by Kumar et al. (2008) using a Varian Atomic Absorption Spectrometer (AA240FS).

Organic-C was analysed by dichromate oxidation and titration with ferrous ammonium sulfate (Walkley, 1947). Total-N was analysed by semi-micro-Kjeldahl digestion and total-P was measured colorimetrically after $HClO_4$ digestion (Jackson, 1958). Water holding capacity (WHC) was measured using perforated circular brass boxes as described by Piper (1944). Bulk density (BD) was determined by measuring the weight of dry soil of a unit volume to a 10-cm depth. Sub-samples (about 10 g) were dried at 105 °C for 24 h (to constant weight) for the determination of gravimetric soil moisture (SM) content (% on dry soil basis). Soil pH was measured in de-ionized water by glass electrode, after shaking for 1 h on a gyratory shaker (1:2.5, soil:water ratio).

Soil NH_4^+ ($\mu g\,g^{-1}$ dry soil basis) was extracted by 2 M KCl and analysed by the phenate method (APHA, 1985). NO_3^- ($\mu g\,g^{-1}$ dry soil basis) was determined using the phenol disulfonilic acid method, with 2 M $CaSO_4$ as the extractant (Jackson, 1958). Ammonium molybdate-stannous chloride method was used for the estimation of soil inorganic-P (PO_4^- $\mu g\,g^{-1}$ dry soil basis) concentrations as described by Jackson (1958). Net N-mineralization and nitrification rates were determined as described by Menyailo (2008). The net N-mineralization was calculated as the difference between the concentration of soil inorganic-N (NH_4^+ and NO_3^-) values after and before the incubation and expressed in $\mu g\,g^{-1}$ dry soil $month^{-1}$.

2.4. Statistics

Influence of various treatments on soil properties (organic-C, total-N and P, WHC, BD and pH) and various growth parameters