Original Research Article

Impact Fly ash on nutrient status of wetland rice cultivation

Abstract:

The phrase, “Rice is life” aptly describes the importance of rice in food as well in nutritional security, particularly in Asian countries. Cereal-pulse based Indian diets were reported to be qualitatively deficient in micronutrients particularly iron, zinc, calcium, vitamin D and B12, vitamin A and riboflavin. This implies the importance of nutritional security beyond national food security. Rice plants also require high quantity of silicate. Coal combustion fly ash has a high available Si content, alkaline pH as well as micronutrient was selected as a potential source in this study and the field experiment was conducted. Abundant supply of micronutrients like Zn, Fe, Cu and Mn along with P and K was recorded in the soil samples of plot treated with fly ash when compared with the plots with NPK alone. Hence the availability has also resulted in the uptake by the plants. Hence this would be scaled as an economically viable solution for hidden hunger in the areas in and around thermal power plants.

Keywords: rice, fly ash, micro nutrients, major nutrients

Introduction:

Rice production in India is an important part of the National economy and livelihood. India is one of the world's largest producers for rice and accounting for 20 per cent of world rice production. The rice plants require additional nutritional supply facilitating optimal nutrients to produce more yields. In general the application of fertilizers involves only NPK and in most cases only N supplies in the form of urea in India.

Even after 75 years of independence the resistant problem of under-nutrition persists, despite of increase in production to sustain the growing population leading to hidden hunger. Micronutrient deficiencies also known as Hidden hunger, afflicts more than 3 billion individuals, globally (UNICEF, 2021). Micronutrient malnutrition in humans is derived from deficiencies of these elements in soils and in-turn in foods (Shukla, 2014).The soil–plant system is instrumental to human nutrition and forms the basis of the “food chain” in which there is micronutrient cycling, resulting in an ecologically sound and sustainable flow of micronutrients (Yang, 2007).

In sub-tropical climate the high intense 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 posses nutritional imbalance which is generally corrected by lime materials. According to IPCC, agricultural lime application contributed to global warming through emission of CO_2 to the atmosphere. Use of fly-ash instead of lime as soil ameliorant could reduce net CO_2 emission and thereby lessen global warming (Sahu *et al*., 2017). Also, in India the production of coal combustion flyash is increasing The addition of fly ash to soil neutralizes the acidity to a level suitable for agriculture, depending on the initial pH of the soil and increases the availability of silicate, sodium, potassium, calcium, magnesium, boron, sulfates, and other nutrients, but not of nitrogen (Neina, 2019; Fernández and Hoeft, 2009; Bagayoko et al., 2000). Eventhough silicate is not a commonly recommended fertilizer, rice crop have a good affinity towards silicate uptake to stimulate the availability and absorption of other nutrients (Guo et al., 2005). This study was focused on the availability of major and micronutrients namely Iron, Zinc, Copper and Manganese in the soil with the application of fly ash along with NPK.

MATERIALS AND METHODS:

Fly Ash collection and properties:

The Flyash was collected from the thermal power plant in Neyveli and the Flyash was analysed for the mechanical, physical properties and nutritional availability. The mechanical composition of Flyash was determined by the International pipette method (Piper, 1966). The physical properties such as bulk density and particle density were determined by Keen Raczkowski Box Method (Keen and Raczkowski, 1921). The pH was determined using glass electrode pH meter and the EC was measured using a conductivity bridge. Soil organic carbon (SOC) was estimated by chromic acid wet digestion method (Walkley and Black, 1934), N by alkaline permanganate method, Soil available phosphorus by Olsen’s extractant method, Soil available K by flame photometer, micronutrient using using Atomic Absorption Spectrometer.

Field experiment:

The field experiment was conducted with recommended dose of NPK alone and NPK along with Flyash at 20 tonnes/ha in Randomized Block Design during Rabi season with a gross plot area of 4m x 5m in the Wetlands of Tamil Nadu Agricultural University, Coimbatore.

Fertilizer application

The recommended dose of NPK for rice variety by TNAU is 150: 50: 50 NPK Kg ha^{-1}. The entire dose of single super phosphate (16% P_2O_5) was applied as basal before planting. Potassium in the form of muriate of potash (60% K_2O) and Nitrogen in the form of urea and Neem coated urea were applied in four equal splits as per the treatment at basal, tillering, panicle initiation and 50 per cent flowering stages.

Soil analysis:

Collection of soil samples

Representative soil samples from all plots were collected at active tillering, panicle initiation, flowering and at maturity stages of rice. The samples were air dried, powdered with a wooden mallet, sieved through 2 mm sieve and stored in polythene bags until further analyses.

Chemical properties

The pH of soil was measured in water (1:2.5) after half an hour equilibration with a glass electrode pH meter (Model: Elico pH meter). The electrical conductivity (EC) of the supernatant suspension was measured using a conductivity bridge (Model: Elico conductivity bridge) (Jackson, 1973).

Soil Organic Carbon

Soil organic carbon (SOC) was estimated by chromic acid wet digestion method (Walkley and Black, 1934). Soil weighing 0.5 g (100 mesh sieved) was taken in a 500 ml conical flask and added 10 ml of 1 N K_2Cr_2 O_7 and 20 ml of conc. H_2SO_4.The contents were then allowed to stand for 30 minutes. Then distilled water (200 ml), H_3PO_4 (10 ml) and diphenylamine (1 ml) indicator were added. This was titrated against 0.5 N Fe $(NH_4)_2$ (SO_4). $6H_2O$. towards the end point of a bright green colour.

Available nitrogen

The available N content of the soil was determined by the alkaline permanganate method (Subbiah and Asija, 1956). Five grams of soil (2 mm sieved) was taken in a distillation flask and 25 ml of each 0.32 % $KMnO_4$ and 2.5 % NaOH was added to the soil. Twenty ml of 2 % boric acid with a drop of double indicator was taken in a beaker and kept near the delivery end. The distillation was carried out and the liberated NH_3 was collected and titrated against 0.02 N sulphuric acid. From the titre value, the soil available nitrogen was calculated.

Available Phosphorus

Soil available phosphorus was determined by Olsen's extractant method (Olsen *et al.*, 1954). Five gram of soil was taken in a polycarbonate shaking bottle. Fifty ml of 0.5 $MNaHCO_3$ adjusted to pH 8.5 and a pinch of activated carbon (Dargo G 60) were added to the soil and shaken for 30 min. The extract was filtered using Whatman No. 40 filter paper. Five ml of filtrate was pipetted out into a 25 ml volumetric flask and 4 ml of reagent B was added and made up to 25 ml. After 30 min the absorbance value of the colour developed in the sample was read at 660 nm in a spectrophotometer (Elico-Model BL 198) and the available phosphorus was calculated from the standard curve.

Available Potassium

The available K as extracted in neutral normal $CH_3COOHNH_4$ was determined. Five grams of the soil was taken in a 100 ml shaking bottle and 25 ml of 1 N $CH_3COOHNH_4$ was added, shaken for 5 min. and then filtered. The $CH_3COOHNH_4$ – K in the extract was determined using a flame photometer (ESICO – Model: 1382) (Jackson, 1973).

DTPA extractable micronutrients

The available micronutrients were extracted with DTPA (0.005 M Diethylene Triamine Penta Acetic Acid + 0.1 M Triethanolamine + 0.01 M $CaC1_2$) extractant adjusted to pH 7.3 ± 0.5 using 1:1 dilute HCl at 1:2 ratio (Soil : DTPA-extractant) after shaking for two hours, filtered through Whatman No.42 filter paper. The DTPA extractable copper, zinc, manganese and iron were estimated in the extractant using Atomic Absorption Spectrometer (Lindsay and Norvell, 1978).

RESULT AND DISCUSSION:

Properties of Fly Ash:

The results showed the texture to be clay loam. Porosity, water holding capacity, nutrient availability and many other factors determines the bulk density of the material. Since the soil is clay loam with 42.8 per cent pore space and maximum WHC to be 65 per cent, the bulk density is 1.05 g cm^{-1}. Flyash is alkaline in nature with slight salinity (EC 2.45 ds m^{-1}). It was also found to have a high amount of available silicate, exchangeable calcium and magnesium. The nature of the lignite, combustion process, and the other processes that it undergo determines the properties of Flyash (Panda and Biswal, 2018). The data are presented in the table 1.

Table 1. Textural and Physico chemical properties of Flyash

Fly Ash characteristics		
I.	**Textural properties (Piper, 1966)**	
	i. Clay (%)	8
	ii. Silt (%)	65
	iii. Fine sand (%)	20
	iv. Coarse sand (%)	6.1
	v. Textural class	Clay loam
	vi. Bulk density (g cm^{-1})	1.05
	vii. Pore space	42.8
	viii. Maximum WHC (%)	65

II.	**Physico Chemical properties**	
	i. pH (1:2 soil water suspension)	10.6
	ii. EC (ds m^{-1})	2.45
	iii. Organic carbon (%)	0.23
	iv. Available silicate (mg ka^{-1})	1123
	v. Available Nitrogen (mg kg^{-1})	45
	vi. Available Phosphorus (mg kg^{-1})	23
	vii. Available Potassium (mg kg^{-1})	389
	viii. Exchangeable Calcium (C mol $(p^{+})kg^{-1}$)	19.6

ix. Exchangeable Magnesium (C mol $(p^{+})kg^{-1}$)	20.1
x. DTPA Zn (mg kg^{-1})	6.1
xi. DTPA Fe (mg kg^{-1})	39.7
xii. DTPA Cu (mg kg^{-1})	1.8
xiii. DTPA Mn (mg kg^{-1})	9.9

SOIL ANALYSIS:

Soil pH and Soil EC

The observation made from the data presented on soil pH statistical significance was observed between treatments at all the four stages of observation (Table 2). A higher soil pH of more than 8 was observed in the plots applied with Flyash as compared to the treatment with NPK alone at all the stages of observation. The increase in pH was found to be 4 to 5 per cent in the plots with NPK+ Flay ash. Similar kind of increase in alkalinity was also noticed by Kalra et al (2000), Lee et al. (2006) and Yadav and Pandita, (2019). The Indian flyash were found to have alkaline pH , hence it could be applied to used as liming material to neutralization of acidic pH (Yousuf et al.,2020). The reason behind this increase might be due to the neutralization of hygrogen cations by alkali salts (Keller et al., 2020) or precipitation of the cations present in the flyash amended soils (Gupta et al. 2007). The soil pH plays a moajor role in the availability of the minerals for the plants. For example, the availability of the Al is higher at the pH of above 8, at which the Aluminium ions become soluble and becomes toxic to plants. Eventhough Al at higher concentration is toxic to the plants, the pH of the wetland soils is always acidic and hence this nutrient exits in relatively insoluble form.

The Electrical conductivity points out the amount of salts present in the soil. The evaluated soil EC between treatments differed significantly in all the stages of observation, it was interesting to note that significantly more soil EC in Flyash applied plots. The EC of the soil during the active tillering stage was found to be 74 per cent higher in the plots that were treated with Fly ash when compare with the plots in which NPK alone were applied. Decrease in the increment of the EC was also noticed with the progress of the crop. At the maturity stage, the increment in the EC with the application of flyash was only 34 per cent. This shows the dynamics of the soil system in buffering the impact of external material on the nature. The increase in EC of the soil with the application of Fly ash is due to the higher availability of minerals that acts electron carrier to conduct the electrical pulse.

Table 2. Impact of Flyash on the soi pH and EC of the soil.

	SOIL PH		SOIL EC	
	NPK	NPK+ FA	NPK	NPK+ FA
Active Tillering stage	7.9	8.3	0.39	0.67
Panicle Initiation stage	7.9	8.3	0.48	0.70
50% flowering stage	7.8	8.2	0.43	0.61
Maturity stage	7.8	8.2	0.45	0.61

Soil organic carbon (Per cent)

Soil organic carbon content of more the one is very important for better growth of rice fields. Considering this concept soil organic carbon content was estimated. The value was ranging from 0.41 to 0.52 per cent across the four stages of observations made. The mean value between different stages also found to be static rather than dynamic. Whatever might be the role of soil organic carbon in rice soils, the results were statistically non-significant in all the four stages of observation concluding that Flyash had no impact on organic carbon. Similar results were also reported by Lee et al. (2006); Dwivedi et al. (2007).

Soil availability of major nutrients (kg ha^{-1})

The data on percentage increase in availability of major plant nutrients (NPK) depicted in the figure 1. The soil available nitrogen was found ranging from 260.3 to 211.0 kg ha^{-1} . Statistically significance was not obtained between treatments in the four stages studied. In general, from the perusal of the mean data across stages it was found that there was decrease in trend on the available soil nitrogen from active tillering stage to maturity stage. The increment was to the maximum of 5 percent and occurred during the maturity stage of the crop.

The soil available Phosphorus values were found ranged from 17.5 to 34.5 kg ha^{-1}. In all the stages the treatment plots with NPK+FA did exhibit higher soil available Phosphorus when compared with treatment plots with NPK alone. This increase was due to the presence of 23 mg of P per kg of fly ash and was supplied with 4.66 kg of available P per hectare by application of 20 tonnes of flyash ha^{-1}. The increment was between 27 and 39 per cent among the different stages of the rice crop. Also, the presence of higher amount of silicate interacts with the availability of P and enhances its availability (Lee et al., 2007, Schaller et al., 2019, Frank Stephano et al., 2021).

The result of potassium was similar to the results furnished for soil available Phosphorus at active tillering, panicle initiation, 50 per cent flowering and maturity stages. 32 to 46 percent increment in the availability of potassium in the soil was noticed in the treatments with fly ash.

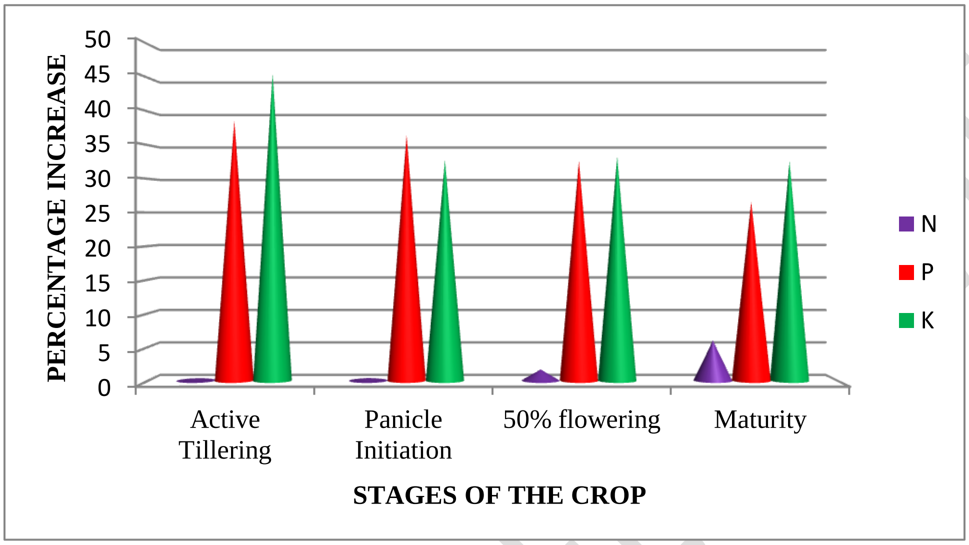

Figure 1 The percentage increase in availability of major nutrients

DTPA Micronutrient availability (mg kg^{-1}):

Significant difference was observed between the treatments evaluated in all the four stages. The observation on mean data revealed that there was a decrease in trend in DTPA nutrients from active tillering to maturity stage. The increment in the amended soils was about 9.7 to 15.6, 5.9 to 18.3, 3.4 to 5.2 and 6.5 to 11.3 per cent of DTPA copper, Zinc, Iron and Manganese (Figure 2).

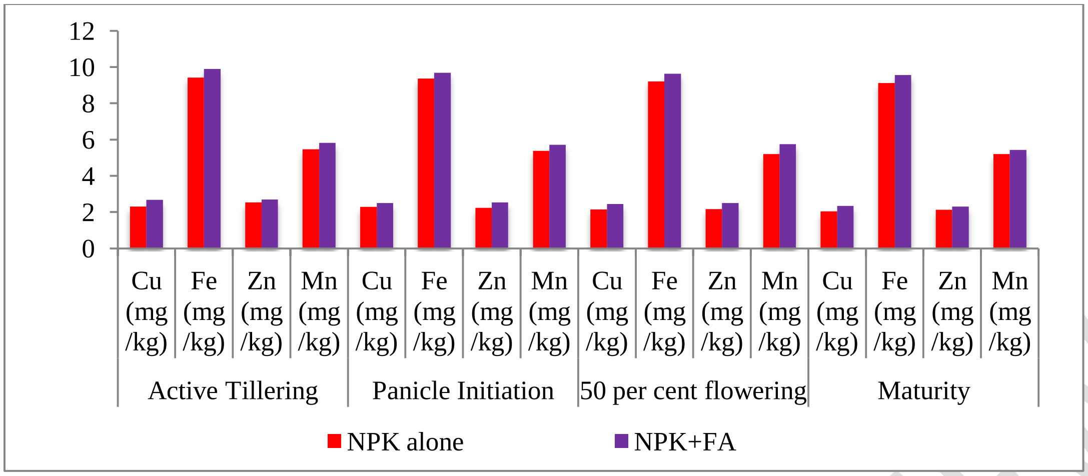

Figure 2 The percentage increase in availability of micro-nutrients

Conclusion :

Flyash is rich in silicate which is an important nutrient in case of rice cultivation and it enhances the availability of other nutrients. Therefore, it could be concluded from the results that a combination of fly ash at 20 t ha^{-1} along with recommended dose of NPK in field experiment would help to increase availability of the major nutrients P and K and micronutrients like Zn, Cu, Fe and Mn in the soil, since fly ash is a mineral of. Hence this increase could improve the yield parameters and hence raising up the yield. Not only increasing the yield but also it would act as overall supplement to other inorganic soil amendments for improving the nutritional balance in the wetland paddy soil as well as economically viable source of nutrients to rice plants hence increasing the Rice yield and inturn enhancing the livelihood of the rice farmers. The use of fly ash in Agriculture and waste land development has large potential.

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