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Improved rice production in acid soil utilizing fly ash

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Abstract
Fly Ash, a waste material from thermal power station is used as a nutrient source in agricultural sector to enhance soil fertility and also as a soil ameliorant. The present investigation was carried out during 2015 – 2016 at Rice Research Station, Ambasamudram, Tamil Nadu to reclaim acidic soil of pH 4.75. The treatments include control, 100% RDF alone, Lime + RDF, Dolomite + RDF, FA @ 10,20,30 and 40 t ha^{-1} along with RDF, 50% Lime + 50% FA + RDF and 50% Dolomite + 50% FA + RDF. The application of 50% Dolomite + 50% Lime + RDF significantly increased the soil reaction (7.08) whereas in case of EC only a small magnitude of increase was observed over control. The highest CEC was observed with 50% Dolomite + 50% FA + RDF (43.1 cmol(p+) kg^{-1}). The addition of FA @ 40 t ha^{-1} recorded higher BS % value of 34.1% which was on par with the treatments receiving 50% Dolomite + 50% FA + RDF, 50% Lime + 50% FA + RDF and Dolomite + RDF with the values of 33.5, 32.6 and 31.4%. The lowest sesquioxide value of 5% was recorded with the application of 50% Dolomite + 50% FA + RDF. The highest grain yield (5.93 t ha^{-1}) and straw yield (6.32 t ha^{-1}) were registered with 50% Dolomite + 50% FA + RDF which was then followed by 50% Lime + 50% FA + RDF (grain yield- 5.72 t $ha^{-1}$and straw yield - 6.10 t ha^{-1}). The application of Fly Ash supplemented with other liming materials like Lime and Dolomite can alleviate soil acidity and enhance soil fertility.

Keywords: Fly ash, dolomite, lime, ameliorant, CEC, base saturation, sesquioxide

Introduction
From the past times, liming has been practised to reclaim acid soils that are problematic for plant growth. Fly ash, a byproduct from thermal power station, is being explored to use it as a potential source for reclaiming acid soil. The liming effects of FA come from the hydrolysis of CaO and MgO, the major constituents of Fly Ash present in it (Adriano *et al.*, 1980). These highly reactive CaO in FA, form hydroxyls of basic cations when reacting with H_2O in soil and thus neutralize soil acidity.
Acid soils are toxic to plant growth with a pH < 6.5. The negative effects of soil acidity on plant productivity include: Al and/or Mn toxicity; H ion toxicity; decreased bioavailability of Mg, Ca, K, P, and Mo concentrations; and inhibition of root growth (Marschner, 1995) [1]. These ill effects of soil acidity can be alleviated by saturating such soil with basic cations. With this background, a field experiment was conducted to study the effect of fly ash in reclaiming acid soil at Rice Research station, Ambasamudram, Tamil Nadu, India where soil was acidic with the pH value of 4.75.

Materials and Methods
A comparative field study was taken up to study the effect of FA and other liming materials like Lime and Dolomite on alleviating soil acidity and improving crop growth and yield. The treatments of this study include, absolute control, 100% RDF alone, Lime + RDF, Dolomite + RDF, FA @ 10, 20, 30 and 40 t/ha + RDF, 50% Lime + 50%FA + RDF and 50% Dolomite + 50% FA + RDF. These 10 treatments (T1 to T 10) were tried in Randomized block design with 3 replications and Rice (variety – ASD 16) was used as test crop. The dosages for Lime, Dolomite and FA were fixed with Ca equivalence using Lime buffer method by shoemaker *et al*. (1961) [3]. The FA used in this study was collected from Tuticorin thermal power station, Tamil Nadu, India and it was found to be alkaline with a pH of 8.6. It was also analysed for other chemical properties. The pH and EC values of the fly ash were 8.6 and 1.7 respectively.

The pH and EC values of the initial soil were observed to be 4.65 and 0.50 respectively. The post harvest soil was analysed for pH (potentiometry), EC (conductometry), CEC (Neutral Normal NH_4OAc) and base saturation and total sesquioxide percentage (HCl Extract Method). The results were statistically analysed using Aggress software at 5% level of significance.

Results and Discussion

Soil pH

The study on effect of FA and other liming materials on soil acidity revealed that the Limed soils were highly significant over the control and the plots receiving 100% RDF alone in case of soil physico-chemical properties. The highest soil pH of 7.08 was recorded with application of 50% Dolomite + 50% FA + RDF followed by 50% Lime + 50% FA + RDF (6.90) (Table.1). The treatment FA @ 40 t ha^{-1} recorded the pH of 6.23 and was on par with the application of Lime + RDF (6.05) and Dolomite + RDF (6.13). This increase in soil pH due to fly ash addition at higher levels might be due to the alkaline nature of FA used. The liming potential of Fly Ash is derived from the hydrolysis of CaO and MgO, the major constituents of Fly Ash. These basic oxides in Fly Ash reacting with water in presence of CO_2 form hydroxyl ions and Carbonates precipitate. These basic hydroxides in turn increase soil pH. The treatment receiving 100% RDF alone recorded lower pH and was on par with control (4.76) with the value of 4.95.

Soil EC

Similarly, the soil EC value gradually increased with increments of Fly ash but was safer. The EC of post harvest soils ranged from (0.54 to 0.75 dS m^{-1}). The presence of large amount of soluble salts in FA might cause such a gradual increase in soil EC. Thus, the lowest EC of 0.54 dSm^{-1} was noted with the control plot (Table.1). In FA amended soils, increasing EC might be due to the dissolution of soluble salts from FA in soil moisture that increases ionic concentration of soil solution.

Soil CEC

From the results of CEC (Figure.1), it is implied that there was a significant increase with increments in FA levels. The application of 50% Dolomite + 50% FA + RDF and 50% Lime + 50% FA + RDF recorded highest CEC value of 43.1 and 42.2 cmol(p^+) kg^{-1}, respectively. This was then followed by FA @ 30 and 40 tha^{-1} (38.1 and 39.4 cmol (p^+) kg^{-1}, respectively) and then by Lime + RDF (35.7 cmol(p^+) kg^{-1}) and Dolomite + RDF (37.1 cmol (p^+) kg^{-1}). The lowest CEC was recorded in control plot with the value of 31.7 cmol (p^+) kg^{-1}.

Base Saturation Percentage

The base saturation percentage of post harvest soil ranged from 23.2 to 34.1%. The highest base saturation percentage of 34.1% was found with FA @ 40 t ha^{-1} followed by 50% Dolomite + 50% FA + RDF (33.5%) and 50% Lime + 50% FA + RDF (32.6%) and Dolomite + RDF (31.4 %) which were on par (Figure.1).This might be due to higher amount of bases present in FA. The lowest base saturation percentage of 23.2 % was noted with the control.

Sesquioxide Percentage

The total sesquioxide percentage had a decreasing trend with increments in FA contrary to other physico-chemical parameters, (Table.2). The initial increase of sesquioxides with FA @ 10 and 20 tha^{-1} might be due to higher amount of sesquioxides in FA, which then with increasing pH with higher levels of FA resulted in lower sesquioxide percentage. The least sesquioxide percentage was observed with the application of 50% Dolomite + 50% FA + RDF with the value of 5.0% which was then followed by 50% Lime + 50%FA + RDF (6.5%), Dolomite + RDF (6.5%) and Lime + RDF (7.5%).

Crop Yield

The highest grain yield (5.93 t ha^{-1}) and straw yield (6.32 t ha^{-1}) were registered with 50% Dolomite + 50% FA + RDF which was then followed by 50% Lime + 50% FA + RDF (grain yield- 5.72 t ha^{-1} and straw yield- 6.10 t ha^{-1}) (Table.3). The lower crop yield with FA at higher levels might be due to formation of physical barrier for root elongation with compaction of FA particles at higher levels. But the yields for FA @ 30 and 40 t ha^{-1} + RDF were not lesser than the control plot and plot receiving 100% RDF alone. The increased yield in limed plots compared to that of control plots is due to increased soil pH, CEC and base saturation with less sesquioxide content.

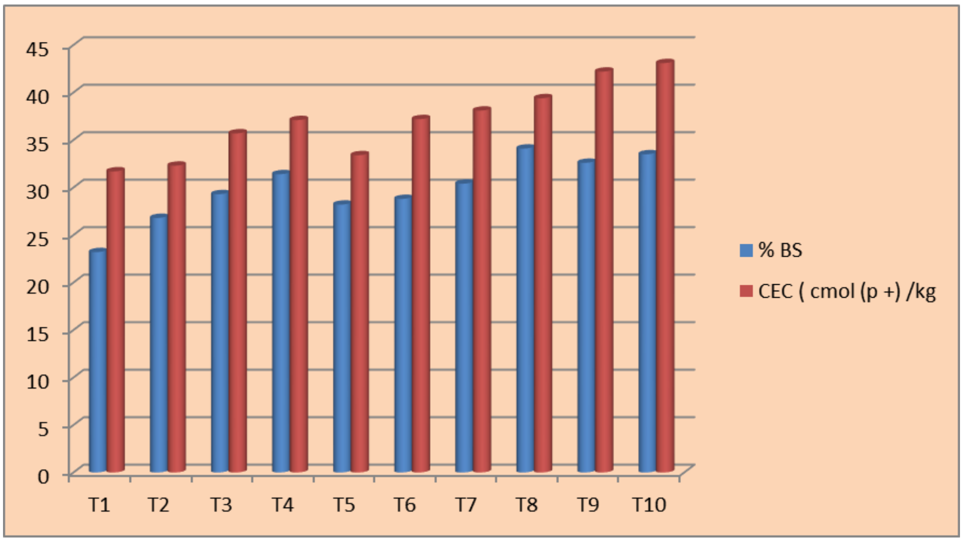

Fig 1: Effect of Fly Ash and other liming materials on CEC (cmol (p^+) kg^{-1}) and %Base Saturation of post harvest soil.

Table 1: Physical, Physico-chemical and Chemical Properties of Fly Ash & Experimental Soil

S. No.	Properties	Fly Ash	Soil
A.	**Physical Properties**		
1.	Particle Size Distribution		
	i. Sand (% w/w)	65.25	61.60
	ii. Silt (% w/w)	26.50	25.00
	iii. Clay (% w/w)	6.25	10.58
2.	Bulk Density (Mg m^{-3})	1.05	1.28
3.	Particle Density (Mg m^{-3})	2.22	2.25
4.	Total Porosity (%)	52.0	45.3
B.	PHYSICO-CHEMICAL PROPERTIES		
1.	pH	8.6	4.75
2.	EC (ds/m)	1.7	0.50
3.	Cation exchange capacity (cmol (p^+) kg^{-1})	20.0	31.0
C.	CHEMICAL PROPERTIES		
1.	Organic carbon (%)	0.30	0.23
2.	Total N (%)	0.003	-
3.	Total P (%)	0.36	-
4.	Total K (%)	0.86	-
5.	Available N (mg kg^{-1})	35.0	185
6.	Available P (mg kg^{-1})	116.0	70.0
7.	Available K (mg kg^{-1})	179.0	230.0
8.	Available Ca (mg kg^{-1})	30.0	12.5
9.	Available Mg (mg kg^{-1})	10.0	4.50
10.	DTPA Fe (mg kg^{-1})	-	20.70
11.	DTPA Mn (mg kg^{-1})	-	10.43
12.	DTPA Zn (mg kg^{-1})	-	0.88
13.	DTPA Cu (mg kg^{-1})	-	0.63

Table 2: Effect of fly ash and other liming materials on soil reaction (pH) and electrical conductivity (dSm^{-1}) of post harvest soil

Treatment	pH	EC (dSm^{-1})
T1	4.76	0.54
T2	4.95	0.69
T3	6.05	0.71
T4	6.13	0.71
T5	5.58	0.67
T6	5.72	0.68
T7	5.83	0.73
T8	6.23	0.75
T9	6.90	0.67
T10	7.08	0.71
Mean	5.92	0.69
SEd	0.34	0.04
CD(p=0.05)	0.72	0.09

Table 3: Effect of fly ash and other liming materials on Sesquioxides % of post harvest soil

Treatments	Sesquioxides %
T1	8.0
T2	10.0
T3	7.5
T4	6.5
T5	13.5
T6	13.0
T7	10.0
T8	9.0
T9	6.5
T10	5.0
Mean	8.9
SEd	0.58
CD(p=0.05)	1.20

Table 4: Effect of fly ash and other liming materials on yield (t ha^{-1}) of rice crop

Treatments	grain (t ha^{-1})	straw (t ha^{-1})
T1	3.84	5.10
T2	4.09	5.27
T3	4.72	5.38
T4	4.97	5.34
T5	5.26	5.45
T6	5.45	5.63
T7	4.63	5.29
T8	4.47	5.20
T9	5.72	6.10
T10	5.93	6.32
Mean	4.9	5.5
SEd	0.29	0.32
CD (p=0.05)	0.61	0.68

Conclusion

The results from the investigations have shown that integrated use of fly ash with Dolomite or Lime and recommended dose of fertilizers (50% Dolomite + 50% FA + RDF and 50% Lime + 50% FA + RDF) could be recommended to reclaim soil acidity which in turn improve fertility status of the soil and maximize the soil productivity. Thus, Fly ash an inorganic soil ameliorant for acid soil will be helpful in reclaiming soil acidity and thus improve crop yield.

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