ISSN 2278-7763

Effect of Integration of Fly Ash with Fertilizers and FYM on Nutrient Availability, Yield and Nutrient Uptake of Rice in Inceptisols of Assam, India.

B. K. Das [a*], B.H.Choudhury[b] and K. N. Das [a]

[a] Department of Soil Science, Assam Agricultural University, Jorhat 785013, Assam, India, E-mail: bedantadas87@gmail.com1 /bh_choudhury@rediffmail.com
[b] Department of Biochemistry, Assam Agricultural University, Jorhat 785013, Assam, India.

ABSTRACT

A field experiments was conducted in *kharif* season 2012 at Instructional Cum Research Farm of Assam Agricultural University, Jorhat on Inceptisols to study the effect of application of fly ash alone and in combination with recommended dose of fertilizers and farm yard manure on yield and uptake of rice, physicochemical properties and nutrient availability of the soil. The results indicated that the treatments which received fly ash @ 5 and 15 t ha^{-1} recorded a yield increase of 23.3% and 32.4%, respectively over absolute control. The highest rice yield (34.1 t ha^{-1}) was recorded in treatment 50% RDF + FYM 5 t ha^{-1} + FA 15 t ha^{-1}. On the other hand, fly ash applied @ 5 t ha^{-1} in combination with RDF 50% + FYM 5 t ha^{-1} produced 40.1% more yield over absolute control. The significant increase in the uptake indicated that fly ash could serve as a source of plant nutrients. Under integrated plant nutrient supply system with fly ash, its effect was well pronounced. The addition of fly ash resulted in significant increase in pH, EC, organic-C, CEC and available nutrient in the post harvest soil.

Key words: Fly ash, FYM, RDF, rice, nutrient uptake, available nutrients.

*Corresponding authors: *E-mail:* bedantadas87@gmail.com1 /bh_choudhury@rediffmail.com

1 INTRODUCTION

The use of chemical fertilizers is the quickest and surest way of boosting crop production. However their cost and other constrains frequently deter farmers from using them in recommended quantities and in balanced proportions. As a consequences of this and other constraints there seems to be no option but to fully exploit potential alternative sources of plant nutrients. Complimentary use of plant nutrients from waste materials along with chemical fertilizers is of great importance for soil productivity *i.e.* soil structure, soil bio-activity, soil exchange capacity and water holding capacity [1].

Fly ash, the inorganic residue from the combustion of powdered coal is a waste material produced in large quantity has already been recognized as a potential source for increasing the availability of mineral nutrients for plant growth [2], [3],[4]. Presence of essential plant nutrients such as N, P, K, Ca, Mg, S and micronutrients make it a source of plant nutrients [5],[6], [7], [8]

ISSN 2278-7763

and increases yield of several crops after application. In combination with various organic manure, fly ash can enhance soil microbial activities, nutrient availability and plant productivity. [9],[10],[11]. Hence the present investigation was undertaken to explore the feasibility of using fly ash as component of Integrated Plant Nutrient System for sustaining soil productivity and crop yield.

2 MATERIALS AND METHOD

2.1 Experimental site and treatment

A fly ash was collected from the dumping sites of Nagaon Paper Mill, Jagiroad, Morigaon, Assam. To determine the effect of the application of fly ash on rice, paddy soils were selected in Instructional Cum Research farm of Assam Agricultural University belonging to inceptisols. The initial characteristics of soil and fly ash are shown in Table 1and Table 2.

Table 1**.** Initial Physical Properties of Soil and Fly Ash.

Properties	Soil	Fly Ash
Sand (%)	44.5	61.3
Silt (%)	32.9	10.4
Clay (%)	21.5	26.2
Textural Class	Loam	Sandy clay loam
BD (g cm^{-3})	1.29	0.57
Particle density (g cm^{-3})	2.01	0.95
Porosity (%)	32.0	31.0
WHC (%)	30.5	78.2
Volume expansion (%)	12.5	30.34

Table 2. Initial Chemical Properties of Soil and Fly Ash.

Properties	Soil	Fly Ash
pH	4.48	5.3
EC ($dScm^{-1}$)	0.138	0.146
OC (%)	0.634	1.73

ISSN 2278-7763

Av- N (kg ha^{-1})	472.1	0.015 (%)
Av- P_2O_5 (kg ha^{-1})	26.8	0.002 (%)
Av- K_2O (kg ha^{-1})	173.9	0.005 (%)
Av- S (ppm)	12.5	37.5
Exch-Ca [c mol(p^+)kg^{-1}]	2.2	4.2
Exch-Mg [c mol(p^+)kg^{-1}]	3.8	34.8
Exch-Na [c mol(p^+)kg^{-1}]	0.51	0.69
Exch-K [c mol(p^+)kg^{-1}]	0.24	0.78
DTPA – Fe (ppm)	98.5	73.9
DTPA – Mn (ppm)	2.09	0.105
DTPA – Zn (ppm)	1.84	0.53
DTPA – Cu (ppm)	0.78	0.287
Fe_d (%)	0.408	0.86
Fe_o (%)	0.129	1.49
Al_d (%)	0.340	4.86
Al_o (%)	0.124	5.66
Total Fe_2O_3 + Al_2O_3 (%)	1.07	12.87

Experimental plots, 21 m^2 (7 m x 3 m) in size, were arranged in a split plot design and each treatment was carried out in triplicate. The main plot treatment included T_1 : control, T_2 : application of 100 % recommended dose of fertilizer (N : P_2O_5 : K_2O :: 60: 20 : 40) (RDF – Recommended Dose of Fertilizers 100 %) and T_3 : application of 50 % RDF + 5 t ha^{-1} farm yard manure (FYM) (50 % RDF + FYM 5 t ha^{-1}). The sub plot treatment included different levels of fly ash *viz.* FA_0 : no fly ash, FA_5 : 5 t ha^{-1} , FA_{10} : 10 t ha^{-1} and FA_{15} : 15 t ha^{-1}. The rice cultivar Mahsuri was selected as test crop and twenty five days old rice seedlings were transplanted in field with 20 x 15 cm^2 spacing. The fly ash was applied into the respective plot 15 days prior to transplanting. The fertilizer and the FYM were applied one day ahead of transplanting. The crop was harvested on 3rd Nov., 2009 after 132 days. Data were recorded for crop yield and other agronomical parameters in 1 m^2 area from three random spots of each plot.

2.2 Chemical analysis

ISSN 2278-7763

Composite soil samples were collected from the Ap horizons (0-15 cm depth) before and after the experiment and air-dried for chemical analysis. The chemical properties of the sieved soils (<2 mm) were determined as follows: pH (1: 2.5 soil : water ratio) and (1:5 fly ash : water ratio); organic carbon [12]; soil texture (International pipette method); CEC [13]; Ca^{2+}, Mg^{2+} Na^{+}, K^{+} (Neutral *N* NH_4OAc extraction) [14]; available N (Alkaline Potassium Permanganate , $KMnO_4$) method [15]; available P_2O_5 -Bray's 1 method [16]; available K_2O-Ammonium Acetate extraction [13]; available S (Turbidimetric method in monocalcium phosphate extract [17]; Fe, Mn, Cu and Zn (DTPA extraction); Free oxides of iron and aluminium were extracted by sodium-dithionite-citrate-bicarbonate buffer solution [18]. The extract was analysed for its Fe content by 0.20% orthophenanthroline method [19]and aluminum content by aluminum method [20].

The rice plants were oven-dried at 70^{o} C for 72 hrs, ground and then digested using H_2SO_4 for the determination of total N. A ternary solution (HNO_3: H_2SO_4:$HClO_4$, 10:1:4 volume/volume) was used for the determination of total P, K, Fe, Mn, Cu, Zn

Statistical analysis

Statistical analysis of experimental data was done by CoStat Professional, Version 6.311, Copyright © 1998-2005 CoHort Software. CoHort Software, 798 Lighthouse Ave, PMB 320, Monterey, CA 93940, USA.

3 RESULTS AND DISCUSSION

3.1 Grain and Straw yield

The results on yield showed that both grain and straw yield of rice (var. Mahsuri) increased significantly over control with RDF 100% and 50% RDF + FYM 5 t ha^{-1}. The highest grain and straw yield was recorded (29.2 q ha^{-1} and 51.0 qha^{-1}, respectively) under the treatment 50% RDF + FYM 5 t ha^{-1} which might be due to favorable soil condition created by application of organic matter along with chemical fertilizers. On the other hand, subsequent increase in doses of fly ash also increased grain yield significantly over control. Similar observation was reported by Selvakumari [21], Yelendhalli *et al.* [22]. The highest grain yield of 30.32 q ha^{-1} was recorded with application of fly ash @ 15 t ha^{-1}. It is noteworthy to observe that application of fly ash increased grain yield by 23.3% with 5 t ha^{-1} to 32.4% with 15 t ha^{-1} of fly ash over control. Kumar *et al.* [23] and Arivazhagan *et al*. [24] also recorded an increase in yield of maize from 36-40%, red gram from 55-58%, mustard from 28-32% and potato from 25-37% over control due to application of fly ash @ 50 t ha^{-1}. On the other hand fly ash applied @ 5 t ha^{-1} in combination with RDF 50% + FYM 5 t ha^{-1} produced 40.1% more yield over absolute control. Similarly, the interaction affect of fly ash and fertilizer level was also found to be statistically significant (Table 3 and 4). Bhople *et al*. [25] also observed that application of fly ash at increasing level in

ISSN 2278-7763

combination with recommended dose of N P K increased the grain and straw yield of paddy. In general, integration of fly ash with inorganic fertilizer and FYM produced considerably higher grain and straw yield than all other treatment combination. Similar observation was reported by Yelendhalli *et al*. [22] and Reddy *et al*. [26]. Selvakumari *et al*. [21] also reported highest yield in rice when fly ash was applied in combination with compost, fertilizer and Azospirillum. The supply of nutrients, conducive physical environment leading to better aeration, increase in soil moisture holding capacity, root activity and nutrient absorption and the consequent complementary effect in fly ash and FYM treated plots would have resulted in higher straw and grain yield of rice. Matte and Kene [27]; Selvakumari *et al.* [21] and Yelendhalli *at al.* [22] reported similar increase in yield due to addition of fly ash in several crops.

Table 3. Effect of Fly Ash, FYM and Inorganic Fertilizer on Grain Yield of rice (q ha^{-1}) var. Mahsuri.

Treatments	**Control**	**RDF 100%**	**RDF 50% + FYM 5 t ha^{-1}**	**Mean**
FA0	18.37	21.83	21.27	**20.49^{d}**
FA 5 t ha^{-1}	22.20	27.23	30.68	**26.70^{c}**
FA 10 t ha^{-1}	23.37	29.07	31.07	**27.72^{b}**
FA 15 t ha^{-1}	25.33	31.53	34.10	**30.32^{a}**
Mean	**22.32^{b}**	**27.42^{a}**	**29.28^{a}**	
LSD (5%)				
RDF			1.81	
FA			0.91	
RDF x FA			0.75	
CV%			6.5	

Table 4. Effect of Fly Ash, FYM and Inorganic Fertilizer on Straw Yield of rice (q ha^{-1}) var. Mahsuri.

ISSN 2278-7763

Treatments	Control	RDF 100%	RDF 50% + FYM 5 t ha^{-1}	Mean
FA0	33.66	41.04	37.61	**37.44^{d}**
FA 5 t ha^{-1}	37.8	47.22	51.47	**45.50^{c}**
FA 10 t ha^{-1}	42.65	51.87	54.77	**49.76^{b}**
FA 15 t ha^{-1}	48.9	54.87	60.23	**54.67^{a}**
Mean	**40.75^{c}**	**48.75^{b}**	**51.02^{a}**	
LSD (5%)				
RDF		0.98		
FA		1.74		
RDF x FA		1.43		
CV%		5.9		

3.2 Nutrient uptake

The effect of RDF and fly ash on uptake of N, P, K and micronutrients (Fe, Mn, Cu and Zn) showed that, their uptake in straw and grain increased significantly over control with 100% RDF and RDF 50% + FYM 5 t ha^{-1} (Table 5 and 6). Addition of chemical fertilizer alone or in combination with FYM resulted in higher available nutrient contents in soil and subsequent uptake of them in increased amount. Similarly it has been seen that uptake of available macro and micro nutrients increased significantly with increasing doses of fly ash (Table 5 and 7). The interaction effect of fertilizer, FYM and fly ash was also statistically significant on uptake of available nutrients. The highest total uptake of N, P, K and Fe, Mn, Zn, Cu (119.22, 73.84 and 209.69 kg ha^{-1} and 3574.9, 1354.3, 180.2 and 104.9 g ha^{-1}, respectively) were recorded in treatment RDF 50% + FYM 5 t ha^{-1} + FA 15 t ha^{-1} and the lowest being 49.01, 27.83 and 53.87 kg ha^{-1} and 546.0, 397.3, 53.1 and 23.1 g ha^{-1}, respectively, in control (Table 7 and 8). The probable root growth, supply of nutrient and conducive physical environment created on account of addition of fly ash in combination with FYM to the soil would have facilitated better absorption of N, P and K. Lanjewar [28], Warambhe *et al*. [29] and Selvakumari *et al.* [21] also observed increased uptake of N, P and K by rice plant due to the application of fly ash.

ISSN 2278-7763

Table 5. Effect of Fly Ash, FYM and Inorganic Fertilizers on uptake of N, P & K (kg ha^{-1}) by rice.

Treatments	N			P			K		
	Straw	**Grain**	**Total**	**Straw**	**Grain**	**Total**	**Straw**	**Grain**	**Total**
				Recommended Dose of Fertilizers					
Control	35.31	29.27	64.58	13.53	22.80	36.33	50.41	25.63	76.01
RDF 100%	46.25	43.76	90.00	19.11	30.14	49.25	72.66	35.00	107.66
RDF 50% + FYM 5 t ha^{-1}	52.29	47.93	100.22	23.27	34.00	57.26	117.60	36.92	154.59
				Fly ash (t ha^{-1})					
FA0	34.98	32.34	67.32	11.85	22.09	33.94	54.75	21.99	76.70
FA 5	44.09	40.41	84.50	19.36	28.12	47.48	72.41	28.20	100.61
FA 10	49.08	42.23	91.31	20.54	30.49	51.04	89.50	35.51	125.01
FA 15	50.31	46.29	96.60	22.78	35.21	57.99	104.24	44.35	148.70
LSD (5%)									
RDF	1.48	2.06	3.19	1.89	1.25	2.65	1.48	2.06	3.190
FA	3.99	1.31	4.26	3.07	1.26	2.89	3.99	1.31	4.26
RDF x FA	1.39	1.95	3.01	1.79	1.18	2.50	1.39	1.95	3.01
CV%	3.81	5.95	4.35	8.26	4.99	6.20	3.81	5.95	4.35

Table 6. Interaction effect of Fly Ash, FYM and Inorganic Fertilizers on Uptake of N, P & K (kg ha^{-1}) by Rice .

Treatments	N			P			K		
	Straw	**Grain**	**Total**	**Straw**	**Grain**	**Total**	**Straw**	**Grain**	**Total**
Absolute Control	27.82	21.20	49.01	9.19	18.64	27.83	38.82	15.15	53.87
RDF 100% + FA0	38.52	36.09	74.61	13.43	25.45	38.88	50.21	27.41	77.62
RDF 50% + FYM 5 t ha^{-1} + FA0	38.59	39.74	78.33	12.94	22.17	35.11	75.22	23.40	98.62
FA 5 t ha^{-1}	32.83	26.72	59.55	13.95	20.46	34.41	44.35	20.37	64.72
RDF 100% + FA5 t ha^{-1}	47.66	45.03	92.69	22.33	27.02	49.35	57.92	29.90	87.83
RDF 50% + FYM 5 t ha^{-1} +	51.79	49.48	101.26	21.81	36.88	58.69	114.95	34.32	149.27

ISSN 2278-7763

FA 5 t ha^{-1}									
FA 10 t ha^{-1}	38.93	33.26	72.19	14.99	24.23	39.22	53.27	28.75	82.02
RDF 100% + FA10 t ha^{-1}	51.49	48.19	99.67	20.02	32.47	52.48	94.73	37.49	132.22
RDF 50% + FYM 5 t ha^{-1} + FA 10 t ha^{-1}	56.82	45.25	102.07	26.62	34.78	61.41	120.49	40.29	160.79
FA 15 t ha^{-1}	41.66	35.89	77.56	15.98	27.86	43.84	65.20	38.23	103.43
RDF 100% + FA15 t ha^{-1}	47.31	45.71	93.02	20.67	35.63	56.30	87.79	45.18	132.98
RDF 50% + FYM 5 t ha^{-1} + FA15 t ha^{-1}	61.96	57.26	119.22	31.69	42.15	73.84	159.73	49.65	209.69
Mean	**44.61**	**39.99**	**84.93**	**18.63**	**28.98**	**47.61**	**80.22**	**32.51**	**112.74**
LSD 0.05									
RDF	1.48	2.06	3.19	1.89	1.25	2.65	1.48	2.06	3.190
FA	3.99	1.31	4.26	3.07	1.26	2.89	3.99	1.31	4.26
FA x RDF	1.39	1.95	3.01	1.79	1.18	2.50	1.39	1.95	3.01
CV%	3.81	5.95	4.35	8.26	4.99	6.20	3.81	5.95	4.35

Table 7. Effect of Fly Ash, FYM and Inorganic Fertilizers on uptake (g ha^{-1}) of Fe, Mn, Zn, Cu by rice.

Treatments	Fe			Mn			Zn			Cu		
	Straw	Grain	Total	Straw	Grain	Total	Straw	Grain	Total	Straw	Grain	Total
Recommended Dose of Fertilizers												
Control	814.60	280.08	1094.68	328.38	204.48	532.85	63.48	7.35	70.83	27.03	6.40	33.38
RDF 100%	1054.70	909.88	1964.55	458.55	282.53	741.08	90.78	11.35	102.15	42.28	10.03	52.30
RDF 50% + FYM 5 t ha^{-1}	1240.48	1123.93	2364.40	548.80	350.63	899.43	104.48	23.33	127.80	51.33	15.05	66.40
Fly ash (t ha^{-1})												
FA0	461.67	212.40	674.03	300.10	187.53	487.63	58.17	9.53	67.70	21.23	6.50	27.73
FA 5	935.50	733.57	1669.07	413.97	256.03	670.00	82.87	12.33	95.20	32.97	9.03	41.97
FA 10	1158.13	881.10	2039.23	460.20	286.93	747.13	92.97	15.23	108.20	43.87	9.97	53.83
FA 15	1591.07	1258.10	2849.17	606.70	386.33	993.03	110.97	18.93	129.93	62.77	16.47	79.23

ISSN 2278-7763

LSD (5%)												
RDF	56.0	82.0	116.0	22.0	11.0	25.0	4.0	1.0	5.0	2.0	0.9	2.0
FA	77.0	83.0	128.0	35.0	13.0	42.0	5.0	1.0	5.0	2.0	0.9	2.0
RDF x FA	53.0	78.0	110.0	21.0	10.0	24.0	4.0	0.9	4.0	2.0	0.8	2.0
CV%	6.3	7.9	7.4	5.8	4.6	4.0	6.0	8.3	5.4	4.5	8.1	4.5

Table 8. Interaction effect of Fly Ash, FYM and Inorganic Fertilizers on Uptake (g ha^{-1}) of Fe, Mn, Zn, Cu by Rice.

Treatments	**Fe**			**Mn**			**Zn**			**Cu**		
	Straw	**Grain**	**Total**	**Straw**	**Grain**	**Total**	**Straw**	**Grain**	**Total**	**Straw**	**Grain**	**Total**
Absolute Control	404.4	141.6	546.0	247.7	149.6	397.3	49.4	3.7	53.1	16.9	6.3	23.1
RDF 100% + FA0	478.4	176.7	655.0	314.2	239.7	553.9	72.5	9.7	82.2	20.5	6.7	27.3
RDF 50% + FYM 5 t ha^{-1} + FA0	502.2	318.9	821.1	338.4	173.3	511.7	52.6	15.2	67.8	26.3	6.5	32.8
FA 5 t ha^{-1}	628.9	238.1	867.0	302.4	203.1	505.5	54.2	6.3	60.5	22.7	4.9	27.5
RDF 100% + FA5 t ha^{-1}	993.9	847.0	1840.9	424.8	262.3	687.1	89.7	13.1	102.8	29.9	10.5	40.3
RDF 50% + FYM 5 t ha^{-1} + FA 5 t ha^{-1}	1183.7	1115.6	2299.3	514.7	302.7	817.4	104.7	17.6	122.3	46.3	11.7	58.1
FA 10 t ha^{-1}	840.0	280.5	1120.5	323.3	217.7	541.0	67.2	10.2	77.4	29.4	7.3	36.7
RDF 100% + FA10 t ha^{-1}	1155.7	1079.2	2234.9	473.7	312.4	786.1	94.9	11.4	106.3	47.4	7.6	55.0
RDF 50% + FYM 5 t ha^{-1} + FA 10 t ha^{-1}	1478.7	1283.6	2762.3	583.6	330.7	914.3	116.8	24.1	140.9	54.8	15.0	69.8
FA 15 t ha^{-1}	1385.1	460.1	1845.2	440.1	247.5	687.6	83.1	9.2	92.3	39.1	7.1	46.2
RDF 100% + FA 15 t ha^{-1}	1590.8	1536.6	3127.4	621.5	315.7	937.2	106.0	11.2	117.3	71.3	15.3	86.6
RDF 50% + FYM 5 t ha^{-1} + FA 15 t ha^{-1}	1797.3	1777.6	3574.9	758.5	595.8	1354.3	143.8	36.4	180.2	77.9	27.0	104.9
Mean	**1026.6**	**781.3**	**1807.9**	**445.2**	**279.2**	**724.5**	**86.2**	**14.0**	**100.2**	**40.2**	**10.5**	**50.7**

ISSN 2278-7763

LSD 0.05												
RDF	56.0	82.0	116.0	22.0	11.0	25.0	4.0	1.0	5.0	2.0	0.9	2.0
FA	77.0	83.0	128.0	35.0	13.0	42.0	5.0	1.0	5.0	2.0	0.9	2.0
FA x RDF	53.0	78.0	110.0	21.0	10.0	24.0	4.0	0.9	4.0	2.0	0.8	2.0
CV%	6.3	7.9	7.4	5.8	4.6	4.0	6.0	8.3	5.4	4.5	8.1	4.5

3.3 Physicochemical properties of soil

There was a significant increased in soil pH from its initial value of 5.38 to a maximum of 6.01 in the post harvest soils due to addition of fly ash (Table 10), while pH observed with 5 and 10 tones of fly ash was at par (Table 9). The interaction effect was also found to be statistically significant. The CaO of the fly ash might have interacted with water in the presence of CO_2 and produced hydroxyl and other ionic forms in the soil solution and the carbonates are precipitates [30],[21]. These reactions and the presence of Na, would explain the high pH value [31],[21]. Pitchel and Hayer [32] also reported increase in pH with the addition of fly ash. It was also reported that uptake of Si by rice would tend to raise the soil pH [32].

Table 9. Effect of Fly Ash, FYM and Inorganic Fertilizers on Soil properties.

Treatments	pH	EC (dS cm^{-1})	Org-C (%)	CEC { cmol (p+) kg^{-1}}	Fe_d (%)	Al_d (%)	Fe_o (%)	Al_o (%)	Total Fe_2O_3 + Al_2O_3 (%)
Recommended Dose of Fertilizers									
Control	5.55	0.14	0.90	7.38	0.57	0.48	0.29	0.28	1.62
RDF100%	5.80	0.17	0.78	7.25	0.56	0.49	0.33	0.31	1.68
RDF 50% + FYM 5 t ha^{-1}	5.84	0.15	0.82	6.78	0.46	0.42	0.45	0.42	1.75
Fly Ash (t ha^{-1})									
FA0	5.73	0.12	0.63	7.00	0.35	0.27	0.14	0.15	0.9
FA5	5.60	0.15	0.77	7.07	0.46	0.4	0.26	0.22	1.34
FA10	5.67	0.16	0.91	7.20	0.55	0.51	0.45	0.42	1.92
FA15	5.91	0.18	1.01	7.27	0.75	0.69	0.57	0.56	2.57
LSD 5%									
RDF	0.13	0.02	0.08	0.58	0.06	0.01	0.04	0.04	0.07

ISSN 2278-7763

FA	0.21	0.03	0.11	0.26	0.08	0.05	0.04	0.03	0.05
RDF x FA	0.26	NS	0.12	0.91	NS	NS	0.09	0.07	0.18
CV%	3.6	5.1	5.6	3.7	6.51	5.64	5.09	3.24	2.88

Table 10. Interaction effect of Fly Ash, FYM and Inorganic Fertilizers on Soil properties.

Treatment	pH	EC (dS cm^{-1})	Org-C (%)	CEC { cmol (p+) kg^{-1}}	Fe_d (%)	Al_d (%)	Fe_o (%)	Al_o (%)	Total Fe_2O_3 + Al_2O_3 (%)
Absolute control	5.38	0.12	0.5	6.6	0.398	0.31	0.109	0.104	0.921
RDF 100% + FA0	5.9	0.11	0.69	7.3	0.381	0.293	0.092	0.095	0.861
RDF 50% + FYM 5 t ha^{-1} + FA0	5.92	0.13	0.7	6.7	0.281	0.193	0.212	0.245	0.931
FA 5 t ha^{-1}	5.46	0.14	0.88	7.2	0.501	0.413	0.222	0.215	1.351
RDF 100% + FA 5 t ha^{-1}	5.49	0.15	0.64	7.2	0.491	0.403	0.202	0.205	1.301
RDF 50 % + FYM 5 t ha^{-1} + FA 5 t ha^{-1}	5.86	0.15	0.79	7	0.393	0.382	0.342	0.245	1.362
FA 10 t ha^{-1}	5.59	0.12	0.98	7.5	0.581	0.493	0.292	0.295	1.661
RDF 100% + FA 10 t ha^{-1}	5.78	0.2	0.84	7.4	0.563	0.552	0.512	0.415	2.042
RDF 50% + FYM 5 t ha^{-1} + FA 10 t ha^{-1}	5.64	0.15	0.91	7.01	0.496	0.483	0.542	0.545	2.066
FA 15 t ha^{-1}	5.78	0.17	1.24	7.6	0.801	0.713	0.522	0.515	2.551
RDF 100% + FA 15 t ha^{-1}	6.01	0.21	0.94	7.3	0.791	0.703	0.502	0.505	2.501
RDF 50% + FYM 5 t ha^{-1}+ FA 15 t ha^{-1}	5.93	0.16	0.86	6.8	0.663	0.639	0.692	0.658	2.652
LSD (5%)									

ISSN 2278-7763

RDF	0.13	0.02	0.08	0.58	0.06	0.01	0.04	0.04	0.07
FA	0.21	0.03	0.11	0.26	0.08	0.05	0.04	0.03	0.05
RDF x FA	0.26	NS	0.12	0.91	NS	NS	0.09	0.07	0.18
CV%	3.6	5.1	5.6	3.7	6.51	5.64	5.09	3.24	2.88

The addition of graded dose of fly ash gradually increased EC values of the soils (Table 9). But no significant difference was observed in EC between FA 5 and FA 10. Increasing EC value of soil is due to addition of fly ash may be attributed to the fact that the soluble salts from fly ash might have dissolved in soil moisture and there by increased the ionic concentration of the soil solution [21].

The organic carbon status of soil was found to be improved significantly with addition of FYM over control, as FYM contains considerable amount of organic matter (Table 9 and 10). .Organic-C increased significantly with every subsequent increase in doses of fly ash over control. It has been seen that soil organic carbon tended to increase significantly when fly ash was applied alone in comparison to fly ash integrated with RDF and FYM (Table 10). This might be due to faster oxidation (decomposition) of fly ash under the influence of chemical fertilizer and FYM [33], which have resulted in accumulation of lower amount of organic matter in contrast to the former.

The DCB-extractable Fe and Al (Fe_d and Al_d) in soil was found to be significantly decreased with RDF 50% + FYM 5 t ha^{-1} over control, while oxalate extractable Fe and Al (Fe_o and Al_o) was affected just reversed. Total Fe_2O_3 + Al_2O_3 followed similar trend of oxalate Fe and Al. on the other hand all these forms of Fe and Al increased significantly at 5 % level of significance with every increment of fly ash.

3.4 Available nutrients

In soil, apart from mineral nitrogen, a major portion of soil nitrogen exist in combination with the organic matter. Only a negligible fraction of soil-N, which is inorganic in form is available to plant. Therefore, organic-N mineralized to inorganic form is then available to plants [34]. The treatment consisting of RDF 50% + FYM 5 t ha^{-1} + FA 5 t ha^{-1} recorded significantly the higher available nitrogen (700.0 kg ha^{-1}) while absolute control showed the lowest (420.0 kg ha^{-1}) (Table 12). Bhoyar [35] reported that application of fly ash @ 15 t ha^{-1} in combination with NPK to black soil had resulted in significant improvement in the content of available nitrogen, phosphorus and potassium. Addition of fly ash at graded levels produced marked variation in available nitrogen content in soil (Table 11). Considerable amount of total N

ISSN 2278-7763

in fly ash might have been sufficient enough to cause distinct increase in the level of available N in the post harvest soil. Rani and Kalpana [36] also reported that application of fly ash to soil increased the nutrient availability such as nitrogen, phosphorus, and other micronutrients.

Table11. Effect of Fly Ash, FYM and Inorganic Fertilizers on available nutrients in soil after harvesting of rice.

Treatments	Available Nutrients (kg ha^{-1})				DTPA (mg kg^{-1})			
	N	P_2O_5	K_2O	S (ppm)	Fe	Mn	Zn	Cu
Recommended Dose of Fertilizers								
Control	483.25	39.90	197.65	22.90	132.59	7.76	2.80	2.43
RDF 100%	638.08	45.85	208.38	26.13	157.37	8.58	4.38	3.09
RDF 50% + FYM 5 t ha^{-1}	591.5	49.23	220.25	25.10	162.82	10.13	6.16	10.25
Fly ash (t ha^{-1})								
FA0	518.67	26.90	164.37	16.47	127.81	7.81	3.27	3.81
FA 5	613.1	44.40	186.97	20.43	152.44	8.70	4.10	4.41
FA 10	586.57	49.47	223.67	25.70	159.03	9.37	5.18	5.05
FA 15	565.43	59.20	260.03	36.23	164.41	9.40	5.22	7.75
LSD (5%)								
RDF	34.4	2.15	3.85	0.99	9.95	0.779	0.493	0.276
FA	36.85	2.38	5.91	1.07	10.96	0.451	0.398	0.300
RDF x FA	26.67	2.24	3.33	1.68	9.036	0.372	0.328	0.248
CV%	5.7	4.5	1.73	3.77	7.33	5.16	9.05	5.77

Table12. Interaction effect of Fly Ash, FYM and Inorganic Fertilizers on available nutrients in soil after harvesting of rice.

Treatment	Available Nutrients (kg ha^{-1})				DTPA micronutrients (mg kg^{-1})			
	N	P_2O_5	K_2O	S (ppm)	Fe	Mn	Zn	Cu
Absolute control	420.0	25.0	157.6	16.4	128.98	7.00	2.48	2.36
RDF 100% + FA0	623.0	27.9	167.1	16.6	127.56	7.66	3.32	2.75
RDF 50% + FYM 5 t ha^{-1} + FA0	513.0	27.8	168.4	16.4	126.90	8.78	4.01	6.31

ISSN 2278-7763

FA 5 t ha^{-1}	533.0	36.8	167.1	19.1	145.78	8.18	3.23	2.42
RDF 100% + FA 5 t ha^{-1}	606.3	47.0	175.7	21.8	145.61	8.54	3.52	4.63
RDF 50 % + FYM 5 t ha^{-1} + FA 5 t ha^{-1}	700.0	49.4	218.1	20.4	165.94	9.38	5.55	6.19
FAS 10 t ha^{-1}	513.3	43.7	217.5	22.7	109.61	7.31	3.19	2.61
RDF 100% + FA 10 t ha^{-1}	699.7	49.4	225.7	27.9	178.47	8.66	5.46	1.22
RDF 50% + FYM 5 t ha^{-1} + FA 10 t ha^{-1}	546.7	55.3	227.8	26.5	189.02	12.15	6.89	11.31
FA 15 t ha^{-1}	466.7	54.1	248.4	33.4	145.99	8.55	2.29	2.34
RDF 100% + FA 15 t ha^{-1}	623.3	59.1	265.0	38.2	177.82	9.44	5.20	3.74
RDF 50% + FYM 5 t ha^{-1} + FA 15 t ha^{-1}	606.3	64.4	266.7	37.1	169.43	10.21	8.18	17.18
Mean	**571.0**	**45.0**	**208.8**	**24.7**	**150.92**	**8.82**	**4.44**	**5.25**
LSD (5%)								
RDF	34.40	2.15	3.85	0.99	9.95	0.779	0.493	0.276
FA	36.85	2.38	5.91	1.07	10.96	0.451	0.398	0.300
RDF x FA	26.67	2.24	3.33	1.68	9.036	0.372	0.328	0.248
CV (%)	5.70	4.50	1.73	3.77	7.33	5.16	9.05	5.77

Data on available phosphorus (Table 11) indicated that the doses of fly ash @ 5 t ha^{-1}, 10 t ha^{-1} and 15 t ha^{-1} increased available P content of soil significantly and the highest value was recorded in treatment RDF 50% + FYM 5 t ha^{-1} + FA 15 t ha^{-1} (Table 12). The available P content of the soils increased with an increase in the quantity of fly ash added due to the high content of available P in the fly ash. The fly ash used in this experiment contained about 45.8 mg kg^{-1} of available P_2O_5 (Table 2) and around 229, 458 and 687 kg ha^{-1} of available P_2O_5 were supplied by the application of 5, 10 and 15 t ha^{-1} fly ash, respectively. Similar trend of increase in P_2O_5 content due to application of graded doses of fly ash was also observed by Lee *et al.* [10]. The favourable effect of fly ash on P availability was ascribed to its effect on biotic activity and the P release via biotic activity. The Si which is present in fly ash would also have played a major role in releasing the P to available pool from the insoluble sources in fly ash as well as soil. Matte and Kene [27] reported similar increase in available P content of soil. Koter *et al.* [37] also observed increase in available P status and they attributed it to the P content of fly ash.

The data in Table 11 revealed that K_2O increased significantly over control in the treatment consisting of RDF 50% + FYM 5 t ha^{-1} blended with various doses of fly ash. The highest significant increase was observed in the treatment RDF 50% + FYM 5 t ha^{-1} + FA 15 t ha^{-1} (266.7 kg ha^{-1}) (Table 12). Similar trend of increase in available K content of soil was reported by

ISSN 2278-7763

Kuchanwar *et al.* [38] and Bhople *et al.* [25]. Positive effect of fly ash addition on potash content of soil was also reported by Warambhe *et al.* [29].

The available S content in post harvest soil was found to be increased in 100% RDF irrespective of doses of fly ash and effect was found to be statistically significant (Table 11). Significant increase in available S was also noticed due to the addition of FYM. The presence of appreciable amount of Ca, Mg and S in the fly ash might be the reason for their increased availability in post harvest soil. Kuchanvar *et al.* [38] and Gangloff *et al.* [39] also reported enhanced availability of secondary nutrients by the addition of fly ash.

The DTPA extractable micronutrients (Fe, Mn, Zn, Cu) were significantly increased with application of RDF 100% and RDF 50% + FYM 5 t ha^{-1} over control. On the other hand, all the DTPA micronutrients increased significantly and consistently with increasing doses of fly ash (Table 11). Rani and Kalpana [36] reported build up of micronutrient cations in soil due to application of fly ash. The interaction affect of RDF and fly ash was also found to be statistically significant (Table 12). Fly ash contains considerable amount of Fe, Mn, Cu and Zn which might have increased the DTPA micronutrients in post harvest soils.

4 CONCLUSION

The result generated from the study showed that fly ash could be a source of plant nutrient and it could be used in any agricultural soil for production of crop. Fly ash integrated with recommended fertilizers and FYM imprinted significant positive effect on availability nutrient in soil, its uptake and crop yield. Keeping in mind the acceptability and ease of application, the treatment consisting of 50% RDF + FYM 5 t ha^{-1} + FA 5 t ha^{-1} was revealed to be the best treatment with respect to availability and uptake of nutrients as well as yield of rice.

REFERENCES

1.Roy, R.N., 1994. In *Fertilisers, Organic manures, recyclable Wastes and Biofertilisers Components of Inteegrated Plant Nutrition.* (ed) H.L.S. Tandon. FDCO, New Delhi. pp 1-11.

2. Mittra, B.N., Karmakar, S., Swain, D.K. and Ghosh, B.C., 2005. Fly ash a potential source of soil amendment and a component of integrated plant nutrient supply system. Fuel 84, 447-1451.

3.Lee, C.H., Lee, Y.B., Lee, H. and Kim, P.J., 2007. Reducing phosphorus release from paddy soils by a fly ash gypsum mixture. Bioresource Technol 98, 1980-1984.

ISSN 2278-7763

4. Pandey, V.C. and Singh, N., 2010. Impact of fly ash incorporation in soil systems. Agriculture Ecosystem and Environment 136, 16-27.

5. Aitken, R.L., Campbell, D.J. and Bell, L.C., 1984. Properties of Australian fly ash relevant to their agronomic utilization. Australian Journal of Soil Research 12, 443

6. Wong, M.H. and Wong, J.W.C., 1989. Germination and seedling growth of vegetable crops in fly ash amended soils. Agriculture Ecosystem and Environment 26, 23-35.

7. Kene, D.R., Lanjewar, S.A., Darange, O.G., Deotale, Y.D. and Chaphale, S.D., 1991. Physical-chemical properties of coal fly ash from thermal power station, Koradi. Journal of Soils and Crops 1, 120.

8. Ko, B.G.,2000 . Effects of fly ash and gypsum application on soil improvement and rice cultivation. Ph.D. Diss. Gyeongsang National University, Chinju (in Korean with English Summary).

9.Sikka, R. and Kansal, B.D., 2000. Effect of flyash application on yield and nutrient composition of rice, wheat and on pH and available nutrient status of soils. Deptt. of soils, PAU, Ludhiana, India.

10. Lee, H., Ha, H.S., Lee, C.H., Lee, Y.B. and Kim, P.J., 2005. Fly ash effect on improving soil properties and rice productivity in Korean paddy soils. Bioresource Technology 97, 1490-1497.

11. Jala, S. and Goel, D., 2006. Fly ash as a soil ameliorant for improving crop production – a review. Boiresourse Technology. 97,1136-1147.

12. Walkley, A. and Black, C.A., 1934. An examination of method for determination of soil organic matter and a proposed modification of the chromic acid titration method. Soil Science 37, 29-38.

13.Jackson, M.L., 1973. Soil chemical analysis. Prentice Hall of India Private Limited, New Delhi.

14. Hesse, P.R. ,1971. A text book of soil chemical analysis. William Clowes and Sons Ltd., London, Beceles and Colchester, London.

15. Subbiah, B.V. and Asija, G.L., 1956. A rapid procedure for the determination of available nitrogen in soils. Current Science 25, 259-260.

16. Bray, R.H. and Kurtz, L.T., 1945. Determination of total organic and available forms of phosphorus in soils. Soil Science 59, 39-45.

17. Ensminger, L.E., 1954. Some factors affecting the adsorption of sulphate by Alabama soils. Proceeding of Soil Science Society of America 18, 259-262.

18. Coffin, D.E. ,1963. A method for the determination of free iron in soil and clays. Canadian Journal of Soil Science 43, 821-822.

19. Mehra, O.P. and Jackson, M.L., 1960. Iron oxide removal from soils and clays by dithionite citrate system buffered with sodium bicarbonate. Clays and Clay Minerals 7, 317-327.

20. Krishna Murti, G.S.R., Sharma, V.A.K. and Rangasoni, P., 1974. Spectrometric determination of aluminium with aluminon. Indian Technology. 12, 270-271.

21. Selvakumari, G., Bhaskar, M., Jayanthi, D. and Mathan, K.K., 2000. Effect of integration of flyash and fertilizers and organic manure on nutrient availability, yield and nutrient uptake of rice on Alfisols. Journal of the Indian Society of Soil Science 48, 268-278.

22. Yelendhalli, N.A., Prakash, S.S., Ravi, M.V. and Narayanarao, K. ,2008. Long term effect of fly ash on crop yield and soil properties. Karnataka Journal of Agricultural Science 21, 507-512.

23. Kumar, V., Singh, G. and Rai, R., 2005. Fly ash : a material for another green revolution. Fly ash utilization programme (FAUP), TIFAC, DST, New Delhi.

24.Arivazhagan, K., Ravichandran, M., Dube, S.K., Mathur, V.K., Khandarkar, R.K., Yagnanaryana, K., Kamal Pasha, M.M., Sinha, A.K., Sarangi, B.D., Tripathi, V.K.M., Gupta, S.K.;,Singh, R., Ali, M., Thakur, A.S. and Narayan, R., 2011. Effect of coal fly ash on agricultural crops : show case project on use of fly ash in agriculture in and around thermal power station areas of national thermal power corporation ltd., India. World of Coal Ash (WOCA) Conference – May 9-12, 2011, in Denver, Co, USA.

25. Bhople, B.S., Bhoyan, S.M. and Nimje, A.M., 2011. Impact of fly ash on physical and chemical properties of black cotton soil and yield of sunflower crop. Journal of Soils and Crops 21(2), 234-238.

ISSN 2278-7763

26. Reddy, T. , Prabhakar, U., Rao, M. and Chandrasekhar, R. 2010. Effect of fly ash and farm yard manure on soil properties and yield of rice grown on an inceptisol. Agricultural Science Digest 30, 281-285.

27. Matte, D.B. and Kene, D.R., 1995. In proceedings of National Seminar on use of lignite fly ash in Agriculture. Annamalainagan, 44-48.

28. Lanjewar, S.A.,1989. M.Sc.(Ag.) Thesis submitted to Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

29. Warambhe, P.E., Kene, D.R., Thakre, K.K., Drange, O.G. and Bhoyan, S.M., 1992. Evaluation of physico-chemical properties of fly ash of thermal power station Koradi (Nagpur) for its likely use in agriculture. Journal of Soils and Crops 2(2), 73-74.

30.Hollis, J.E., Keren, R. and Gal, M., 1988. *Journal of Environment Quality* **17**: 181.

31. Garau, M.A., Dalman, J.L. and Felipo, M.J., 1991. Nitrogen mineralization in soil amended with sewage sludge and fly ash. Biology and Fertility of Soils 12, 199.

32. Pitchel, J.R. and Hayes, J.M., 1998. Effect of compost, coal ash and straw amendments on restoring soil properties. Journal of Environment Quality 19, 593.

33. Brady, N.C., 1995. Nature and Properties of Soil.

34. Maiti, S.K., 2003. Handbook of methods in environment studies, Vol. 1 : Air, Noise and Overburden Analysis, ABD Publishers, Jaipur, India.

35. Bhoyar, S.M. ,1998. Effect of fly ash application on micronutrient status of black soil in multiple cropping systems. Unpublished Ph.D. Thesis, Dr. P.D.K., Akola.

36. Rani, K. and Kalpana, S. ,2010. Utilization in agricultural and related field; a better alternative for ecofriendly maintenance of coal fly ash. Journal of Chemical and Pharmaceutical Resesarch 2(5), 365-372.

37. *Koter, M., Nowak, G. and Czapla, J. ,1984. Effect of coal ashes on the physicochemical properties of the soil. Roczniki glehoznaweze 35, 97.

38. Kuchanwar, O.D.,Matte, D.B. and Kene, D.R., 1997. Effect of fly ash application physico-chemical properties of soil. Journal of Soil and Crops 7(1), 73-75.

ISSN 2278-7763

39. Gangloff, W.J., Ggidratum, M., Sims, J.T. and Vasilas, B.L., 1997. Journal of Environment Quality 26,714.

