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Integrated Effect of Fly ash, Organic Additives and Fertilizers on Yield and Uptake of Rice (*Oryza sativa* L.)

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Abstract: ***Investigation into the effect of fly ash in combination with three organic manures viz., Farm yard manure (FYM), green leaf manure (GLM) and Humic acid (HA) and inorganic fertilizers on the yield and uptake of rice was studied. The test crop was rice variety (ADT 49). Field experiment was conducted during 2014-15 in Krishi Vigyan Kendra, Tirur. Fly ash generated from Mettur Thermal Power Station was selected for the study and examined for its physical and chemical properties. Analysis of fly ash revealed that it is neutral to alkaline (pH 8.1) in reaction. The results confirmed that fly ash contains all the essential elements required for the plant growth as that of soil except organic carbon and nitrogen. It was observed that fly ash (@ 20 t ha^{-1}) + GLM (@ 6.25 t ha^{-1}) with RDF (150:50:50) supported maximum growth, yield and uptake. The treatment which received fly ash + GLM with RDF (150:50:50) recorded the highest grain (5.49 t ha^{-1}) and straw yield (6.59 t ha^{-1}). The highest nutrient uptake by the grain and straw were observed under the treatment of fly ash+ GLM with RDF. Thus the integrated effect of fly ash, manures and fertilizer was well pronounced in improving the productivity of rice.***

Keywords: fly ash, FYM, GLM, HA, rice, yield uptake

1. Introduction

In India, more than 70 per cent of energy needs are met by coal based thermal power plants (Merajul *et al.,* 2010). Burning of coal produces huge quantity of fly ash. Chemically, fly ash contains oxides, hydroxides, carbonates, silicates, and sulfates of calcium, iron, aluminum, and other metals in trace amount (Adriano *et al.,* 1980). The mineralogical, physical and chemical properties of fly ash depend on the nature of the parent coal, conditions of combustion, type of emission control devices and storage and handling methods. Formation of fly ash depends on the ash content of coal and Indian coal used in power plants generally has very high ash content (35–45%) and is of lower quality (Mathur *et al.*, 2003). Presence of essential plant nutrients such as N, P, K, Ca, Mg, S and micronutrients make it a source of plant nutrients and increases yield of several crops after application. Fly ash increased the yield in various crops by 20-25 % with high nutritional value and found beneficial for soil and crop when it was applied in minimal quantity (Yavarzadeh *et al*., 2012).

Rice is the staple food for majority of the population in the world. In south India, rice is the major food grain, which is cultivated under wet conditions. Recent high yielding rice varieties remove huge quantity of nutrients from the soil and hence to sustain rice productivity, these nutrients are to be replaced through fertilizers. Utilization of fly ash in rice farming as a source of nutrient will help to sustain rice productivity. However, a proper management strategy has to be developed to abate the land pollution from the dumping of fly ash. Hence, with a view to study the possibility of using fly ash as a component of integrated plant nutrient supply system in rice crop, the present study was initiated.

2. Materials and Methods

In the present experiment, Mettur Thermal Power plant was selected as a source of fly ash. The properties of the fly ash were completely studied. The experiment was designed with split plot design replicated three times with four main plot treatments and seven sub plot treatments. In main plot fly ash (FA) @20 t ha^{-1} was applied along with different organics namely Farm Yard Manure (FYM), humic acid (HA) and Green Leaf Manure (GLM - *Glyricidia*), (M_0 – FA alone; M_1 - FA + FYM (@12.5 t ha^{-1}); M_2 - Fly ash + HA (@15 liters ac^{-1}); M_3 - Fly ash + GLM (@ 6.25 t ha^{-1})). The sub plot treatments comprised of fertilizer treatments as listed: S_0 – No Fertilizer; S_1 – 100 % RDF (150:50:50) kg NPK + $ZnSO_4$ @ 25 kg ha^{-1}+ $FeSO_4$ @ 50 kg ha^{-1}; S_2 – NP + $ZnSO_4$ + $FeSO_4$; S_3 – NP + 50% K + $ZnSO_4$ + $FeSO_4$; S_4 – NPK + $ZnSO_4$; S_5 - NPK + $FeSO_4$; S_6 – NPK. The fly ash was quantified and applied as a basal dose ten days before transplanting. The GLM and FYM were applied one week before transplanting. The calculated quantity of N, P and K was applied as basal and N and K were applied in three equal splits. The crop was harvested at maturity stage and the yield (grain and straw) and nutrient uptake was recorded.

3. Results and Discussion

Characteristics of fly ash
The fly ash was neutral in soil reaction and non saline. Particle size analysis evinced its texture as silt loam. The physical properties *viz.*, bulk density, particle density, porosity and water holding capacity were 1.24 (Mg m^{-3}), 1.99 (Mg m^{-3}), 42 per cent and 33 per cent respectively. With reference to the CEC, fly ash recorded 2.1 c mol (p^{+}) kg^{-1} and organic carbon was found to be very low (0.01 per cent). The fly ash were analysed chemically for the total N, P, K, micronutrients and heavy metal content. The total N

content of the fly ash was found to be very low (0.04 per cent). With regard to the total P content, fly ash recorded (0.22 per cent) and the total K was comparatively high (0.51 per cent) among three macro nutrients. The analytical results of DTPA extractable micronutrients *viz.*, Zn, Fe, Cu and Mn were 6.8, 17.0, 1.5 and 1.3 mg kg^{-1} respectively. Regarding the total heavy metals, the content of Cr was 2.1 mg kg^{-1}, Pb 2.6 mg kg^{-1} and 1.1 mg kg^{-1} Cd.

Characteristics of soil

The pH of the experimental soil was slightly alkaline in reaction and non saline. The textural analysis revealed that it is silty clay loam in nature. The physical properties *viz.*, bulk density, particle density, porosity and water holding capacity were 1.35 (Mg m^{-3}), 2.64 (Mg m^{-3}), 47.3 per cent and 40.1 per cent respectively. The organic carbon status was medium and the exchange reactions of soil in respect of cations were 13.4 cmol (p^+) kg^{-1}. The available nutrient status of soil with respect to N, P and K showed high K, medium P and low N.

Nutrient Composition of the Manures used

FYM contained 0.97 per cent N, 0.58 per cent P and 0.72 per cent K, GLM contained 2.76 per cent N, 0.28 per cent P and 4.6 per cent K, HA contained 3.5 per cent N, 1.5 per cent P and 2.1 per cent K.

Grain Yield

On perusal of grain yield data, the fly ash + GLM recorded the maximum yield. The grain yield was ranged from 4.0 to 5.84 t ha^{-1}. The highest mean yield of 5.49 t ha^{-1} was recorded by the addition of fly ash + GLM which might be due to the favorable soil condition created by the fly ash with manures and fertilizers (Das *et al.*, 2013). The application of fertilizers in varied levels also recorded corresponding increase in yield. The highest mean yield of 5.20 t ha^{-1} was recorded by the application of RDF. The least grain yield of 4.60 t ha^{-1} was recorded in no fertilizer treated plots.

The interaction of treatments with varied levels of fertilizers was significant. The highest grain yield of 5.84 t ha^{-1} was recorded by the addition of RDF with fly ash + GLM. Mittra *et al.* (2003) also reported that fly ash in combination with organic sources and fertilizers increased the grain yield of rice by 31% as compared to the chemical fertilizers alone. The interaction of fly ash and manures in combination with the fertilizer meets the crop demand sufficiently (Arivazhagan *et al.*, 2011). Selvakumari *et al.* (2001) 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. Selvakumari *et al.* (2001) and Yelendhalli *at al.* (2008) reported similar increase in yield due to addition of fly ash in several crops.

Straw Yield

The straw yield was ranged from 5.10 to 6.95 t ha^{-1}. Among the manurial treatments, fly ash + GLM registered the higher yield of (6.59 t ha^{-1}). Among the fertilizers in varied levels, application of RDF recorded 6.21 t ha^{-1} of straw yield. Interaction of varied levels of fertilizers with different treatments showed a significant variation in straw yield. Maximum straw yield of 6.95 t ha^{-1} was recorded due to the application of RDF with fly ash + GLM. The treatment fly ash + GLM had superiority over other treatments at all levels of fertilizers in terms of straw yield. Similar results were observed by Arivazhagan *et al.* (2011). Among the varied levels of fertilizers, RDF markedly increased the straw yield. The results were in line with the findings of Suhas *et al.* (2014).

Table 1: Effect of fly ash, manures and fertilizers on yield (t ha^{-1}) of rice crop

Treatments	Grain					Straw				
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean
S_0	4.01	4.78	4.48	5.13	**4.60**	5.10	6.02	5.51	6.32	**5.73**
S_1	4.47	5.57	4.95	5.84	**5.20**	5.38	6.67	5.84	6.95	**6.21**
S_2	4.31	5.20	4.84	5.63	**4.99**	5.00	6.41	5.46	6.61	**5.87**
S_3	4.39	5.41	4.89	5.72	**5.10**	5.42	6.57	5.59	6.83	**6.10**
S_4	4.26	5.32	4.68	5.47	**4.93**	5.07	6.21	5.34	6.45	**5.76**
S_5	4.21	5.25	4.52	5.39	**4.84**	5.32	6.17	5.12	6.51	**5.78**
S_6	4.18	5.18	4.50	5.30	**4.79**	5.20	6.06	5.30	6.46	**5.75**
Mean	**4.26**	**5.24**	**4.69**	**5.49**	**4.92**	**5.21**	**6.30**	**5.45**	**6.59**	**5.88**

	Grain SE d	Grain CD (P = 0.05)	Straw SE d	Straw CD (P = 0.05)
Main Plot	0.6	1.6	0.5	1.7
Sub Plot	0.5	1.0	0.9	1.8
M at S	1.1	2.4	1.8	3.9
S at M	1.0	2.0	1.7	3.8

Effect of Fly Ash, Manures and Fertilizers on Nutrient Uptake

Nitrogen Uptake

Application of fly ash with GLM increased the N uptake. The highest N uptake by grain (71.41 kg ha^{-1}) and straw (28.87 kg ha^{-1}) was recorded in fly ash + GLM treatment and the least was in fly ash alone 50.40 kg ha^{-1} by grain and 22.67 kg ha^{-1} by straw. The increased uptake with the addition of manures was statistically significant. Among the fertilizer treatment RDF registered highest N uptake of 63.25 and 26.4 kg ha^{-1} in the grain and straw respectively. The lowest N uptake of 59.61 kg ha^{-1} by grain and 25.07 kg ha^{-1} by straw was recorded in the no fertilizer treatment.

Among the interaction effect, fly ash + GLM with RDF recorded the highest N uptake 73.40 kg ha^{-1} and 29.50 kg ha^{-1} by the grain and straw respectively. The lowest N uptake of

48.75 kg ha^{-1} and 22.20 kg ha^{-1} was recorded in the fly ash alone and control (no fertilizer) treated plots. The N uptake was statistically significant among the interaction of manures with fertilizers. The fly ash would have stimulated the microbial activity by providing all the nutrients which in turn mobilized the native N. The above results corroborated with the findings of Tripathi *et al.* (2009). Application of RDF recorded the highest N uptake in straw and grain. The results are in agreement with the findings of Thanunathan *et al.* (2001). Thus the interaction of fly ash and GLM with RDF registered the highest uptake of N in grain and straw. The results were in line with the findings of Das *et al.* (2013).

Table 2: Effect of fly ash, manures and fertilizers on N uptake (kg ha^{-1}) of rice crop

Treatments	Grain					Straw				
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean
S_0	48.75	64.15	57.00	68.55	**59.61**	22.20	25.95	23.95	28.20	**25.07**
S_1	51.55	55.40	61.65	73.40	**63.25**	23.30	27.35	25.45	29.50	**26.40**
S_2	51.25	65.30	60.95	71.95	**62.36**	22.80	27.15	25.65	29.00	**26.15**
S_3	51.25	65.80	60.70	72.60	**62.58**	22.95	27.40	24.70	29.25	**26.07**
S_4	50.80	65.75	60.45	71.35	**62.08**	22.55	27.25	24.45	29.00	**25.81**
S_5	50.25	65.50	60.05	71.15	**61.73**	22.50	26.25	24.25	28.75	**25.43**
S_6	49.60	65.05	58.85	70.90	**61.10**	22.45	25.85	24.45	28.45	**25.30**
Mean	**50.49**	**65.42**	**59.95**	**71.41**	**61.81**	**22.67**	**26.74**	**24.70**	**28.87**	**25.75**
	SE d			CD (P = 0.05)		SE d		CD (P = 0.05)		
Main Plot	0.13			0.43		0.08		0.27		
Sub Plot	0.14			0.29		0.12		0.25		
M at S	0.30			0.69		0.24		0.54		
S at M	0.28			0.59		0.24		0.51		

Phosphorus Uptake

Similar to the uptake of N, the uptake of P was also observed in same trend where the uptake was higher in the grain when compared to the straw. Among the manurial treatments, fly ash + GLM had the highest P uptake of 15.22 kg ha^{-1} in grain and 8.96 kg ha^{-1} in straw followed by fly ash + FYM scored 14.38 kg ha^{-1} in grain and 8.57 kg ha^{-1} in straw. The lowest P uptake of 7.34 kg ha^{-1} in grain and 5.35 kg ha^{-1} in straw was recorded in unmanured (fly ash alone) treatment. With regard to the varied levels of fertilizers, the application of RDF recorded the highest uptake of 13.05 kg ha^{-1} in grain and straw (7.77 kg ha^{-1}), in the control (no fertilizer) P uptake was decreased to 7.38 kg ha^{-1}. With regard to the interaction of fly ash, manures and fertilizers, the treatment fly ash + GLM with RDF registered highest N uptake of 16.25 kg ha^{-1} and 9.14 kg ha^{-1} by the grain and straw and the least uptake of 6.80 kg ha^{-1} and 5.24 kg ha^{-1} was observed in the fly ash with no fertilizer treatment. The interaction between different treatments integrated with varied levels of fertilizers was not statistically significant in terms of N uptake by grain but the case was significant for straw. Urvashi *et al.*, (2007) also recorded similar results where the P release from fly ash was high when it was combined with organic manures. Application of RDF recorded the highest P uptake followed by RDF with 50% K. The results are in line with the findings of Singh and Raunaq (2012). Interaction of fly ash and manures with RDF resulted in highest P uptake. The results corroborated with the findings of Das *et al.* (2013).

Table 3: Effect of fly ash, manures and fertilizers on P uptake (kg ha^{-1}) of rice crop

Treatments	Grain					Straw				
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean
S_0	6.80	13.50	12.30	15.15	**11.93**	5.24	8.41	7.44	8.45	**7.38**
S_1	7.55	15.05	13.35	16.25	**13.05**	5.47	8.65	7.84	9.14	**7.77**
S_2	7.50	14.55	13.05	16.05	**12.78**	5.41	8.63	7.81	9.08	**7.73**
S_3	7.50	14.80	13.15	16.31	**12.94**	5.42	8.64	7.63	9.11	**7.70**
S_4	7.45	14.50	12.85	15.80	**12.65**	5.32	8.62	7.64	9.05	**7.65**
S_5	7.35	14.35	12.70	15.60	**12.50**	5.30	8.57	7.67	9.02	**7.64**
S_6	7.25	13.95	12.65	15.40	**12.33**	5.27	8.51	7.41	8.90	**7.52**
Mean	**7.34**	**14.38**	**12.86**	**15.22**	**12.45**	**5.35**	**8.57**	**7.63**	**8.96**	**7.63**
	SE d			CD (P = 0.05)		SE d		CD (P = 0.05)		
Main Plot	0.35			1.11		0.011		0.036		
Sub Plot	0.50			NS		0.017		0.035		
M at S	0.99			NS		0.03		0.07		
S at M	1.0			NS		0.03		0.07		

Potassium Uptake

Application of fly ash + GLM recorded the highest mean K uptake 7.52 kg ha^{-1} in grain and 90.32 kg ha^{-1} in straw. With regard to varied level of fertilizers, RDF treatment showed a marked and highest level of K uptake by the grain (6.72 kg ha^{-1}) and straw (72.86 kg ha^{-1}). In the control plot the K uptake was low in both (5.72 kg ha^{-1}) grain and straw (70.86 kg ha^{-1}). With regard to the interaction effect, application of fly ash + GLM with RDF recorded highest K uptake of 7.90 kg ha^{-1} and 91.40 kg ha^{-1} by the grain and straw. The lowest value of 3.75 kg ha^{-1} and 33.35 kg ha^{-1} was recorded in the fly ash without manure and fertilizer. The interaction of graded level of fertilizers with different manurial treatments was not statistically significant in grain uptake of K. The results were in line with the findings of Balasubramaniam (2003). 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 (Das *et al.*, 2013).

Table 4: Effect of fly ash, manures and fertilizers on K uptake (kg ha^{-1}) of rice crop

Treatments	Grain					Straw				
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean
S_0	3.75	6.35	5.55	7.25	**5.72**	33.35	85.40	75.35	89.35	**70.86**
S_1	4.90	7.40	6.70	7.90	**6.72**	35.80	87.85	76.40	91.40	**72.86**
S_2	4.25	6.65	6.25	7.25	**6.10**	34.85	86.55	76.05	90.25	**71.92**
S_3	4.80	7.25	6.55	7.80	**6.60**	35.30	87.60	76.25	90.90	**72.51**
S_4	4.35	7.10	6.25	7.55	**6.31**	35.15	86.75	76.25	90.15	**72.07**
S_5	4.25	7.05	6.35	7.60	**6.31**	35.10	86.45	76.20	90.15	**71.97**
S_6	4.30	6.70	6.10	7.35	**6.11**	34.85	86.10	75.80	90.05	**71.70**
Mean	**4.37**	**6.92**	**6.25**	**7.52**	6.26	**34.91**	**86.67**	**76.04**	**90.32**	**71.98**
	SE d		CD (P = 0.05)			SE d		CD (P = 0.05)		
Main Plot	0.03		0.10			0.05		0.016		
Sub Plot	0.07		0.14			0.07		0.15		
M at S	0.13		NS			0.15		0.33		
S at M	0.14		NS			0.15		0.31		

Micronutrients Uptake

Zn Uptake

The uptake of Zn in grain and straw were assessed at the harvest stage of the crop. The Zn uptake was increased with the manurial application. Among the main treatments the application of fly ash + GLM showed the highest Zn uptake of 155.9 g ha^{-1} in grain and 237.3 g ha^{-1} in straw followed by fly ash + FYM registered 150.7 g ha^{-1} in grain and 222.5 g ha^{-1} in straw. The unmanured treatment (fly ash alone) recorded the lowest Zn uptake of 83.2 g ha^{-1} in grain and 120.7 g ha^{-1} in straw. The varied levels of fertilizer have increased the uptake of zinc, among which the RDF treated plots showed a highest Zn uptake in grain (135.2 g ha^{-1}) and straw (203.6 g ha^{-1}). The least uptake of 126.1 g ha^{-1} in grain and 193.3 g ha^{-1} in straw was observed in control (without fertilizer). In the interaction effect, fly ash + GLM with RDF showed highest Zn uptake of 159 g ha^{-1} and 239 g ha^{-1} by the grain and straw respectively. The progressive and significant increase in the Zn uptake was noticed by the application of manurial treatments with different levels of fertilizer and its interaction was statistically significant in both grain and straw.

Table 5: Effect of fly ash, manures and fertilizers on Zn uptake (g ha^{-1}) of rice crop

Treatments	Grain					Straw				
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean
S_0	77.0	143.0	134.0	150.5	**126.1**	111.5	219.0	212.5	230.5	**193.3**
S_1	88.0	154.5	139.5	159.0	**135.2**	127.0	227.5	220.5	239.5	**203.6**
S_2	84.5	152.5	138.0	156.5	**132.8**	124.5	222.0	218.5	237.5	**200.6**
S_3	85.5	153.0	137.5	157.0	**133.2**	124.0	222.0	219.0	238.5	**200.8**
S_4	86.0	153.0	138.0	158.5	**133.8**	123.5	225.5	221.0	240.5	**202.6**
S_5	82.0	149.5	135.0	155.5	**130.5**	118.5	221.0	218.0	237.5	**198.7**
S_6	80.0	150.0	134.5	154.5	**129.7**	116.5	220.5	217.0	237.5	**197.8**
Mean	**83.2**	**150.7**	**136.6**	**155.9**	**131.6**	**120.7**	**222.5**	**218.0**	**237.3**	**199.6**
	SE d		CD (P = 0.05)			SE d		CD (P = 0.05)		
Main Plot	0.19		0.60			0.41		1.32		
Sub Plot	0.39		0.81			0.51		1.05		
M at S	0.75		1.60			1.03		2.3		
S at M	0.78		1.62			1.02		2.1		

Copper Uptake

Application of fly ash and manures with varied levels of fertilizers increased the uptake of Cu by the grain and straw. The uptake of Cu recorded by the fly ash + GLM (70.16 g ha^{-1}) was the highest uptake by the grain and straw (90.30 g ha^{-1}), followed by fly ash + FYM (68.70 g ha^{-1}) in grain and (89.88 g ha^{-1}) in straw. The fly ash alone treated plots showed a decreased level of 33.4 g ha^{-1} in grain and 49.57 g ha^{-1} in straw. The manurial treatments showed a marked increase in the Cu uptake due to the application of fly ash and manures. Regarding the varied levels of fertilizers the highest Cu uptake in the RDF treatment was 50.95 g ha^{-1} in grain and 79.15 g ha^{-1} in straw and the zero level fertilizers registered the least uptake of 58.20 g ha^{-1} and 76.58 g ha^{-1} in grain and straw respectively. With respect to interaction effect, application of fly ash + GLM with RDF registered a highest level of Cu uptake of 71.35 g ha^{-1} and 91.50 g ha^{-1} by the grain and straw respectively. The least Cu uptake of 32.25 g ha^{-1} by grain and 49.10 g ha^{-1} by straw was showed by fly ash without manure and fertilizer treatment. The treatment fly ash + GLM along with RDF had superiority over the other treatments in all the varied levels of fertilizers in terms of Cu uptake.

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Table 6: Effect of fly ash, manures and fertilizers on Cu uptake (g ha^{-1}) of rice crop

Treatments	Grain					Straw				
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean
S_0	32.25	68.60	63.75	68.20	**58.20**	49.10	87.80	80.40	89.05	**76.58**
S_1	34.05	69.25	65.15	71.35	**50.95**	50.05	90.60	84.45	91.50	**79.15**
S_2	33.85	68.80	64.85	70.75	**59.56**	49.65	90.15	84.05	90.65	**78.62**
S_3	33.75	68.95	64.50	70.55	**59.43**	49.45	90.25	83.65	90.45	**78.45**
S_4	33.45	68.70	64.25	70.75	**59.28**	49.80	90.65	84.30	91.05	**78.95**
S_5	33.50	68.70	64.30	70.05	**59.13**	49.50	89.90	84.05	90.15	**78.40**
S_6	33.25	67.95	64.05	69.50	**58.68**	49.45	80.85	83.05	89.30	**77.91**
Mean	**33.44**	**68.70**	**64.40**	**70.16**	**59.18**	**49.57**	**89.88**	**83.42**	**90.30**	**78.29**
	SE d		CD (P = 0.05)			SE d		CD (P = 0.05)		
Main Plot	0.11		0.36			0.03		0.9		
Sub Plot	0.11		0.24			0.05		0.1		
M at S	0.24		0.56			0.1		0.2		
S at M	0.23		0.48			0.1		0.2		

Iron Uptake

The uptake of Fe in rice varied greatly. In the grain and straw the uptake ranged from 0.475 to 0.597 kg ha^{-1} and 2.2 to 2.58 kg ha^{-1} respectively. The highest uptake was observed in straw (2.5 kg ha^{-1}) and in grain (0.594 kg ha^{-1}) with fly ash + GLM application. The fly ash alone treatment registered the least uptake of 0.482 kg ha^{-1} and 2.2 kg ha^{-1} in grain and straw respectively. Application of RDF favoured the highest Fe uptake of 0.55 kg ha^{-1} in grain and 2.4 kg ha^{-1} in straw followed by RDF excluding K in grain and straw of 0.549 kg ha^{-1} and 2.44 kg ha^{-1} and the other fertilizer treatment also revealed the nearest range of Fe uptake. The zero level fertilizers registered the uptake of 0.54 and 2.44 kg ha^{-1} in grain and straw respectively. The varied levels of fertilizers did not display any significant variation. The interaction between manurial treatments and fertilizers was not significant.

Table 7: Effect of fly ash, manures and fertilizers on Fe uptake (g ha^{-1}) of rice crop

Treatments	Grain					Straw				
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean
S_0	475	566	538	591	**542**	2202	2501	2487	2574	**2441**
S_1	488	572	546	597	**551**	2208	2510	2493	2582	**2448**
S_2	486	571	544	596	**549**	2207	2510	2492	2580	**2447**
S_3	486	571	543	595	**549**	2206	2509	2491	2579	**2446**
S_4	480	570	540	591	**545**	2205	2507	2490	2578	**2445**
S_5	484	662	543	595	**571**	22.07	2509	2492	2580	**2447**
S_6	479	570	539	591	**545**	2204	2506	2464	2577	**2438**
Mean	**482**	**583**	**542**	**594**	**550**	**2205**	**2507**	**2487**	**2579**	**2444**
	SE d		CD (P = 0.05)			SE d		CD (P = 0.05)		
Main Plot	9.11		28.9			2.38		7.5		
Sub Plot	12.09		NS			3.46		7.1		
M at S	24.17		NS			6.85		NS		
S at M	24.18		NS			6.93		NS		

Manganese Uptake

The uptake of Mn in the grain and straw revealed that the application of different treatments increased significantly. On revealing the results of Mn uptake in grain and straw, the values are ranged from 0.28 to 0.42 kg ha^{-1} and 1.1 to 1.28 kg ha^{-1} respectively. Among the treatments, fly ash + GLM showed the highest Mn uptake in grain and straw of 0.4 and 1.2 kg ha^{-1} respectively. The uptake of Mn was found to be very low in fly ash alone treatment.

With regard to the varied fertilizer level, the RDF application revealed the highest Mn uptake in grain (0.37 kg ha^{-1}) as well as in straw (1.24 kg ha^{-1}). The control (without fertilizer) registered a least uptake of 0.35 kg ha^{-1} in grain and 1.23 kg ha^{-1} in straw. Application of fly ash + GLM with RDF recorded the highest uptake of 422 g ha^{-1} and 1280 g ha^{-1} by the grain and straw respectively. Among the interactions, the lowest Mn uptake was shown in the fly ash alone without fertilizer treatment. The main treatments interaction with the varied levels of fertilizers showed that the effect was significant.

Table 8: Effect of fly ash, manures and fertilizers on Mn uptake (g ha^{-1}) of rice crop

Treatments	Grain					Straw				
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean
S_0	286.0	377.0	367.5	393.0	**355.8**	1178.5	1242.5	1235.5	1272.5	**1232.2**
S_1	297.5	400..5	380.5	422.0	**375.1**	1185.0	1259.5	1253.0	1280.5	**1244.5**
S_2	295.5	397.5	377.5	418.5	**372.2**	1184.0	1257.5	1248.5	1277.0	**1241.7**
S_3	295.0	396.0	377.5	418.5	**371.7**	1181.5	1257.5	1248.5	1275.5	**1240.7**
S_4	294.5	396.0	379.5	420.0	**372.5**	1183.0	1256.0	1250.0	1277.0	**1241.5**
S_5	291.5	394.0	375.0	416.5	**369.2**	1181.0	1256.5	1246.0	1275.0	**1239.6**
S_6	290.5	390.0	370.5	405.5	**364.1**	1178.5	1255.5	1244.5	1274.0	**1238.1**
Mean	**292.9**	**393.0**	**375.4**	**413.4**	**368.6**	**1181.6**	**1255.0**	**1246.5**	**1275.9**	**1239.7**
	SE d		CD (P = 0.05)			SE d		CD (P = 0.05)		
Main Plot	0.85		2.7			0.58		1.8		
Sub Plot	0.76		1.5			0.5		1.1		
M at S	1.6		3.8			1.1		2.7		
S at M	1.5		3.1			1.0		2.3		

Under submerged conditions, addition of coal fly ash had pronounced effect on the uptake of Zn, Fe, Cu and B. The uptake was high in fly ash + GLM treated plots followed by fly ash + FYM, fly ash + HA treated plots. The least uptake was recorded in the unmanured plots (fly ash alone). Among the fertilizers levels, RDF registered the highest micronutrients uptake followed by RDF with 50% K. The RDF excluding Zn, Fe, Zn and Fe showed variation in the uptake in small units in both grain and straw. The above results were in corroboration with the findings of Hall and Williams (2003). Similar interaction effect was reported by Das *et al.* (2013). The increased accumulation of essential ions such as Zn, Mn and Cu by the paddy shoot/grain might be due to increased activity of ionic transporters (Hall and Williams, 2003) in turn due to the higher essential ion availability in the fly ash.

4. Conclusion

The results recorded from the study reveals that fly ash supplies nutrient essential for crops growth and it could be used for crop production. The application of fly ash @ 20 t ha^{-1} + GLM @ 6.25 t ha^{-1} along with RDF (150:50:50) had significant effect on yield and uptake of rice. Fly ash application enriched the soil with P, K and micronutrients led to the relative impoverishment of grain and straw in macro and micronutrients. When combining fly ash with GLM, more pronounced beneficial effects were recorded in the present study. So fly ash when applied along with other organics can be a potential source of nutrient for crops.

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