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Enriched Coal Ash Utilization for Augmenting Production of Rice under Acid Lateritic Soil

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ABSTRACT

The use of industrial wastes such as fly ash (FA) or rice husk ash (RHA), along with paper factory sludge (PFS), farmyard manure (FYM), and chemical fertilizers (CF), under integrated nutrient management, was studied in acid lateritic soil on rice. Application of combined fertilization sources increased growth, yield attributes, and yield (up to 92.3 and 9.7% over control and CF, respectively) of wet season rice. The uptake of N, P, K, Ca, Mg, Fe, Mn, Zn, Cu, and Co was increased under combined fertilization sources. The study also indicated that such integrated plant nutrition system improved physico-chemical properties of soil with respect to bulk density, pH, electrical conductivity, organic carbon, and available nutrient content. Utilization of these wastes saved chemical fertilizers to the extent of 37.8, 59.7, and 86.5% N, P, and K respectively, with an added advantage of minimizing environmental pollution.

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1. Introduction

Apart from their high cost, indiscriminate and continuous use of high analysis chemical fertilizers mostly N, P, and K often leads to nutritional imbalance, particularly for micronutrients which ultimately cause deterioration in physico-chemical properties of soil and steady decrease crop yield. In high-rainfall regions of Eastern India, rice is commonly grown during the wet season (June – October) to meet food requirement. Characteristically, acid-laterites are low in organic matter, nitrogen, and phosphorus. In the management of these soils, addition of liming materials becomes essential (Sew Ram *et al.*, 1992). Besides, with intensification of cropping and use chemical fertilizers, the importance of supplementary and complementary roles of organic materials is being felt for retaining or regaining soil productivity (Modgal and Singh, 1990). Lime and farmyard manure, the latter a common source of organic matter, are costly and often inadequate during the peak period of cultivation. Consequently, adoption of the integrated plant nutrition system becomes difficult. Hence, it is imperative to look for alternative sources to substitute these materials. Recent reports have revealed that there is considerable scope of using some of the industrial wastes like alkaline fly ash of thermal power plants (Yeledhalli *et al.*, 2008), rice husk ash of rice mills, and paper factory sludge of paper mill for these purposes. These materials are cheap, easily available around the production site, and can be effectively used in agriculture for soil enrichment and amendment (Mesa, 1991; Guerini *et al.*, 1994; Sims *et al.*, 1995); otherwise, they pollute the environment and encroach upon vast productive agricultural land in their present mode of disposal in lagoons. Keeping these points in view, it becomes imperative to evaluate the role of these industrial wastes as components of integrated nutrient management in sustaining productivity of rice under acid lateritic soils.

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2. Materials and methods

2.1 Experimental site

The experiment was conducted at the Experimental Farm of the Department of Agricultural and Food Engineering, Indian Institute Technology, Kharagpur, (22° 19′ N Latitude and 87° 19′ E longitude) to study the response of wet-season rice to combined fertilization through organic source and chemical fertilizers, with or without soil amendment, for two consecutive years. The climate of the region was warm and humid with an average annual rainfall 1400 mm.

2.2 Soil characteristics

The soil was acid lateritic (Haplustalf) and sandy-loam in texture with low organic carbon (2.9 g kg^{-1}), and N (150.6 kg ha^{-1}) and medium P (14.31 kg ha^{-1}) and K (123.6 kg ha^{-1}) content. The availability of Ca, Mg, Fe, Mn, Zn, and Cu in soil ranged from 245.0, 54.3, 54.7, 7.5, 0.84 and 1.19 mg kg^{-1} respectively.

2.3 Materials used

Two organic sources viz., farmyard manure (FYM) and paper factory sludge (PFS) at 30 kg N ha^{-1}; three amendments viz., fly ash (FA) at 5 and 10 Mg ha^{-1}, rice husk ash (RHA) at 5 Mg ha^{-1} and lime (L) at 2 Mg ha^{-1} were used for treatment comparison. A uniform nutrient level of 90 -kg N, 26.4 - kg P and 33.2 - kg K ha^{-1} through these materials and chemical fertilizers (CF) was maintained for all the treatments except in control plots. After final land preparation and division of the plots as per layout, FYM, PFS (powdered), RHA, FA, and lime were applied and thoroughly mixed with soil to satisfy the treatment requirements. The experiment, comprising thirteen treatment combinations, was laid out in the randomized complete block design with three replications. The variety used for rice was IR 36 (SIAM × Chianan 8) which was photo-insensitive and of medium duration (110–120 days).

2.4 Observations and analysis

Periodic observations on number of tillers per hill and dry matter production at 30 days after transplanting (DAT), 60 DAT and at harvest were recorded. Grain and straw yield of rice were recorded from the harvest of the net plot area. Nutrient content from the harvested plant samples were estimated separately and total uptake was calculated accordingly. Soil samples from 0–15 - cm depth were collected after harvest of crop and analyzed for organic carbon; pH; bulk density (BD); and available N, P, and K content in soils. The contents of Ca, Mg, Fe, Mn, Zn, Cu, Co, Se, Ni, and Cd were measured by atomic absorption spectro photometer - GBC 932 AA using a Graphite Furnace with PAL 3000 auto sampler. The chemical composition of industrial wastes and farmyard manure is shown in Table 1.

3. Results and discussion

3.1 Growth

The tiller number per hill and dry matter accumulation per hill were influenced by the treatments (Table 2). In general, there was a sharp increase in tiller number up to 60 days after transplanting (DAT) and thereafter, a gradual decrease was noted. The decrease was most prominent where FA was applied alone. Combined application of FA and CF with either PFS during first year or FYM during second year helped in promoting the tiller number. Beneficial effect of FA and RHA was comparable to lime application when they were supplemented with organic and chemical fertilizers. Similar trend was noted in case of dry matter accumulation. In general, combined application of organic materials (FYM or PFS) and soil amendment (FA, RHA or lime) along with CF produced higher number of tillers and more dry matter than application of any of the organic materials and CF. Application of organic materials in conjunction with CF helped in improving nutrient supplying capacity of soil (Prasad and Singh, 1980; Modgal and Singh, 1990) which was further increased when any of the soil amendments was added (Sims *et al*., 1993). Under adequate supply of nutrients, the dry matters as well as tiller number per hill were increased. A significant positive correlation between growth parameters and nutrient uptake further justifies the above findings.

Table 1
Physical and chemical properties of FYM, PFS, FA and RHA used in experiment

Particulars	FYM	PFS	FA	RHA
Bulk density, Mg m^{-3}	0.51	0.60	0.96	0.45
pH (1: 2.5, material: water)	5.86*	5.48*	8.47	7.50
Org. C, g kg^{-1}	216.0	196.1	3.4	49.7
N, g kg^{-1}	11.6	7.6	0.5	0.6
P, g kg^{-1}	3.8	1.4	0.3	2.6
K, g kg^{-1}	7.6	4.0	1.6	1.2
Ca, g kg^{-1}	1.9	1.5	4.2	2.7
Mg, g kg^{-1}	1.5	1.4	2.2	1.8
Fe, g kg^{-1}	4.9	33	9.2	0.7
Mn, mg kg^{-1}	286.85	350.5	288.20	282.50
Zn, mg kg^{-1}	140.70	335.15	25.80	35.50
Cu, mg kg^{-1}	46.90	28.70	21.50	18.80
Co, mg kg^{-1}	15.05	16.75	2.24	1.38
Cd, mg kg^{-1}	0.43	0.39	0.21	0.63
Se, mg kg^{-1}	5.40	6.52	3.18	0.98
Ni, mg kg^{-1}	2.56	3.12	1.95	6.23

* Material: water, 1:5

3.2 Yield components

There was significant increase in the number of panicles and grains per panicle in all the treatments as compared to FA alone or control (Table 3). The increase was discernible when either FYM or PFS was applied with CF and FA, RHA or lime. The effect of the treatments in increasing the test weight was not consistent. The experimental soil was poor in organic matter. Hence, organic enrichment of the soil with any of the sources proved advantageous and increased tiller number per hill and grains per tiller. As a result, yield of rice increased under combined application of organic materials, soil amendment and chemical fertilizers. These findings are in conformity with that of Sajwan (1995).

3.3 Yield

The grain and straw yield under all the treatments except FA alone increased significantly over control during both the years. A marginal increase in yield was noted under FA over control. Further, there was an improvement in yield under the combined application of CF, FYM or PFS, and soil amendment (lime, FA or

Table 2
Effect of different fertilization sources on tiller number and dry matter production of rice

Fertilization sources	Tiller/Hill						Dry matter production/Hill, g					
	30 DAT		60 DAT		At harvest		30 DAT		60 DAT		At harvest	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
Control	7.2	7.9	9.4	11.2	8.2	9.7	9.8	10.2	24.1	26.5	33.1	33.2
CF	12.5	13.1	14.3	15.2	13.4	13.3	21.9	22.9	39.2	41.1	51.7	52.1
FA_{10}	10.1	10.4	13.2	13.1	10.1	11.8	10.7	11.5	29.6	31.4	35.2	39.6
FYM+CF	11.3	11.7	14.4	15.6	14.6	13.9	16.3	18.1	38.2	39.3	46.3	50.1
FYM+FA_{10}+CF	12.7	13.1	16.5	17.8	15.7	15.2	19.2	21.7	40.8	41.4	50.9	59.2
FYM+FA_5+CF	11.9	12.9	15.2	16.2	14.7	14.6	17.8	19.5	37.6	40.9	48.8	54.8
FYM+RHA_5+CF	13.2	13.9	16.8	19.1	15.9	16.9	19.8	21.4	42.5	44.2	58.2	65.1
FYM+L_2+CF	12.3	12.8	15.3	16.4	14.8	14.8	17.4	19.2	38.9	40.4	55.3	53.2
PFS+CF	13.4	12.8	15.2	15.4	13.2	14.1	19.0	19.6	39.5	43.7	53.9	51.2
PFS+FA_{10}+CF	13.2	12.6	17.8	17.2	16.1	16.2	21.1	23.1	41.6	42.3	55.8	58.1
PFS+FA_5+CF	12.8	12.5	15.6	16.9	13.9	14.7	19.5	22.2	39.3	39.8	49.5	53.8
PFS+RHA_5+CF	12.1	13.7	16.2	18.4	15.0	16.5	20.2	24.8	41.9	43.3	56.8	61.6
PFS+L_2+CF	12.6	11.9	16.4	16.1	14.5	15.4	21.4	22.4	40.1	39.7	56.6	55.2
LSD (P=0.05)	NS	1.8	2.4	2.6	2.1	2.3	2.4	2.6	4.1	4.6	5.4	5.9

Values as suffix of FA, RHA and L denote t ha^{-1}; DAT = Days after Transplanting

RHA) as compared to CF alone or combined application of CF, and FYM or PFS. Integrated fertilization with paper-factory sludge proved superior to that with FYM during first year, whereas, the trend was reverse during second year. The effect of FA or RHA in combination with CF and FYM or PFS was comparable to lime in similar combinations in the first year. In the second year, the former two were superior to lime (Table 4). Due to addition of soil amendment, the pH of soil improved, resulting in an increase in availability and, thereby, utilization of nutrients (Sims *et al.*, 1995). Fly ash and rice husk ash having pH of 8.5 and 7.5, respectively, added a large number of nutrients to soil. Hence, in the second year, the yield was higher with fly ash or rice husk ash combinations as compared to lime combinations. The fly ash, PFS, and RHA are sources of a large number of essential plant nutrients (Karmakar *et al.*, 2001). Hence, their application promoted supply either through soil enrichment or raising soil pH under which availability of nutrients increased (Sajwan, 1995; Sims *et al.*, 1995) resulting an increase in nutrient uptake. A significant positive correlation between grain yield and nutrient uptake further justifies the above findings (Fig. 1).

3.4 Nutrient uptake

The uptake of N, K, and Mg by grains and plants was increased appreciably in all the treatments except FA alone and control in both years. During the first year, uptake of all the nutrients under FA alone and control remained comparable (Table 4). In the second year, FA alone recorded significantly higher total P uptake and K, as well as Ca, uptake by plant than that of the control. The increase was discernible under the combined application of an organic source with a soil amendment and CF as compared to application of CF, FA, FYM+CF, or PFS+CF. The extent of increase remained comparable in all the treatments of combined applications of PFS or FYM with FA and CF except in the treatment combinations with FA at 5t ha^{-1} where uptake decreased. Among the soil amendments, FA, RHA, and lime, the uptake of N, P, and K was on a par while the uptake of Ca and Mg was higher in the treatment combinations with lime than those with FA. The beneficial effect of better nutrient utilization on growth, yield, and yield attributes was noted above. As a result, there was an increase in uptake of N, P, K, Ca and Mg under combined application as compared to chemical fertilizers alone.

Table 3
Effect of different fertilization sources on yield attribute and yield of rice

Fertilization sources	Panicles/m^2		Grains/panicle		Test weight (g)		Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
Control	301	280	49.2	49.1	20.26	20.98	1827	2043	2657	2824
CF	405	393	66.9	68.5	21.48	22.14	3406	3379	5102	4828
FA_{10}	312	330	53.4	55.7	21.42	21.86	2063	2322	2889	3134
FYM+CF	360	401	62.9	62.3	21.63	22.25	3238	3462	4399	4673
FYM+FA_{10}+CF	421	453	65.3	71.6	22.02	22.52	3503	3816	4737	5152
FYM+FA_5+CF	399	432	66.9	70.4	22.22	22.41	3394	3664	4151	4947
FYM+RHA_5+CF	439	514	67.0	74.4	22.24	24.12	3650	4154	4977	5608
FYM+L_2+CF	421	420	70.0	72.6	22.12	22.88	3632	3527	4885	4762
PFS+CF	396	410	64.0	67.3	21.68	22.54	3426	3474	4629	4609
PFS+FA_{10}+CF	461	466	71.5	74.2	22.30	23.18	3840	3793	5175	5151
PFS+FA_5+CF	416	431	65.5	71.4	21.92	22.94	3546	3571	4772	4821
PFS+RHA_5+CF	487	480	70.2	72.5	22.18	23.67	3722	3832	5077	5173
PFS+L_2+CF	434	443	70.8	72.3	21.95	22.65	3734	3617	4995	4882
LSD (P=0.05)	82	73	9.2	6.1	0.69	0.65	509	584	657	779

Values as suffix of FA, RHA and L denote t ha^{-1}

Table 4
Effect of different fertilization sources on total uptake of major nutrients (kg ha^{-1}) by rice

Fertilization sources	N		P		K		Ca		Mg	
	1^{st} year	2^{nd} year	1^{st} year	2^{nd} year	1^{st} year	2^{nd} year	1^{st} year	2^{nd} year	1^{st} year	2^{nd} year
Control	37.88	47.80	12.27	11.21	39.89	45.90	4.52	5.61	3.68	4.83
CF	93.78	100.27	25.06	21.60	82.53	84.63	9.48	10.12	8.15	9.08
FA_{10}	46.38	55.47	15.76	14.89	45.07	48.59	5.62	7.47	4.78	6.40
FYM+CF	76.11	81.37	23.76	20.87	76.49	85.00	9.67	12.50	8.49	9.61
FYM+FA_{10}+CF	93.87	107.65	27.45	24.56	85.59	93.05	11.82	14.65	10.81	12.90
FYM+FA_5+CF	78.67	98.44	23.88	23.94	75.90	49.56	9.89	13.72	9.65	10.95
FYM+RHA_5+CF	108.93	117.80	31.18	26.93	93.64	102.20	14.28	15.80	12.67	16.99
FYM+L_2+CF	103.15	100.37	25.34	22.22	87.36	89.07	17.09	17.72	12.23	14.50
PFS+CF	80.47	87.15	25.26	19.59	81.36	83.09	11.06	13.17	8.89	8.32
PFS+FA_{10}+CF	105.74	105.74	29.19	23.29	92.95	92.58	14.62	15.70	11.47	11.51
PFS+FA_5+CF	97.85	97.86	28.22	21.42	89.72	86.76	13.14	14.55	10.66	10.30
PFS+RHA_5+CF	100.96	109.28	27.28	24.23	86.82	93.57	16.47	16.18	11.80	14.64
PFS+L_2+CF	108.21	108.12	27.91	22.48	90.66	87.47	17.72	18.38	12.67	14.32
LSD (P=0.05)	14.79	15.38	4.22	3.63	13.43	14.05	2.05	2.31	1.67	1.90

Values as suffix of FA, RHA and L denote t ha^{-1}

Uptake of different micronutrient varied significantly in different treatments. In case of Zn, Cu, and Mn, a higher uptake was recorded where CF was supplemented by either FYM or PFS as compared to CF alone. In case of Fe uptake, the opposite trend was noted. Among the soil amendments, when lime was applied along with CF and FYM or PFS, the uptake of Fe, Zn, Cu, and Co was significantly lower than where the other two soil amendments, FA and RHA were applied in similar combinations. With respect to Mn uptake, all three amendments remain comparable (Table 5).

3.5 Heavy metal

The content of heavy metals Cd, Ni, and Se in grain and straw of rice was studied (Table 6). There was marginal increase in Se content when FYM+CF was applied with soil amendments like FA, RHA, or lime, whereas the content decreased when PFS+CF was applied with those amendments. In both grain and straw, the Cd content varied marginally among the different treatments. In case Ni content, no definite trend was found. However, these marginal variations did not show any adverse effect on plant and remained under safe limit (Lee *et al.*, 2002).

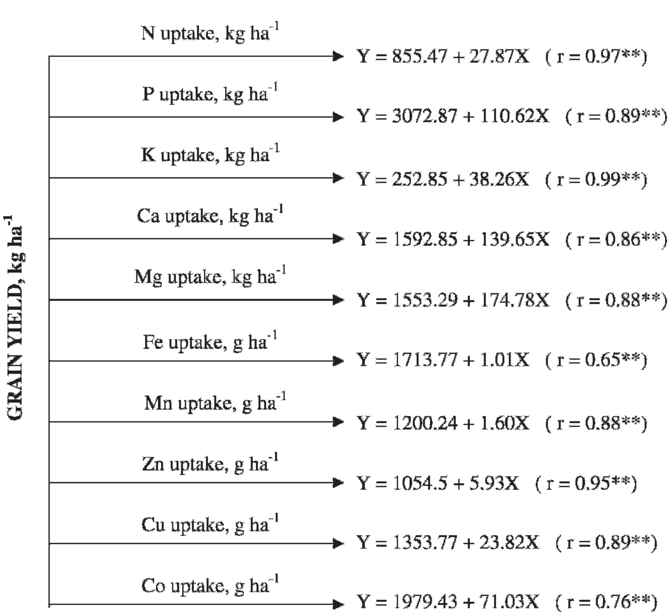

Fig. 1. Correlation and regression between grain yield and nutrient uptake of rice under different fertilization sources.

3.6 Soil

3.6.1 Physical and chemical properties

The changes in bulk density (BD), organic carbon, and pH of the top soil (0–15 cm) as affected by the different treatments are presented in Table 7. The bulk density was noticeably decreased under the treatments with combined application of organic source, soil amendment, and CF as compared to control and only CF. Similar findings were observed by Yeledhalli *et al.* (2008). The organic carbon content of the soil increased remarkably where FYM or PFS was applied with or without soil amendment and CF. Combined application of organic source, lime, and CF showed highest increase in pH. Fly ash alone also increased the pH as compared to CF, organic source, and Control. The reduction of bulk density in treated soil was due to lower bulk density of FA (0.96 Mg m^{-3}), RHA (0.45 Mg m^{-3}) and organic sources (0.51 to 0.60 Mg m^{-3}) as compared to the bulk density of soil (1.65 Mg m^{-3}).

3.6.2 Available nutrients

The content of N, P, and K was higher in soil where FYM or PFS was applied with CF and FA or RHA over the remaining treatments (Table 7). A marginal increase in the nutrient content under FA was noted as compared to control. The N, P, and K content of soil increased from 150.6 to 261, 14.31 to 27.80, and 123.6 to 168.0 kg ha^{-1}, respectively, due to addition of combined fertilization. A lower status of N and P in soil was found under CF and control than the FA-treated plot.

3.7 Nutrient use efficiency

The advantage of integrated plant nutrition could be further established on the basis of nutrient-use efficiency where it was observed that the efficiency of all the three nutrients N, P, and K increased over chemical fertilizers alone. The nutrient use efficiency of N, P, and K in rice was increased from 37.69 - to 42.09 -, 128.49 - to 143.48 - and 102.17 - to 114.1 - kg grain/kg nutrient, respectively, as shown in Table 8. It is apparent from the table that an increment in the efficiency under integrated plant

Table 5
Effect of different fertilization sources on total uptake of micronutrients (g ha^{-1}) by rice

	Fe		Mn		Zn		Cu		Co	
Fertilization sources	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
Control	1030.9	1073.6	539.8	691.8	164.1	199.9	33.7	39.9	4.74	6.95
CF	2302.6	2081.8	1064.9	1171.8	339.1	370.2	74.1	77.6	10.11	12.22
FA_{10}	1095.3	1186.4	652.4	641.2	175.9	211.4	35.5	46.7	6.17	10.11
FYM+CF	1712.1	1701.8	1152.6	1606.4	354.5	416.2	85.4	98.5	10.56	13.12
FYM+FA_{10}+CF	1473.9	1675.2	1616.7	1788.1	408.9	467.3	87.6	100.8	15.33	21.03
FYM+FA_5+CF	1483.6	1695.1	1346.5	1525.6	356.8	431.1	82.4	104.4	13.59	19.00
FYM+RHA_5+CF	2385.9	2246.7	1683.8	1784.1	482.9	541.4	89.1	115.1	15.76	18.78
FYM+L_2+CF	1085.1	1385.5	1526.3	1567.4	382.8	366.5	70.7	72.8	10.94	12.68
PFS+CF	2002.9	1417.5	1202.1	1452.8	384.9	438.5	100.0	110.4	14.17	15.21
PFS+FA_{10}+CF	1925.0	1602.3	1396.6	1662.5	452.0	495.6	106.7	106.4	20.74	22.32
PFS+FA_5+CF	2104.0	1397.7	1266.8	1502.0	427.1	461.8	106.8	108.0	19.06	19.84
PFS+RHA_5+CF	2112.9	1930.4	1542.9	1629.9	478.4	526.1	87.1	104.2	18.06	20.48
PFS+L_2+CF	1218.6	1445.2	1436.7	1579.2	405.4	402.0	77.9	79.2	11.74	14.11
LSD (P=0.05)	282.7	262.8	221.2	283.2	69.4	70.3	14.1	15.9	2.50	2.79

Values as suffix of FA, RHA and L denote t ha^{-1}

Table 6
Effect of different fertilization sources on heavy metal content (ppm) in grain and straw of rice

	Cd				Ni				Se			
	Grain		Straw		Grain		Straw		Grain		Straw	
Fertilization sources	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
Control	0.144	0.162	0.249	0.261	1.42	1.38	1.74	2.22	1.86	1.91	2.89	2.88
CF	0.178	0.180	0.288	0.338	1.44	1.42	2.05	2.11	1.89	1.81	3.02	2.84
FA_{10}	0.152	0.172	0.281	0.312	1.60	1.71	2.14	2.45	2.28	2.26	3.36	3.22
FYM+CF	0.181	0.217	0.358	0.405	1.41	1.58	2.38	1.95	1.71	1.95	2.88	3.41
FYM+FA_{10}+CF	0.149	0.178	0.321	0.308	1.95	1.81	3.05	2.42	2.26	2.51	3.57	3.78
FYM+FA_5+CF	0.176	0.192	0.352	0.388	1.35	1.95	2.59	2.35	2.11	2.23	2.98	3.48
FYM+RHA_5+CF	0.168	0.197	0.344	0.358	1.89	1.74	3.10	2.16	2.42	2.79	3.68	3.62
FYM+L_2+CF	0.147	0.176	0.318	0.301	1.32	1.25	2.02	1.82	2.36	2.68	3.22	3.65
PFS+CF	0.174	0.161	0.338	0.363	1.40	1.60	2.15	2.65	1.84	2.53	2.42	3.08
PFS+FA_{10}+CF	0.161	0.139	0.284	0.334	2.09	1.73	2.65	2.79	2.13	2.95	2.98	3.92
PFS+FA_5+CF	0.158	0.175	0.275	0.336	1.98	1.62	2.22	2.68	2.16	2.47	2.91	3.51
PFS+RHA_5+CF	0.186	0.159	0.352	0.291	2.05	1.65	2.51	2.76	2.37	2.92	3.16	3.98
PFS+L_2+CF	0.181	0.197	0.278	0.269	1.21	1.45	1.82	2.28	2.09	2.81	2.85	3.04

Values as suffix of FA, RHA and L denote t ha^{-1}

Table 7
Effect of different modes fertilization sources on physico-chemical properties of soil after second year rice

	Bulk density		Organic C	N	P	K
Fertilization sources	Mg m^{-3}	pH	g kg^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}
Control	1.66	5.30	4.7	161.9	14.48	121.8
CF	1.64	5.40	3.1	218.0	21.80	159.7
FA_{10}	1.61	5.85	4.8	186.3	16.79	142.3
FYM+CF	1.58	5.60	4.8	251.2	25.17	161.5
FYM+FA_{10}+CF	1.50	6.15	4.6	261.3	27.42	166.3
FYM+FA_5+CF	1.51	6.00	5.6	255.8	26.36	154.5
FYM+RHA_5+CF	1.49	6.10	5.4	251.4	26.50	163.2
FYM+L_2+CF	1.54	6.60	3.8	252.5	27.90	159.1
PFS+CF	1.55	5.55	3.3	242.8	24.73	164.8
PFS+FA_{10}+CF	1.51	5.95	5.2	259.3	27.12	167.3
PFS+FA_5+CF	1.53	5.90	4.9	254.5	26.24	158.5
PFS+RHA_5+CF	1.50	6.00	4.9	256.5	26.68	168.0
PFS+L_2+CF	1.54	6.60	4.1	253.4	27.80	163.6
Initial	1.65	5.32	2.9	150.6	14.31	123.6

Values as suffix of FA, RHA and L denote t ha^{-1}

Table 8
Saving of chemical fertilizers and nutrient use efficiency under different modes of fertilization sources in rice

	Saving of chemical fertilizers (%)			Nutrient use efficiency kg grain / kg nutrient		
Fertilization sources	N	P	K	N	P	K
Chemical fertilizers (CF)	-	-	-	37.69	128.49	102.17
Organic[1] + CF	33.3	29.3	53.3	37.78	128.79	102.41
Organic[1]+Amendment[2]+ CF	37.8	59.3	86.5	42.09	143.48	114.10

Organic[1] = Mean of FYM and PFS @ 30 kg N ha^{-1} and Amendment[2] = Mean of FA @ 10 t ha^{-1} and RHA @ 5 t ha^{-1}

nutrient system combining organic material, soil amendment and chemical fertilizers was recorded to the extent of 4.4 -, 15.0 - and 11.9 - kg grain/kg N, P, and K, respectively, over the treatment where only chemical fertilizers were applied. In addition to this increase in nutrient use efficiency, there was an added advantage of saving of the chemical fertilizers. The extent of saving of chemical fertilizer with respect to N, P, and K were 37.8, 59.3, and 86.5%, respectively.

4. Conclusion

The integrated use of fly ash or rice husk ash, paper factory sludge or farmyard manure, and chemical fertilizers improves growth, yield, and nutrient uptake of rice. Such integrated plant nutrition system not only improves soil health but also results in a saving of chemical fertilizers to a considerable extent in rice production. Use of fly ash or rice husk ash as substitute of lime for ameliorating soil may also minimize environmental hazards.

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