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Fly Ash – a Potential Source of Soil Amendment and a Component of Integrated Plant Nutrient Supply System

Mittra B. N. [1], **S. Karmakar** [2], **D. K. Swain** [3] **and B. C. Ghosh** [1]

[1] Indian Institute of Technology, Department of Agricultural and Food Engineering, Khargpur, W.B., 721302, INDIA,; [2] Uttarbanga Krishi Vishwa Vidyalaya, Pundibari, Coochbehar, W.B. and [3] Central Rice Research Institute, Division of Agronomy, Cuttack, Orissa, 753006. INDIA

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ABSTRACT

To justify suitability of fly ash in agricultural applications, field investigation was carried out for six years, 1996 to 2001. An attempt was made to develop an integrated plant nutrition system (IPNS) utilizing fly ash (FA), and paper factory sludge (PFS), along with farm yard manure (FYM), crop residue (CR) and chemical fertilizers (CF) for rice- peanut cropping system. Direct and residual effects of FA was assessed on the basis of crop response and changes in soil characteristics.

Application of FA @ 10t ha^{-1} in combination with organic sources (PFS/ FYM/ CR) and CF increased the grains yield of rice, pod yield of peanut and equivalent yield of both the crops by 31, 24 and 26 per cent respectively as compared to CF alone. There was beneficial effect of repeated application of FA as compared to one time application at the same level and yield advantage derived by peanut through IPNS was greater than rice. Moreover, there was saving of CF in the order of 64.4 % N, 44 % P_2O_5, 43.3 % K_2O. the alkaline fly ash (pH 8.4) could be used as substitute of lime a costlier material, for amending acidic soils and increased the availability of P, K, Ca, Mg, Zn, Cu and Co besides improving soil physico-chemical properties. The results indicated prospect of safe disposal and utilization of fly ash and organic wastes in agriculture for retaining productivity of problem soils, reduced the usage of costly chemical fertilizer, bring greater economy in cultivation and minimize environmental problems.

INTRODUCTION

In intensive cropping, indiscriminate use of chemical fertilizer has led to deterioration of soil fertility and depletion of essential micronutrients. This has resulted in low and inconsistent production of crops in rice based cropping system. In acid soil such problem gets aggravated which calls for development of an integrated nutrient management system. One of the possible ways of enhancing productivity of acid lateritic soil is use of fly ash and other industrial wastes in appropriate combinations with organic matter and chemical fertilizer which would act as a soil amendment and source of nutrient supply system.

Fly ash, a finely divided residue resulting from the combustion of bituminous coal of Thermal power Plant is regarded as an amorphous ferro- alumino – silicate mineral containing the naturally occurring essential elements similar to that of soil except humus and nitrogen (**9**). It has a pH of 8.5 (**2**) and has certain physical and chemical properties that might be useful as soil amendment acting as a liming agent to neutralize soil acidity (**1, 8**) and improve crop production (**7**). Since it is composed of mostly silt size particles, addition of fly ash to sandy soils could permanently alter soil texture, increase micro porosity and improve water retention capacity (**3**).

Paper factory sludge is also an important industrial waste that can be used effectively in agriculture. It is a rich source of carbon with active silicic acid (**6**) and improves soil organic matter content, water holding capacity, soil structure and bulk density (**10**).

Organic materials like farmyard manure and crop residues are commonly used for enrichment of soil. These materials are easily available through crop and animal production system. Organic materials with varying C/N ratios and biochemical compositions release nutrients at different pace and in varying quantity. It is also known that chemical fertilizer and organic materials are not substitute for each other rather their role is complementary. Therefore application of chemical fertilizer, industrial wastes and agricultural animal wastes in an integrated manner may bring changes in the decomposition process of organic materials and hence are likely to alter the nutrient release pattern of the soil.

In general organic sources of fertilizers applied to one crop meet a part of the requirement of the succeeding crop. The present investigation was therefore, conducted to study the direct and residual effect of different sources of fertilizers applied in an integrated manner on crop productivity, restoration of soil fertility and minimization of environmental hazards in rice-peanut cropping sequence.

MATERIALS AND METHOD

The investigation was carried out at the experimental farm of the Agricultural and Food Engineering Department, Indian Institute of Technology, Kharagpur, India. The climate of this region was warm and humid with average annual rainfall ranges from 1300 – 1600 mm, most of which received during wet season of June to October. The soil of the experimental site was acid lateritic, sandy clay loam (Haplustalf) with pH 5.4, CEC 8.4 cmol kg $^{-1}$, organic carbon 3.8 g kg^{-1} and total N, P, K 0.045, 0.036, 0.066 % respectively. Field experiments were conducted with rice (var. IR 36) during the wet season followed by peanut (var. JL 24), during dry season. The availability of Ca, Mg, Fe, Mn, Zn, and Cu in soil ranged from 242 to 251, 51 to 58, 52 to 60, 7 to 12, 0.84 to 0.91 and 1.19 to 1.34 mg kg $^{-1}$ respectively.

Industrial wastes viz., fly ash (FA) and paper factory sludge (PFS), organic manure like farm yard manure (FYM), crop residue (CR), lime (L) as soil amendment and chemical fertilizer were used in different combinations. Fly ash was applied @ 10t ha^{-1}. Organic material such as FYM or PFS or CR were applied in quantity to supply 30 kg N ha^{-1}. Lime was applied @ 2t ha^{-1}. For rice the recommended dose of N: P_2O_5: K_2O @ 90:60:40 kg ha^{-1} respectively were applied in different treatment combinations except two treatments where FA was applied @ 10t ha^{-1} and an absolute control treatment where nothing was applied. After harvest of wet season rice the residual effect of these fertilizer treatments was studied on the subsequent dry season peanut crop. Besides residual fertility the crop also received a uniform dose of N: P_2O_5: K_2O supplied @ 30:60:40 kg ha^{-1} respectively through chemical fertilizer in all treatments. The experimental design was randomized complete block with three replications

Periodic observations on plant growth and yield of rice and peanut were recorded. The nutrient uptake for N, P, K, Ca, Mg, Fe, Mn, Zn, Cu and Co were calculated at harvest of the crop. Besides accumulation of heavy metals (As, Cd, Ni, and Se) and radioactive elements were determined. Soils samples from 0 to 15 cm depth were collected after harvest of the crop for physico-chemical analysis. The content of nutrients and heavy metals were measured by Atomic Absorption Spectrophotometer (GBC 932 AA). A detailed gamma spectrophotometric analysis was done for two samples i.e. FA and soil treated with FA. The physical and chemical properties of the industrial waste materials and FYM are presented in table –1.

Table – 1. Physical and chemical properties of Farm Yard Manure, Paper Factory Sludge and Fly Ash used in experiments

Particulars	FYM	PFS	FA
Bulk density, g/cc	0.50	0.62	0.96
pH (1: 2.5, soil: water)	5.92*	5.45*	8.47
Org. C, %	22.66	20.06	0.34
N %	1.25	0.71	0.05
P %	0.35	0.16	0.03
K %	0.68	0.36	0.18
Ca %	0.20	0.14	0.42
Mg %	0.15	0.14	0.22
Fe %	0.53	0.34	0.92
Mn, ppm	282.60	398.20	288.20
Zn, ppm	135.10	344.90	25.80
Cu, ppm	44.30	126.30	21.50
Co, ppm	15.30	16.30	2.24
Cd, ppm	0.43	0.39	0.21
As, ppm	5.64	6.85	1.23
Ni, ppm	2.56	3.12	1.95
Se, ppm	5.40	6.52	3.18

*Soil: water, 1: 5

RESULT AND DICCUSSION

EFFECT ON RICE

Combined application of FYM, or PFS or CR as organic source, FA or lime as soil amendment and chemical fertilizer favorably improved dry matter production, yield and nutrient uptake of rice (Table 2 & 3). Application of organic material in combination with the chemical fertilizer helped in increasing nutrient supplying capacity of the soil (**5**) and thus improved soil fertility. Paper factory sludge combination was similar to FYM combination. The effect of FA was comparable to lime when applied in different treatment combinations. The uptake of macronutrients N, P, K, Ca and Mg as well as micronutrients like Fe, Mn Zn Cu, Co was increased under the combined application of FYM or PFS, FA or lime and CF as compared to CF alone or its combination with organic source. Increase of uptake of nutrients improved growth and yield of rice. Application of FA @10t ha^{-1} is estimated to add a meager amount of organic carbon (27 kg) but considerable amount of phosphorous (32 kg), potassium (25 kg), calcium (33 kg), magnesium (17 kg), iron (127 kg), manganese (2.8 kg), zinc (238 gm) and copper (178 gm).However organic material like FYM, PFS and CR, supplied substantial quantity of organic material (500 to 1000 kg) besides supplementing macro and micro nutrients. So blending of FA with any of the organic material in suitable proportion, form a complete mixture of organic carbon and nutrients essential for augmenting the crop yield. Further the alkaline FA accelerated the mineralization of organic matter in acid lateritic (**4**) soil and also promoted the nutrient supplying capacity of the soil by raising pH level from 5.3 to 5.9 in soil. Even, FA based treatment was superior to lime based treatment in increasing grain yield of rice.

Table 2 Grain and straw yield (kg ha^{-1}) of rice as influenced by direct application of different fertilization treatments and their residual effect as well as direct effect of chemical fertilizer on peanut in rice – peanut cropping system

Treatment	Rice		Peanut		Rice grain equivalent yield, kg/ha
	Grain	straw	Pod	Haulm	
Control	2019	2697	1239	2566	2559
FA	2208	2208	2565	4600	4310
CF	3745	4730	2396	4625	4868
FA+CF	4014	4925	2791	4725	5496
FYM+CF	3998	4723	2716	4624	5406
FA+FYM+CF	4210	5000	2945	4789	5798
L+FYM+CF	3761	4662	3122	4779	5784
PFS+CF	3980	4962	2734	4433	5406
FA+PFS+CF	4174	5261	2977	4771	5809
L+PFS+CF	3734	4694	3039	4666	5666
CR+CF	3948	4877	2806	4812	5482
FA+CR+CF	4088	5206	2967	4979	5753
LSD	426	608	408	704	416

Table 3. Effect of different fertilization sources on total nutrients uptake by wet season rice.

Fertilization source	N Kg ha^{-1}	P Kg ha^{-1}	K Kg ha^{-1}	Ca Kg ha^{-1}	Mg Kg ha^{-1}	Fe g ha^{-1}	Mn g ha^{-1}	Zn g ha^{-1}	Cu g ha^{-1}	Co g ha^{-1}
CF	93.78	25.06	82.53	9.480	8.146	2302.6	1064.9	339.1	74.1	10.11
FA_{10}	46.38	15.76	45.07	5.623	4.779	1095.3	652.4	175.9	35.5	6.17
FYM + CF	76.11	23.76	76.49	9.669	8.489	1712.1	1152.6	354.5	85.4	10.56
FYM + FA_{10} + CF	93.87	27.45	85.59	11.818	10.815	1473.9	1616.7	408.9	87.6	15.33
FYM + FA_5 + CF	78.67	23.88	75.90	9.897	9.648	1483.6	1346.5	356.8	82.4	13.59
FYM + L_2 + CF	103.15	25.34	87.36	17.093	12.228	1085.1	1526.3	382.8	70.7	10.94
PFS + CF	80.47	25.26	81.36	11.063	8.894	2002.9	1202.1	384.9	100.0	14.17
PFS + FA_{10} + CF	105.74	29.19	92.95	14.625	11.468	1925.0	1396.6	452.0	106.7	20.74
PFS + FA_5 + CF	97.85	28.22	89.72	13.139	10.665	2104.0	1266.8	427.1	106.8	19.06
PFS + L_2 + CF	108.21	27.91	90.66	17.724	12.672	1218.6	1436.7	405.4	77.9	11.74
Control	37.88	12.27	39.89	4.521	3.676	1030.9	539.8	164.1	33.7	4.74
LSD ($P = 0.05$)	14.79	4.22	13.43	2.054	1.668	282.7	221.2	69.4	14.1	2.50

EFFECT ON PEANUT

The pod yield of peanut was higher under residual fertility of FA or lime based treatments. The residual effect of FA or lime imposed to previous rice crop along with direct application of only CF to peanut crop increased the pod yield significantly as compared to continuous application of only CF (Table 2). Application of FYM or PFS in a rice peanut cropping system helped to build up ample nutrient reserve in the soil assuring continuous and adequate supply of the nutrients to the succeeding crop of peanut. This eventually resulted higher uptake of nutrient elements. The increase in pod yield was associated with increase in nodule number and other associated yield attributing characters. Application of FA reduced bulk density of soil which helped better pegging and pod formation.

Application of PFS and FYM along with FA and CF increased the content of Zn, Cu, and Co in grain and straw of rice and kernel and haulm of peanut as compared to the treatment where only CF was applied. As per the available safe limit values given in the Prevention of Food Adulteration Act (1997) for certain elements viz. Zn, Cu, As and Cd are to the extent of 100, 50, 5, and 1.5 ppm respectively, the concentration of these elements in the present investigation remained within the safe range.

EFFECT ON SOIL FERTILITY

The physico – chemical properties of soil were improved when chemical fertilizer was supplemented with FA and PFS or CR. Such integrated application decreased bulk density and increased organic carbon and pH of soil besides increasing the available nutrients like N, P, K, Ca, Mg, Zn, Cu and Co. The effect was more pronounced when organic sources were applied along with fly ash. The combined application of PFS and CF with or without FA showed comparable result to that of FYM in similar combination. Besides, PFS contains more micronutrients like Zn and Cu than FYM. The bulk density under treatment combination of FA along with PFS or CR was reduced, while it remained unchanged under CF and control treatment. The reduction in bulk density in soil was because of lower bulk density of FA (0.93 Mg m^{-3}) and also organic materials (0.46-0.61 Mg m^{-3}) as compared to bulk density of soil (1.67 Mg m^{-3}).

The organic carbon content of the soil increased remarkably under FYM or PFS along with or without FA treated plots. The increase in pH was noted under FA or lime based treatment (Fig -1). Under integrated fertilizer treatment with FA or lime the soil pH was increased from 5.3 to 5.9 as compared to CF alone where no change in pH was observed. Thus FA can be used as substitute of lime for the amelioration of acid lateritic soil. Among the heavy metals in soil with the addition of FA along with CF and organic sources the content of Cd and Ni was decreased as compared to the treatment CF alone, whereas the content of Se and As increased without any adverse effect on crops.

The analysis of radioactivity (Bq kg^{-1}) of fly ash and soil treated with fly ash @ 40t ha^{-1} revealed that higher radioactivity of ^{226}Ra, ^{228}Ac and ^{40}K was recorded in the latter than the former whereas, the activity of ^{137}Cs was reverse. The radioactivity due to addition of fly ash was subjected to dilution effect in soil. However, these marginal variations remained within the safe limit.

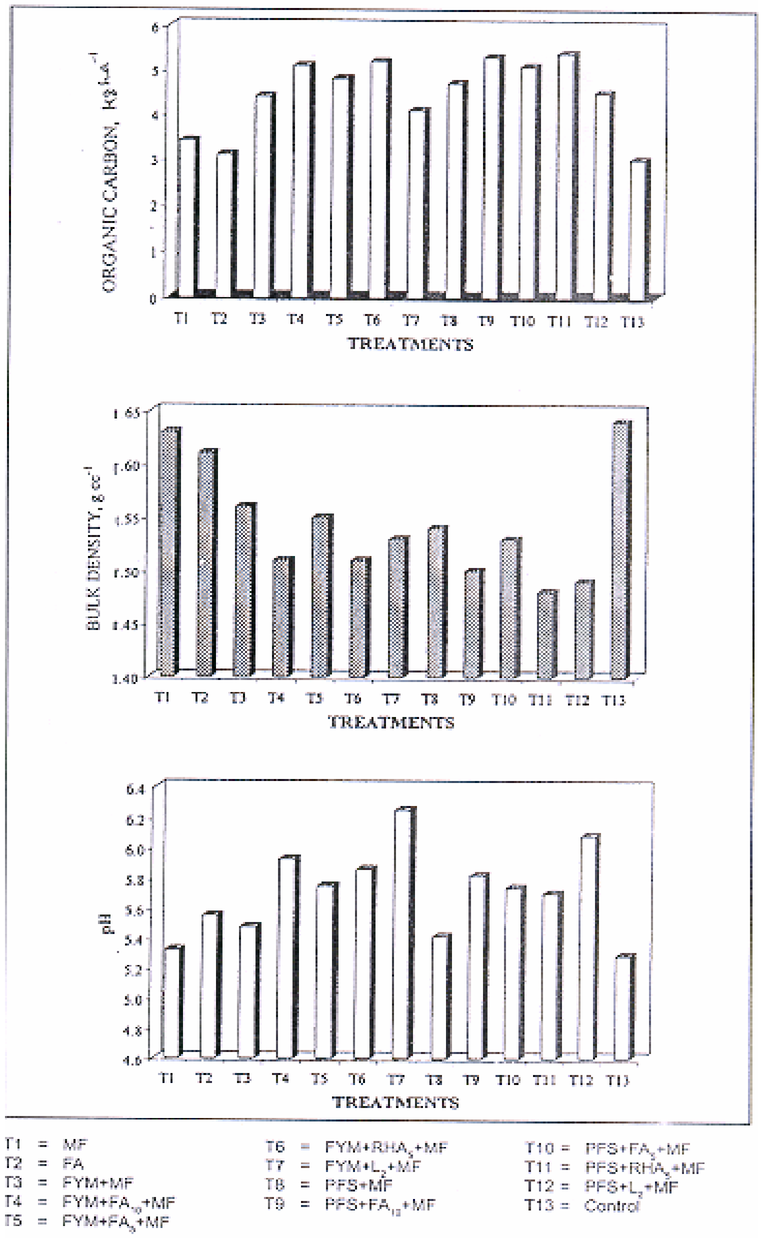

Fig -1 Effect of different fertilizer treatments on changes in Organic carbon, Bulk density and pH of soil.

SAVING OF CHEMICAL FERTILIZER

The advantage of integrated plant nutrition in the rice-peanut system could be further established on the basis of nutrient use efficiency. It was observed that the efficiency of all the three nutrients N, P and K increased over CF alone. It is apparent from the table 4 that the increase under combined application of organic sources, soil amendment and CF was as high as 45.4, 45.4 and 60.5 kg grain kg $^{-1}$ N, P_2O_5 and K_2O respectively. In addition to this increase in nutrient use efficiency, there was an added advantage of saving of the CF. The extent of saving of CF in the rice-peanut system with respect to N, P and K were 45.8, 33.3 and 69.6 per cent respectively.

Table 4. Saving of chemical fertilizers and nutrient use efficiency under different modes of fertilization sources in rice – peanut system

Fertilization sources	Saving of chemical fertilizers (%)			Fertilizer use efficiency kg grain or pod/ kg nutrient		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Chemical fertilizer (CF)	-	-	-	34.40	34.40	45.87
Organic + CF	37.5	22	32	37.20	37.20	49.60
Organic + FA + CF	45.8	33.5	69.6	45.36	45.36	60.48

Organic = Mean of FYM and PFS @ 30 kg N ha^{-1} for rice and half of these does for peanut

CONCLUSION

The study concludes that there is an ample scope for safe utilization of different industrial waste including fly ash in combination with chemical fertilizer for improving soil fertility and augmenting yield of both rice and peanut in acid lateritic soil. Thus, fly ash can be incorporated with safe in soil as a soil ameliorates and also source of nutrient particularly in acid lateritic soil. Such utilization of industrial waste in an integrated manner can save chemical fertilizer to greater extent with the added advantage of minimizing environment pollution.

REFERENCES

1. Chang, A. C., L. J. Lund, A. L. Page, and J. E. Warneke.. Physical properties of fly ash amended soils. *J. Environ. Qual.* 6 (3): 267 – 270 (1977).
2. George. J, and B. N. Mittra, Effect of application of fly ash and paper factory sludge as source of micronutrient on the performance of sweet potato. Abstracts; *Int. Meet Tropical tuber crops*. 9-12 December, 61 pp (1996), Trivandrum, India.
3. Ghodrati, M., J. T. Sims and B. L. Vasilas. Evaluation of fly ash as a soil amendment for the Atlantic coastal plain. I. Soil hydraulic properties and elemental leaching *J. Water, Soil, Air Pollut*. 81: 349 -361 (1995).
4. Khan, R. K. and Khan, M. W. *Environ. Pollut.* 92: 105 -111 (1996)
5. Prasad, B. and Singh, A. P. *J. Indian Soc. Soil S*ci. 28: 465 – 468 (1980)
6. Rasp, H., and E. Koch. Waste material from paper manufacture and its utilization in Agriculture – one experience. In Kongress band, Gottirgen. VOLUFA – VERLAG. 345 – 348 (1992).
7. Sims, J. T., Vasilas, B. L. and Ghodarti, M. Water, *Air, Soil Pollut*. 81: 363 -372 (1995)
8. Taylor, E. M. and G. E. Schumann. Fly ash and lime amendment of acidic coal soil to aid revegetation. *J. Environ. Qual*. 17: 120 – 124 (1988).
9. Tripathi, A., and R. K. Sahu. Effect of coal fly ash on growth and yield of wheat. *J. Environ. Biol*. 18 (2), 131 – 135. (1997).
10. Zhang, X., Campbell, A. G. and Mahler, R. L. *Commun. in Soil Sci. and Plant Analysis*. 24: 11 -12 (1993)