

Fly ash- Its impact on yield and trace metal uptake by crops grown in acid soils

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ABSTRACT

Fly ash generated by captive power plants of Bokaro Steel Plant of SAIL was analysed for various properties and their role as plant nutrients. The yield of crops such as rice, wheat and soyabean and uptake of trace metals in fly ash amended soils by plants were assessed under green house conditions. Analysis of Fly ash reveal that it is moderately acidic (pH 6.0). Exchangeable Ca^{2+} and Mg^{2+} were major cations in the exchange complex. Total content of P, K, S and Fe in fly ash were high, while among nutrients in plant available forms, S (513 mg kg^{-1}) and K (258 mg kg^{-1}) were high. Content of DTPA extractable Ni was above toxic limit (29 mg kg^{-1}). Experiments conducted in fly ash amended soils indicate increase in dry matter yield to soyabean, rice and wheat up to 16% (w/w) fly ash addition. Addition of fly ash increased the concentration as well as uptake of different trace metals viz., Fe, Cu, Zn, Mn, Co, Pb and Ni by rice plant. Uptake of Ni by rice and wheat plants was reduced to some extent by soil application of lime along with fly ash. In case of wheat, uptake of Fe and Ni increased considerably with fly ash additions to soil which is matter of concern from the point of trace metal contamination of soils. Uptake of Pb and Co by rice and wheat plants grown in fly ash amended soils was within the tolerance limits. Results indicate that fly ash can be used for soil amendment and as a secondary source of several essential plant nutrients and thereby help in increasing crop production. For mitigating the effects of certain toxic metals in fly ash, lime and or FYM application in soil along with fly ash is necessary.

INTRODUCTION

Fly ash, a ferro-alumino silicate is a major solid industrial waste. Land disposal of fly ash is currently a favourable practice for its disposal. Fly ash contains many nutrients essential for plant growth which can be made use of in increasing crop productivity (Page et al. 1979; Adriano et al. 1980). However, inconsistent results of fly ash application on plant growth have been reported over the years (Furr et al. 1976; Aitken and Bell; 1985). In view of the escalating fertilizer prices, a judicious blend of

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fertiliser — fly ash could help sustain soil productivity and increase crop yields. On this background, the present study was undertaken to (i) Characterise fly ash as a source of plant nutrients and (ii) study its effect on yield and nutrition of crops.

MATERIALS AND METHODS

Fly ash obtained from Bokaro Steel Plant was analysed for physical, physico-chemical and chemical properties. Total, available and water soluble contents of plants nutrients including trace metals were analysed by standard methods (Jackson 1973).

Pot culture experiments with soyabean (*Glycine max* L.) Var. Birsa Soyabean 101 was conducted during Kharif 1993 in a complete randomized design with five replications. 5 kg soil was filled in polythene lined earthen pots and six levels of Bokaro fly ash (0, 4, 8, 16, 32 and 100% w/w), three fertiliser levels (0, 50 and 100% of recommended NPK dose) and FYM @ 10 t ha⁻¹ were applied as basal. Five plants were maintained in each pot for 45 days in the glass house. After recording the dry-matter yield of plants, plant samples were digested in tri-acid mixture and total P and total K were determined by Spectrophotometer and flame photometer, respectively. N content of plant samples was determined by Kjeldahl's method (Jackson 1973).

Experiment with rice (Var. IR 36) was conducted in a similar design with three levels each of fly ash (0, 8 & 16% w/w), and fertiliser (0, 50 and 100% of recommended dose) and two levels of lime (0 and 1 LR @ 5.5 t ha⁻¹). Each pot contained 24 days old 10 seedlings @ 2 seedlings hill with 5 hills. Submerged condition was maintained throughout the experiment by adding deionized water. 45 days after transplanting, aerial portion of plants were harvested, air-dried and oven-dried at 65°C and dry matter yield was recorded, 0.5g sample of plant material was digested in tri-acid (HNO₃ : H₂SO₄ : HClO₄ in 10:3:1) and 50 ml final volume was prepared with double distilled water. Total Zn, Cu, Fe, Mn, Pb, Co and Ni were determined in the aliquot of tri-acid digested sample with the help of GBC-902 Atomic Absorption Spectrophotometer. Rice crop was followed by wheat with fresh addition of fertilizers and lime but no-addition of fly ash. The experimental details were similar as given earlier for rice.

RESULTS AND DISCUSSION

Characterization of Fly ash : Results (Table 1) indicate that pH of fly ash (1:2.5 in H₂O) is 6.0 indicating moderately acidic reaction. Sand particles (62.6%) dominate in the ash followed by silt (36.4%) and clay (1%). Water holding capacity of fly ash was high (65.9%). Aitken *et al.* (1985) in Australian fly ash and Maiti *et*

al. (1990) in Indian fly ash reported similar values Exchangeable Ca^{+2} and Mg were dominant cations in the exchange complex. Total content of trace metals in Bokaro fly ash was fairly high ranging from 9770 mg kg^{-1} Fe to 55 mg kg^{-1} Co. DTPA extractable as well as water soluble content of trace metals were low except Ni, Fe, Pb and Zn (Table-1).

Table-1 : Some important physical characteristics and content of plant nutrients & trace metals on Bokaro fly ash

(A)	Physical & chemical properties	...	Value	
	pH (1:2.5 in H ₂ O)	...	6.0	
	Particle size distribution (%)			
	Sand	...	62.60	
	Silt	...	36.40	
	Clay	...	1.40	
	Water holding capacity (%)	...	65.90	
	Exchangeable cations (C moles (P ⁺) kg ⁻¹)			
	Calcium	...	12.14	
	Magnesium	...	6.58	
(B)	Chemical constituents (content in mg kg ⁻¹)	Total	Available	Water soluble
	Nitrogen	89.00	63.00	-
	Phosphorus	8600.00	119.10	-
	Potassium	9700.00	258.00	-
	Sulphur	4875.00	513.05	22.14
	Iron	9770.80	116.70	0.08
	Manganese	591.70	9.20	0.35
	Zinc	275.00	7.060	0.74
	Copper	62.20	0.790	0.04
	Cobalt	55.00	0.44	0.33
	Nickel	282.70	29.30	1.30
	Lead	72.90	1.50	0.31

Growth and nutrition of crops in fly ash amended soil

Soyabean : Dry matter yield of soybean increased with graded levels of fly ash application up to 16% level beyond which a significant reduction was recorded (Table-2). Shukla and Mishra (1986) had reported lethal effect of fly ash on growth of corn at high level. At recommended level of fertiliser, the beneficial effect of fly ash application (8 and 16%) was more apparent compared to that at half the

recommended level or unfertilized pots. Uptake of major plant nutrients e.g. N, P and K by soybean plants was highest at 16% level of fly ash in fertilized soil (0.38, 0.16, 0.25 g pot⁻¹ N, P and K, respectively). In fact, N content of plants grown in fly ash amended soils did not vary much. This was mainly due to poor N content of fly ash. It was interesting to note that there was a drastic reduction in the content as well as uptake of N, P and K of soyabean plants grown in 32% and 100% fly ash Table-3.

Table-2 : Effect of flyash and fertilizer levels on dry matter yield (g pot⁻¹) of soyabean

Fly ash/Fert.	Dry-matter yield			
	0% NPK	50% NPK	100% NPK	Mean
0%	11.36	12.80	12.75%	12.31
4%	12.72	13.01	14.21	13.31
8%	12.79	14.42	15.87	14.36
16%	13.27	14.88	16.17	14.78
32%	10.07	12.28	13.80	12.05
100%	5.34	5.79	8.18	6.40
Mean	10.90	12.20	13.50	-

[L.S D. (Flyash) P = 0.05] = 0.50

Table-3 : Effect of flyash on uptake of N, P and K (g pot⁻¹) by soyabean

Fly ash/ Fert.level	No Fertilizer			Recommended Fert. level		
	N	P	K	N	P	K
0%	0.17	0.04	0.15	0.26	0.07	0.19
4%	0.23	0.06	0.16	0.34	0.09	0.20
8%	0.24	0.11	0.17	0.36	0.14	0.21
16%	0.27	0.13	0.18	0.38	0.16	0.25
32%	0.14	0.03	0.16	0.23	0.07	0.18
100%	0.08	0.02	0.04	0.16	0.03	0.07
Mean	0.19	0.07	0.14	0.29	00.09	0.18

L.S.D . (Fly ash) (p = 0.05)= 0.01(N), 0.003(P), 0.002(K)

Rice : Results indicate that 16% addition of fly ash yielded 30.57 g pot⁻¹ which differed significantly from fly ash applied @ 8% (26.17 g pot⁻¹). Singh and singh (1986) earlier reported increase in yield of rice up to 20% fly ash addition. Rao et.al. (1990) recorded maximum growth and biomass accumulation with 15% flyash addition. While lime application was effective in soil not receiving fly ash (Table-4), it did not result in

increasing drymatter yield of rice with 8 and 16% level of fly ash addition. The concentration of micronutrient cations (Fe, Mn, Zn, Cu) in rice plant showed significant variations with fly ash additions (Table-5). Concentrations of Zn 31 mg kg⁻¹) and Cu (9.7 mg kg⁻¹) in rice plant were highest at 16% fly ash level while that of Fe (810 mg kg⁻¹) was highest at 8% flyash. Lime application decreased the content of Fe in rice grown in fly ash amended soil. Mn content of rice showed only a lower range of variation in fly ash amended soil.

Table-4 : Effect of flyash and fertilizer and lime on dry matter yield (g pot⁻¹) of rice

Treatment	0% NPK	Dry-matter yield		
		50% NPK	100% NPK	Mean
Control	13.20	22.03	28.29	21.17
Lime	15.06	24.06	31.40	23.51
Fly ash 8%	18.58	27.43	32.49	26.17
Fly ash 8% + lime	10.21	26.52	29.55	25.43
Fly ash 16%	23.62	31.11	35.97	30.57
Fly ash 16% + lime	27.09	33.48	30.81	30.46
Mean	19.63	27.61	31.42	

[L.S D. (Flyash) P = 0.05)] = 1.88

Table-5 : content (mg kg⁻¹) of trace metals in rice plant grown in fly ash amended soil

Treatment	Content			
	Fe	Mn	Zn	Cu
Control	563	142	27.7	6.1
Lime	231	167	23.1	5.4
Flyash 8%	810	146	28.3	8.0
Flyash 8% + lime	328	128	24.8	6.2
Flyash 16%	754	156	31.0	9.7
Flyash 16% + lime	342	151	24.3	6.9
[L.S D. (Flyash) (P = 0.05)] :	52	16	3.4	1.0

Among the trace metals (Pb, Ni and Co), the concentration and uptake of Pb and Ni increased considerably in fly ash amended soils (Table-6). Pb content of rice plants in control (1.45 mg kg⁻¹) increased with 8 and 16% flyash addition to 4.25 and

6.93 mg kg⁻¹, respectively. Uptake values of Pb in rice plant also was significantly higher in fly ash added pots. Ni content of rice plant was highest (29.1 mg kg⁻¹) at 16% fly ash level and was significantly higher compared to 8% flyash or 0% fly ash level. Co content in rice plant showed a narrow range of variation among different treatments. It was interesting to note that lime application significantly reduced the concentration and uptake of Pb and Ni in rice plant. Increase in soil reaction in limed soil could have contributed to lower levels of Pb and Ni in plant. Cox and Rains (1971) earlier reported similar results.

Table-6 : concentration (mg kg⁻¹) and uptake (mg pot⁻¹) of Pb, Ni & Co by rice plant grown in fly ash amended soil

Treatment	Pb		Ni		Co	
	Conc.	Uptake	Conc.	Uptake	Conc.	Uptake
Control	1.45	0.030	22.7	0.48	3.59	0.076
Lime	1.15	0.027	23.1	0.54	3.58	0.058
Flyash 8%	4.25	0.111	26.3	0.69	3.14	0.80
Flyash 8% + lime	3.41	0.086	22.4	0.57	4.19	0.107
Flyash 16%	6.93	0.211	29.1	0.89	4.68	0.149
Flyash 16% + lime	4.23	0.128	27.9	0.85	4.87	0.148
[L.S.D.(Flyash) (P = 0.05)]: 0.41 0.74 1.4 0.06 0.28 0.01						

Wheat : Residual effect of fly ash incorporation was studied in wheat. Results (Table-7) indicate increase in dry matter yield of wheat plant up to 16% fly ash addition. Mean dry matter yield of wheat at 0.8 and 16% fly ash levels were 2.46, 3.09 and 4.63 g pot⁻¹, respectively. While fertiliser levels positively influenced yield,

Table-7 : Effect of fly ash fertilizer and lime on dry matter yield (g pot⁻¹) of wheat

Treatment	Dry matter yield			
	0% NPK	50% NPK	100% NPK	Mean
Control	0.72	2.41	4.24	2.46
Lime	0.70	2.84	4.71	2.75
Flyash 8%	1.57	3.09	4.60	3.09
Flyash 8% + lime	2.35	3.65	4.16	3.39
Flyash 16%	3.88	4.84	5.16	4.62
Flyash 16% + lime	4.34	4.24	6.38	4.99
Mean	2.26	3.51	4.88	

Table-8: Conc. (mg kg⁻¹) of some trace metals in wheat grown in flyash ammended soil

Treatment	Concentration			
	Fe	Pb	Ni	Co
Control	241	4.95	11.16	14.81
Lime	278	5.01	10.69	16.18
Flyash 8%	309	5.19	12.91	17.03
Flyash 8% + lime	330	5.34	11.75	16.05
Flyash 16%	272	5.36	12.48	16.32
Fillyash16% + lime	224	5.31	10.22	16.07

lime did not have any influence. Analysis of some trace metals in wheat grown in fly ash amended soil (Table-8) reveal less pronounced effect compared to rice, though an increase in concentration of Fe, Pb, Ni and Co was apparent. Content of Fe, Ni and Co in wheat plant actually decreased with increase in fly ash levels from 8 to 16%. Considering the fairly high trace metal load of Bokaro fly ash, regular monitoring of soils and plants grown in soils amended with such material is necessary before deciding on the rate of its application for a favourable effect on crops.

SUMMARY

Fly ash from Bokaro Steel Plant shows high total contents of plant nutrients such as P, K, S and Fe with high plant available S and K and toxic level of Ni. Plant growth experiments in fly ash amended soil with rice, wheat and soyabean as test crops reveal beneficial effect of fly ash added @ 16% (w/w) level. Fly ash application increased the contents of Fe, Cu, Zn, Mn, Co, Pb and Ni in rice plants. Lime application in acidic soil reduced the concentration and uptake of Ni by rice and wheat plants from fly ash amended soil.

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