https://doi.org/10.29321/MAJ.10.A01343

Madras Agric. J. 92 (7-9) : 456-463 July-September 2005

Influence of flyash on soil properties, nutrient uptake and yield of rice in Inceptisol Alluvium

M. BASKAR and G. SELVAKUMARI

Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore- 641 003

Abstract : Field experiment was conducted at Lower Bhavani Project (LBP) area to study the effect of application of flyash in combination with fertilizer, organic manures and biofertiliser (*Azospirillum*) on soil properties and yield of rice. The flyash contains a wide range of nutrients (P, K, Fe, B, Si, Ca, Mg and S) and traces of heavy metals. The results of the experiment revealed that application of flyash @ 20 and 40 t ha^{-1} significantly increased the grain yield of rice crop to the tune of 5.6 and 12.5 t ha^{-1}, respectively. Application of NPK fertilisers as per STCR technology through fertilisers, fertilizer + compost and fertilizer + compost + Azospirillum recorded an yield increase of 3.12, 3.53 and 3.56 t ha^{-1} respectively over the treatments without any fertilizer addition. The highest yield of 7.26 t ha^{-1} was recorded in the treatment which received flyash @ 40 t ha^{-1} along with fertilizer; compost and fertilizer. The significant increase in the nutrient uptake of rice indicated that flyash could serve as source of plant nutrients. The results of the post harvest soil analysis indicated that application NPK ferilisers significantly increased the available NPK status of the soil, while application of flyash significantly increased the available P, K, Ca, Mg, S, Si and B content of the soil. The effect of flyash was more pronounced when applied along with fertilisers and organic manures.

Key words : Flyash, STCR technology, fertiliers, compost, biofertiliser, nutrient uptake, grain yield, available nutrients.

Introduction

The nutrient supply should be such that the crop need are satisfied to produce the highest economic yields and ensure quality of the produce. Fertilisers form the major external input to realise the full expression of the genetic potential of crop. The financial and energy implications of feritiliser as farm inputs impose a degree of restraint on their use. The organic manures such as FYM and compost have become scarce on account of dwindling cattle population in the farms. In this circumstances, inclusion or exploitation of alternative sources of plant nutrients such as farm and industrial wastes and bio-fertilisers has been found to be very useful in saving the costly fertiliser nutrients, obtaining higher crop yields, as well as protecting the environment from pollution.

Flyash, a byproduct of thermal power stations contains essential plant nutrients inclusive of micronutrients (Khungar, 1998). At the rate of 40-45 % ash content in Indian coals, the flyash generation will cross 140 mt by 2020 AD. One of the possible avenues of utilisation of flyash is its use in agriculture because of the favourable effects on physico-chemical properties of soil and presence of essential nutrients. Use of flyash along with bio-wastes and sewage wastes was reported. These wastes were used to supplement the application of chemical fertilisers. Hence an investigation has been envisaged to find out the possibility of using flyash as a component of Integrated plant nutrient supply system for improving soil productivity and yield of crops without affecting soil health and environment.

Materials and methods

Field experiment was conducted at Bhavani to findout the the effect of flyash alone and in combination with organic manures, fertilisers and bio - fertilisers. The soil was Inceptisol alluvium. The soil (*Typic ustocrept*) was sandy clay loam with pH 7.8, EC 0.24 dSm^{-1}, organic carbon 0.52 % and contains 174 kg ha^{-1} of alk. $KMnO_4$ N, 17.9 kg ha^{-1} Olsen - P, 125 kg ha^{-1} of NH_4OAc - K, 12.0 cmol(p+)kg^{-1} of available Ca (water soluble + exchangeable) 3.8 cmol (p+) kg^{-1} of available Mg, 12.1 mg kg^{-1} available S (0.15 % $CaCl_2$-S), 1.26 mg kg^{-1} of hot water soluble B and 0.719, 23,9, 2.51 and 6.38 mg kg^{-1} of DTPA extractable Zn, Fe, Cu and Mn respectively. The heavy metals content of the soil were 49.6, 2.44 and 2.79 mg kg^{-1} of Cr, Pb and Cd, respectively. The flyash collected from Mettur thermal power station was used for the field experiment. The flyash containing the dominance of particles having the size range of (0.002 to 0.2 mm). The bulk density was low (1.11 g cm^{-3}) as compared to normal cultivable soil. The pH of the flyash was 9.2 and EC was 1.10 dSm^{-1}. The CEC (0.90 cmol(p+)kg^{-1}) and organic carbon (0.08 %) contents were very low. The flyash contains moderate amount of P(0.19%), K (0.32%), Zn (40 mg kg^{-1}) Fe (1700 mg kg^{-1}) and B (3.8 mg kg^{-1} of hot water soluble B) and appreciable amount of Si (58 mg kg as SiO_2), Ca (4%) Mg (1.3%) and S (0.3%) and very traces of heavy metals (44, 2.8 and 3.8 mg kg of Cr, Pb and Cd respectively) which is more or less equal to that of normal cultivable soil (49.6, 2.44 and 2.79 mg kg of Cr, Pb and Cd, respectively in the experimental soil).

The main plot treatments includes control (M_0), application of NPK as per Soil Test Crop Response (STCR) technology through fertilisers alone to get 6 t ha^{-1} of grain yield (M_1), application of NPK as per M_1 through fertilisers and organics (FYM @ 12.5 t ha^{-1}) (M_2), application of NPK as per M_1 through fertilisers, organics (FYM @ 12.5 t ha^{-1}) and bio-fertilizer (*Azosspirillum* @ 2 kg ha^{-1}) (M_3). The nutrients (NPK) supplied through FYM and bio-fertilizer were deduced while calculating fertilizer dose for M_2 and M_3. The sub plot treatments includes different levels of flyash *viz.*, no flyash (FA_0), flyash @ 20 (FA_{20}) and 40 (FA_{40}) t ha^{-1}. The experiment was laid out in split plot design and the treatments were replicated thrice. Flyash was incorporated into the soil one week before planting as per the treatment details. Initial and post harvest soil samples were collected and analysed for their physico-chemical properties and nutrient availability. Plant samples (root, straw and grain) were collected after harvest and analysed for nutrient uptake computation. The soil, plant and flyash samples were analysed as per the standard procedures.

Results and Discussion

Grain and straw yield

The Fly Ash (FA) application had pronounced effect on grain and straw yields of rice (Table 1). The grain and straw yields recorded in FA_0 were 4.96 and 5.66 t h^{-1}. The grain yield in FA_{20} and FA_{40} were 5.52 and 6.09 t ha^{-1} and straw yield in FA_{20} and FA_{40} were 6.21 and 6.60 t ha^{-1} respectively. The contribution of essential plant nutrients as well as the favourable physical environment in the soil treated with FA, would have facilitated growth and yield of rice. Addition of Si through flyash was reported to produce erect leaves that could account for a 100 per cent increase in the photosynthesis of the canopy and consequently increased the grain yield of rice. It was also reported that Si is required to balance the applied nutrients, especially applied N. The practice of adding silicate slags @ 1.5 to 2.0 t ha^{-1} for degraded low land rice (Yoshida, 1981) for the sustenance of high rice yields in Japan lent support for the present finding. Addition of old coal flyash from 0 to 80 t ha^{-1} was found to progressively

Table 1. Effect of flyash and manures on yield and nutrient uptake of rice

Treatments	Yield (t ha)		N- uptake		P-uptake		K- uptake		Ca- uptake		Mg- uptake		S- uptake		Si- uptake		B- uptake	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
	t ha^{-1}		kg ha^{-1}														g ha^{-1}	
M_0FA_0	2.51	2.93	33.5	11.8	5.1	2.56	4.70	33.5	10.8	20.3	3.53	3.55	2.75	2.58	39	70	15.3	15.1
M_0FA_{20}	2.90	3.17	39.4	13.2	6.1	3.08	5.5	38.1	13.1	25.0	4.65	4.43	3.27	2.86	50	98	18.6	15.5
M_0FA4_{40}	3.51	3.47	46.3	14.4	7.5	3.40	6.8	42.8	16.1	28.1	5.60	4.90	4.16	3.22	65	131	23.4	17.4
M_1FA_0	5.66	6.30	83.8	38.6	13.7	6.80	11.0	77.1	24.2	44.2	7.95	7.55	6.13	5.55	89	151	34.5	29.4
M_1FA_{20}	6.20	6.93	93.1	43.5	15.5	7.59	12.6	87.9	27.8	54.5	9.95	9.82	7.00	6.25	107	215	40.1	33.6
M_1FA_{40}	6.40	7.15	95.4	45.9	16.9	7.94	14.0	92.0	29.3	57.6	10.2	10.1	7.56	6.52	117	270	42.2	36.4
M_2FA_0	5.84	6.73	87.1	41.8	14.8	7.35	12.1	84.9	25.2	47.2	8.09	8.90	6.37	5.95	96	164	35.6	31.2
M_2FA_{20}	6.47	7.39	98.9	46.9	17.6	8.41	14.2	95.8	29.2	58.4	11.4	10.3	7.29	6.66	115	242	42.4	36.2
M_2FA_{40}	7.18	7.87	109.0	49.8	19.5	8.95	16.7	103	33.0	64.4	11.5	11.0	8.50	7.35	132	301	48.1	40.1
M_3FA_0	5.85	6.64	88.0	42.6	14.5	7.51	12.2	84.5	25.3	47.0	8.12	7.98	6.37	5.79	96	163	35.6	31.2
M_3FA_{20}	6.49	7.35	99.3	48.2	17.9	8.51	14.6	96.1	29.2	58.3	10.3	10.3	7.33	6.66	14	240	42.2	36.1
M_3FA_{40}	7.26	7.93	111.0	50.5	21.0	9.25	16.5	105	33.0	64.4	11.6	11.0	8.54	7.39	134	302	48.2	40.4
M_0	2.97	3.19	38.9	13.1	6.2	3.01	5.7	38.1	13.3	24.5	4.60	4.60	3.39	2.89	51	99	19.1	16.0
M_1	6.09	6.79	62.1	42.7	15.4	7.44	12.5	85.7	27.1	52.1	9.37	9.37	6.89	6.11	104	212	38.9	33.1
M_2	6.50	7.33	98.3	46.2	17.0	8.24	14.3	94.6	29.1	56.4	10.3	10.3	7.39	6.65	114	236	42.0	36.0
M_3	6.53	7.31	99.4	47.1	17.8	8.42	14.4	95.2	29.3	56.6	10.0	10.0	7.41	6.61	15	235	41.9	35.9
FA_0	4.96	5.65	73.2	33.7	12.0	6.06	10.0	70.0	21.4	39.7	8.92	7.00	5.40	4.97	80	137	30.3	26.9
FA_{20}	5.52	6.21	82.5	38.0	14:3	6.90	11.7	79.5	24.8	49.1	9.00	8.72	6.22	5.61	96	199	35.8	30.4
FA_{40}	6.09	6.60	90.4	40.2	16.2	7.39	13.5	85.7	27.9	53.4	9.73	9.25	7.19	6.12	112	251	40.4	33.6
CD																		
FA	0.17	0.17	2.7	2.2	0.40	0.40	0.60	2.5	0.93	1.9	037	0.43	0.23	0.24	3	7	1.6	1.7
M	0.16	0.17	3.2	2.8	0.50	0.50	0.80	3.3	1.15	1.7	0.31	0.37	0.23	0.15	3	9	1.6	1.0
FA x M	0.30	0.34	NS	NS	NS	NS	1.20	5.0	NS	3.8	NS	NS	NS	NS	NS	15	3.0	2.6
M x FA	0.30	0.33	NS	NS	NS	NS	1.10	4.7	NS	3.4	NS	NS	NS	NS	NS	15	3.0	2.4

increase the grain yield of rice (6.2 to 6.4 t ha^{-1}), in India (Kanwar, 1998). Singh and Tewary (2002) reported that dry matter of wheat and Pea increased upto 20% in flyash amended soil.

The manurial treatments had profound influence in enhancing the yield level of rice. In the manurial treatment M_0, M_1, M_2 and M_3, the grain yields were 2.97, 6.79, 7.33 and 7.31 t ha^{-1} respectively. The enhancement may be ascribed to the supply of nutrients in proper proportions. Both for grain and straw, the M_2 and M_3 recorded significantly higer yields than M_1. The M_2 and M_3 were comparable. However, when these manurial treatments were integrated with FA, there were further increase in yield of grain and straw. The highest yield was obtained in fertilizer, compost, Azospirillum and FA system. M_3FA_{40} recorded the highest yield of grain (7.26 t ha^{-1}) straw (7.93 t ha^{-1}) followed by M_2FA_{40} (7.17 t ha^{-1} of grain and straw). Not only the supply of nutrients but also the better utilisation of nutrients made available on account of complementary effect of compost and FA, favourable physical conditions and electro - chemical properties under submerged conditions would have paved the way for realising the full potentials of rice. The integrated supply system of applying flyash, fertilisers, compost and *Azospirillum* had more profound effect on yield than addition of flyash alone and that might be due to the synergistic effect of fertilizer nutrients with flyash. The positive interaction of Si with N, P and K fertilizer nutrients (Gangloff *et al.*,1997) which would have cumulative yield increase in rice under the integrated nutrient supply system. Results from Kharagpur showed increased rice yield for the conjoint application of flyash and paper factory sludge (Zachari *et al.*, 1996). The results of increased grain yield was also supported by the significant and positive correlation obtained with the uptake of N (r^2 = 0.989*) P (r^2 = 0.987**), K (r^2 = 0.991**), Ca (r^2 = 0.982**), Mg (r^2 = 0.943**), S (r^2 = 493 **), Si (r^2 = 0.988**), B (r^2 = 0.988**) and Zn (r^2 0.990**).

Nutrient Uptake

Uptake of macronutrients

The uptake of N by grain and straw (Table 1) was increased significantly for the graded dose of FA. The total N and organic carbon content of coal flyash are 0.08 and 0.01 per cent. Besides contributing N from it, the FA would have stimulated the microbial activity, by providing all the nutrients from it and thus mobilising the native N. The increase obtained by FA addition in the N uptake by grain was small (9.3 to 17.2 kg ha^{-1}) as compared to that observed in manurial treatments (23.2 to 60.5 kg ha^{-1}). In the straw yield similar trend of results was observed. It is natural, since the manurial treatments consisting of fertilisers, compost and *Azospirillum*, are rich sources of N as compared to FA and would have augmented the uptake to a greater extent. The interaction of FA and manurial treatments further enhanced the N uptake. The maximum value of 111 kg in grain and 50.5 kg in straw N uptake ha were recorded by the four component systems *viz.* fertilisers, compost, *Azospirillm* and FA. The added effect might be due to the synergistic effect in the integrated nutrient supply system.

Regarding P and K uptake of rice (Table 1) the trend similar to that of N uptake was observed. The P and K might have been contributed from the FA itself for rice in comparatively larger quantities than N, besides that were supplied from the native source. The increase in P uptake of grain was form 2.3 to 4.3 kg ha^{-1} for FA addition and 9.2 to 11.6 kg ha^{-1} for manurial treatments. The increase in K uptake of grain was from 1.71 to 3.51 kg ha^{-1} in FA treatments and 6.8 to 8.74 kg ha^{-1} for manurial treatments. The interaction of FA and manurial

Table 2. Effect of flyash and manures on available nutrient status of Post harvest-soil

Treatments	N	P	K	Ca	Mg	S	Zn	Fe	Cu	Mn	Si	B
	kg ha^{-1}			cmol(p+)kg^{-1}		mg kg^{-1}						
M_0FA_0	169	15.8	120	11.4	3.53	11.8	0.71	23.8	2.49	6.32	52.0	1.26
M_0FA_{20}	170	16.5	126	11.6	3.49	11.8	0.70	23.4	2.43	5.94	67.0	1.27
M_0FA_{40}	173	17.9	128	12.3	3.55	12.0	0.69	23.2	2.39	5.69	75.0	1.30
M_1FA_0	175	17.5	128	11.1	3.60	12.1	0.70	23.0	2.41	6.02	51.0	1.23
M_1FA_{20}	176	18.2	131	11.5	3.91	13.3	0.69	22.6	2.38	5.64	65.0	1.25
M_1FA_{40}	174	18.2	133	11.9	3.78	13.9	0.68	21.8	2.33	5.41	73.0	1.29
M_2FA_0	179	18.4	131	11.3	3.75	14.8	0.73	23.8	2.37	6.40	53.4	1.26
M_2FA_{20}	181	19.5	135	12.3	4.40	14.7	0.72	23.6	2.35	6.13	73.1	1.29
M_2FA_{40}	182	20.6	139	12.9	4.20	14.8	0.71	23.3	2.26	6.09	79.0	1.31
M_3FA_0	181	18.3	131	11.5	4.10	14.8	0.73	24.0	2.40	6.32	54.0	1.27
M_3FA_{20}	181	19.3	135	12.1	4.08	15.3	0.72	23.7	2.37	6.24	70.0	1.30
M_3FA_{40}	182	20.5	139	12.8	4.71	15.8	0.71	23.6	2.39	6.25	82.0	1.32
M_0	169	16.7	125	11.8	3.88	13.3	0.70	23.4	2.44	5.65	64.7	1.28
M_1	175	18.2	131	11.5	3.79	13.5	0.69	22.4	2.37	5.69	63.0	1.26
M_2	181	19.5	135	12.2	3.78	14.0	0.72	23.4	2.33	6.20	68.5	1.29
M_3	181	19.3	135	12.1	4.24	14.2	0.72	23.8	2.39	6.27	68.6	1.30
FA_0	176	17.5	127	11.4	3.52	11.9	0.72	23.6	2.41	6.27	52.7	1.25
FA_{20}	177	18.4	131	11.9	3.96	14.1	0.71	23.3	2.38	5.99	68.8	1.28
FA_{40}	176	19.5	135	12.5	4.27	15.2	0.70	22.9	2.34	5.86	77.0	1.31
CD (p=0.05)												
FA	NS	0.5.	3.4	0.3	0.2	0.4	NS	NS	NS	NS	1.36	0.02
M	0.4	0.2	4.3	0.4	0.2	0.3	0.02	0.75	NS	0.45	1.74	NS
FA x M	NS	0.9	NS	NS	NS	0.8	NS	NS	NS	0.84	2.82	NS
M x FA	NS	0.9	NS	NS	NS	NS	NS	NS	NS	NS	2.73	NS

Table 3. Effect of flyash on heavy metal content (mg kg^{-1}) of soil and rice crop

FA Levels	Soil			Rice grain			Rice Straw			Rice root		
	Cr	Cd	Pb	Cr	Cd	Pb	Cr	Cd	Pb	Cr	Cd	Pb
FA_0	49.3	2.5	2.71	0.117	0.011	0.720	0.154	0.018	0.632	0.171	0.232	0.726
FA_{20}	49.7	2.5	2.71	0.118	0.011	0.721	0.155	0.018	0.635	0.173	0.232	0.729
FA_{40}	49.8	2.5	2.83	0.118	0.012	0.723	0.156	0.019	0.638	0.176	0.232	0.734
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.003

treatments recorded a maximum of 15.9 kg ha^{-1} of P uptake and 11.9 kg ha^{-1} of K uptake in grain and 16.2 kg ha^{-1} of P uptake and 105.0 kg ha^{-1} of K uptake in straw. The increase in nutrient uptake by rice due to flyash application was also reported by Ramesh and Chhonkar (2001).

Application of FA alone @ 20 and 40 t ha^{-1} registered an increased Si uptake of 11 and 26 kg ha^{-1} by grain and 28 and 61 kg ha^{-1} by straw respectively, over FA_0 (Table 1). It might be due to high Si content of flyash. When fertiliser plus compost were integrated with flyash an increased Si uptake of 19 and 36 kg ha^{-1} in grain and 78 and 137 kg ha^{-1} in straw were recorded by FA_{20} and FA_{40} respectively over FA_0. The uptake was higher in FA plus fertiliser plus compost than FA plus fertiliser. The spectacular rise in the nutrient uptake by the integrated nutrient supply system with FA was superior over that system without FA.

Uptake of secondary and micronutrients

Under submerged conditions, addition of coal flyash at graded dose had pronounced effect on the uptake of secondary and micronutrients (Table 1). The presence of appreciable amounts of these nutrients in flyash would have increased their availability in soil which in turn would have resulted in better use of them by rice. The increase in nutrient uptake by manurial treatments might be due to increase in dry matter production. Jambagi *et al.* (1995) reported similar findings in safflower for flyash and FYM. The increase was attributed to the contribution of the nutrients from both the sources. Elseewi *et al.* (1978) reported increased S uptake in flyash treated crop of alfalfa and bermuda grass grown in calcareous as well as acid soils. Presence of S in FA might have produced a special effect on B uptake. More than the contribution of these micronutrients from FA, the better crop growth and increased dry matter yield due to favourable physical improvement and supply of all the nutrients in balanced proportion would explain the higher uptake of these nutrients by the rice crop.

Sims *et al.* (1994) reported increased concentration of Zn, Cu, Mn in corn plants for the FA treatment @ 30%. Jambagi *et al.* (1995) also reported increased uptake of Zn, Cu, Fe and Mn by safflower in Alfisol for addition of FA with fertilisers and FYM. The increased uptake of micronutrients was ascribed to their increased availability in the soil treated with flyash and manures.

Soil properties

Addition of flyash did not change the pH, EC and available N status of the post harvest soil. In the case of P and K (Table 2), the build-up despite crop removal might be due to the release of P and K from FA. Since P and K found in FA are mostly insoluble in nature, all that were present in FA might not have been used by the crop and that part would have caused build up in residual P and K in the post harvest soil. The favourable effect of FA on P availability was ascribed to its effect on biotic activity and the P release via biotic activity. The addition of Si through flyash may be responsible for the solubilisation and release of soil P and the replacement of adsorbed phosphate ions by silicate ions (Jones and Handreck, 1963). Bastisse (1967) had shown that an increase in the ratio of SiO_2/ P_2O_5 in soil solution.

Application of graded doses of flyash significantly increased the available Si content of the post harvest soil (Table 2). An increase of 16.1 and 24.3 mg kg^{-1} Si was observed due to the addition of flyash @ 20 and 40 t ha^{-1} respectively. The silica which formed the dominant component of FA would have contributed abundantly to available Si content of the soil. The increase due to the conjoint addition of FA and organics may be attributed to the action of CO_2 evolved from the decomposing organics on alumino silicates of FA and soil in releasing Si (Bricker and Godfrey, 1967). The three component system of FA, fertilizer and compost had profound effect on the buildup of available Si in the post harvest soil and this could be ascribed to the cumulative effect of the components on keeping more of Si in available form.

The availability Ca, Mg and S was found to increase in the post harvest soils treated with FA at graded levels than in control (Table 2). The availability of all three nutrients increased with increased dose of FA. An increase of 0.5 and 1.1 cmo (p+)kg^{-1} of Ca, 0.44 and 0.75 cmol (p+) kg^{-1} Mg and 2.2 and 3.4 mg kg^{-1} of S were recorded due to the application of flyash @ 20 and 40 t ha^{-1} respectively. The presence of appreciable amount of Ca, Mg and S in the FA might be the reason for their increased availability. The high availability of these nutrients in the two component system of compost and fertilizers might be ascribed to the additive effect of the sources. The three component system of fertilisers, compost and FA had excelled the two component systems of FA and fertilisers in augmenting the availability of secondary nutrients. As against the control and the treatments with fertilisers alone which-exhibited a sharp decline in the availability of secondary nutrients, the three component system was found to be good. Kuchanwar *et al.* (1997) reported enhanced availability of Ca and Mg in Vertisols by the addition of flyash. Gangloff *et al.* (1997) reported increased availability of secondary nutrients in the top 20 cm of soil (6.1 pH) received flyash. The available micronutrients content *viz* Zn, Fe, Cu and Mn of the post harvest soil (Table 2) were not greatly influenced by flyash application.

Heavy metal content

The results of the post harvest analysis (Table 3) revealed that application of flyash even upto 40 t ha^{-1} did not significantly increase the heavy metal contents of the soil. The low concentration of heavy metals in the flyash used and also the mobility leaching of heavy metals to the subsurface layer (Chiteshwari *et al.*, 1998) might be the reason for the non-significant increase in the heavy metal content of the soil due to flyash addition. The results of the plant analysis indicated that flyash addition significantly increased the Pb content of rice root which might be due to relatively higher solubility of Pb than Cr and Cd. However, addition of flyash did not increase the content of any of the heavy metals in rice grain and straw. It might be attributed to the poor translocation of heavy metals from roots to the above ground portions. Singh and Tripathi (1996) also reported no change in Pb, Cd, Zn and As content of rice, wheat, maize and soybean grain due to the addition of flyash @ as high as 200 t ha^{-1}.

Acknowledgement

The authors express their sincere thanks to Indian Council of Agriculture Research for the financial assistance to carry out this study.

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(Received : December 2003 Revised : December 2005)