IMPACT OF FLY ASH ON IRRIGATED VERTISOLS VIS-À-VIS ON BIOMASS YIELD AND CONTENT OF HEAVY METALS AND ACTIVITY OF RADIO NUCLIDES OF CROPS

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SUMMARY

Fly ash-treated soils have been analyzed for both trace elements and radionuclides to study the effect of application of fly ash to soils and uptake of elements by plant species. This paper describes the details on sampling and sample preparation and analytical techniques and the uptake of trace elements and radionuclides by sunflower-maize crops in sequence over a period of three years. The Results indicated the beneficial effect of fly ash / pond ash along with FYM in increasing the biomass yield of crops. There was no significance difference between fly ash / pond ash and have better residual effect on succeeding crops. The maximum biomass yield of sunflower 23.1 t/ha was recorded due to fly ash @ 40t/ha along with FYM @20 t/ha. And per cent increase over control was 36.7 whereas highest biomass yields of maize of 41.2 q/ha was recorded due to application of fly ash @ 40t/ha every year and percent increase over control was 61.6. The activity of radionuclides namely ^{226}Ra, ^{228}Ac and ^{40}K in fly ash was 101.5, 109.3 and 361.4 Bq/kg and the corresponding values in the pond ash were 98.0, 106.0 and 342.4 Bq/kg which was slightly lower as compared to fly ash. Even though application of fly ash / pond ash at different level has increased the activity of radionuclides in both the crops biomass, the activity of these natural radionuclides are comparable with those crops grown in normal soils.

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Many elements found in fly ash are essential to plants and animals, including some macroelements (K, P, Mg,Ca) and trace elements (Fe, Mn, Mo, Cu, Zn). Seleniuim is commonly found in coal ash and is essential to animals. However, the range between beneficiary and toxicity level is relatively narrow. Little information is available concerning the uptake and movement of potentially toxic elements from coal ash in the ecosystem. Plants grown in soils amended with fly ashe from various sources are knovvn to accumulate a number of elements, of which Pb, As, Se and Mo have been reported to reach levels potentially toxic to grazing animals in some areas (Kefer and Sajwan, 1993). A large fraction of coal extracted from the earth is burn in thermal power stations (Johnes, 1988). In the combustion process, most of the mineral matter in the coal is fussed into fly ash. The physico- chemical properties of soil and fly ash are similar in many respects. Therefore fly ash has a great potential for utilization in agriculture as a soil conditioner and as a provider of nutrients for plants. The radionuclides, which contribute most to environmental radiation are the members of the natural radioactive series and ^{40}K (UNSCEAR, 1988). Coal, like most of the material found in nature, contains trace quantities of the naturally occurring radionuclides arising from the uranium and thorium series and also ^{40}K. The concentrations of these long-lived radionuclides are usually low in the coal, when it is burnt in power stations. The fly ash that is emitted through the stack gets enriched in some of the radionuclides.

The concentration of trace elements/radioactivity in fly ash is extremely variable and depends on the composition of the parent coal, conditions during coal combustion, efficiency of emission control devices, etc. The magnitude of absorption of radionuclides by plants grown on fly ash amended soils depends on the content of elements and radionuclides in fly ash, the rate of application, the soil type and its pH, the type of plant etc. (Furry *et al.,* 1976). The contents of heavy metals and naturally occurring gamma radionuclides in crops grown on fly ash-applied to irrigated vertisols have been analyzed to study the bulk application and long term effect on biomass yield, content of heavy elements and radionuclides in sunflower-maize cropping sequence. The present paper reports the results of such investigations.

MATERIALS AND METHODS

The vertisol represents the Raichur Series (Typic Haplusterts).Sunflower and maize were the test crops. The experiment was laid out in RBD with three replications. Fly ash/ pond ash from Raichur Thermal Power Station, Shaktinagar, Raichur were used as amendments. The ash collected from hoppers is designated as fly ash (FA) while the ash collected from settling pond is called as pond ash (PA). These amendments were applied to soil at recommended dose of 30 t/ha with and without organics @ 20 t/ha. In addition,10 t/ha higher than the recommended dose (40 t/ ha) was also included to assess its impact on soil properties, mobility and transport of toxic heavy metals and radionuclides into food chain. The recommended dose of fertilizers were applied to soil commonly to all treatments.Field experiment was conducted at Agricultural College Farm, Raichur, Karnataka from 2004 to 2006. Raichur is located in the North Eastern Dry Zone (Zone-1) of Karnataka between 16^0 15' N latitude 77^0 20' E longitudes and at an altitude of 389 meters above mean sea level (MSL). Each year during *kharif* season experiment was conducted to study the direct effect of application of fly ash/pond ash on sunflower crop, growth and yield and soil properties. During *rabi* season, the residual effect of fly ash/pond ash on the succeeding crop maize was evaluated. Composite soil samples collected from the experimental site before the start of experiments, fly ash, pond ash and FYM were analyzed for various parameters by adopting standard methods (Jackson, 1973) (Table 1 and 2).

Sampling and sample preparation :

Sunflower and maize were grown during the period 2004-2006 at Agriculture College, Raichur and soil the samples were collected. About 1 kg of each of the straw sample was ashed at 10^0C and powdered. About 500 of each of the soil, sunflower and maize grain /stover samples was dried and powdered.

For heavy metal measurements, the fine powdered sample was mixed with pure cellulose in the ratio of 1: 1 by weight. The mixture was thoroughly ground, homogenized and pressed into pellets of 25mm diameter. For radioactivity analysis, the dry powdered samples (about 200 - 400 gm) were stored in air-tight cylindrical plastic containers(6.5 cm dia. and 7.5cm height) for nearly 1 month so as to ensure that ^{226}Ra and ^{40}K attained radioactive equilibrium with their respective daughters (Vijayan and Behera, 1998).

Analysis of heavy elements :

An Energy Dispersive X-Ray Fluorescence (EDXRF) system was used for the analysis of heavy elements. It incorporated a low power (50 watt) air cooled X-ray tube as an excitation source with triaxial geometry. The X-rays from the tube irradiated on a Mo secondary exciter and the characteristic K X-rays of secondary exciter were used to irradiate the elements present in sample. The X-ray spectrum from the sample was recorded using a Si (Li) detector and PC based Multi Channel Analyser. The spectra were evaluated using a computer programme AXIL. Matrix effects were taken into account in the spectrum deconvolution. Protons of 3MeV, obtained from the 3MV accelerator facility at the Institute of Physics, Bhubaneswar were used for estimation of heavy metals (Vijayan *et al*., 1998).

Analysis of gamma emitting radionuclides :

The Gamma-ray spectrometer used for estimation of radionuclides consisted of a High Purity Germanium (HPGe) detector 'AAth a resolution of 1.95 keV at 1.33 MeV and having a volume of 77 cm^3. The detector was kept at 27t geometry for counting. Emitted gamma rays from the samples, collected by the HPGe detector 'AAth lead shielding lined with 1 mm aluminium and were recorded using a PC based Multi Channel Analyser. The data were analysed and radionuclides such as ^{226}Ra ,^{228}Ac and ^{40}K were estimated.

RESULTS AND DISCUSSION

Characterization of fly ash, pond ash and soil :

The vertisols represented the Raichur series (Typic haplustert). It was clay in texture, alkaline in reaction, low in soluble salt content, but high in water holding capacity. The black soil, in general, has no constraint for crop production (Table 1). Fly ash is silty clay loam in texture with 40 per cent silt sized particles, while texture of pond ash represented silty clay loam with higher proportion of silt sized particles. The pH of fly ash ranged from 9.7 to 10.5, while it was 7.9 to 9.3 in pond ash. High pH of fly ash was due to reserve alkalinity and addition of which might increase the pH of soil. The water holding capacity of fly ash was less than that of pond ash. In view of reserve alkalinity and low water holding capacity, the fly ash was inferior to pond ash for agricultural utilization. Both fly ash or pond ash were the potential sources of major, secondary and micronutrients except nitrogen. The vertisoils was clayey in texture, alkaline in reaction (pH 8.6), low in soluble salt content (0.1 dS/m) and high in organic carbon, available nitrogen and potassium contents. The DTPA extractable Cu, Fe, Mn and Zn content were 1.59, 2.17, 8.13 and 0.90 mg/kg of soil respectively. The total lead, arsenic and selenium contents were 13.9, 1.2 and 0.9 mg/kg of soil.The concentration of heavy metals such as lead, arsenic and selenium in fly ash ranged from 18.4 to 20.4 ppm, 2.3 to 2.8 ppm and 1.6 to 1.60 ppm, respectively. The total contents of (18.7) Pb, As and Se in pond ash ranged

Table 1: Characterization of soil, FYM, fly ashes

Parameters	Vertisol	FYM			Fly ash			Pond ash		
		2004	2005	2006	2004	2005	2006	2004	2005	2006
Physical Properties										
Sand (%)	9.20	-	-	-	21.50	19.80	20.50	30.20	32.81	34.20
Silt (%)	27.00	-	-	-	40.10	50.20	48.40	45.60	48.20	46.50
Clay (%)	63.80	-	-	-	38.40	30.00	31.10	24.20	18.59	19.30
Texture	C	-	-	-	SiCL	SiCL	SiCl	SiL	SiL	SiL
Porosity (%)	50.90	-	-	-	-	-	-	-	-	-
BD (Mg/m-3)	1.30	0.64	0.70	0.66	0.95	0.99	0.94	1.05	1.00	1.12
MWHC (%)	64.20	145.40	155.20	140.35	48.10	50.20	45.20	63.60	66.10	56.50
FC (%)	36.70	84.20	82.00	80.50	24.20	22.50	22.15	38.00	40.00	40.80
PWP (%)	16.40	18.50	17.30	17.90	560	5.70	5.74	11.00	12.20	12.50
Chemical Properties										
pH (1:2)	8.60	7.10	7.70	7.23	10.50	9.82	9.30	9.30	8.99	8.85
EC (dS/m)	0.10	0.32	0.60	0.45	1.00	0.87	0.75	0.50	0.34	0.45
OC (%)	0.90	-	-	-	-	-	-	-	-	-
Total N (%)	0.09	1.12	1.24	1.03	0.008 ppm	0.007	0.008	0.015	0.015	0.024
Av.N (kg/ha)	306.10	310 (ppm)	355 ppm	380 (ppm)	23.60 ppm	30.25	28.45	38.80 ppm	39.60 ppm	30.50 ppm
Total P (%)	0.08	0.62	0.80	0.65	0.23 ppm	0.43	0.32 ppm	0.38	0.42	0.21
Av. P_2O_5 (kg/ha)	10.20	795 (ppm)	890 ppm	803 ppm	13.20 ppm	16.70 ppm	14.5 ppm	10.32 ppm	11.62 ppm	13.8 ppm
Total K (%)	1.65	0.93	1.10	0.98	1.42 ppm	1.80	1.36	1.10	1.60	1.50
Av. K_2O (kg/ha)	770.35	1020(ppm)	1126 ppm	1091 ppm	135.80 ppm	145.20 ppm	155.8 ppm	94.20 ppm	11.20 ppm	29.50 ppm
Total S (%)	0.06	0.26	0.36	0.29	1.70	2.50	2.24	1.40	1.75	1.65
Available (SO_4-S)	38.00	14 (ppm)	15.3 ppm	15.60 ppm	65.00 ppm	78.20 ppm	75.36 ppm	45.10 ppm	51.20 ppm	40.5 ppm
Total Ca (%)	1.30	1.10	1.00	1.20	3.64	3.36	2.92	2.52	2.66	3.80
Amo. Extr Ca (c.mol/kg)	39.70	-	-	-	16.00	19.20	16.91	9.30	10.10	14.20
Total mg (%)	0.78	0.15	0.14	0.09	1.36	1.19	1.65	1.70	1.53	1.25
Amo. Extr Mg (c.mol/kg)	12.10	-	-	-	12.00	13.40	14.25	2.00	5.00	3.80

from 16.4 to 18.7 ppm, 1.90 to 2.1 ppm and 1.3 to 1.5 ppm (Table 2). However, the concentration of Cd in both the ashes was below the detection level.

The gross α activity observed in fly ash was 236.6 Bq/kg and in pond ash 210.8 to 225.1 Bq/kg. There was not much difference in the gross β activity of both ashes. Similarly, the activities of g emitters like ^{40}K, ^{226}Ra and ^{228}Ac were also higher in fly ash than pond ash.

The variations in properties of fly ash might be attributed to the parent coal source, handling and storage of fly ash.The pond ash represented silt loam in texture with high water holding capacity (63.6 to 68.1%). The pH ranged from 7.9 to 9.3 and EC from 0.34 to 0.50 dS/m. The contents of available nutrients in pond ash were

Table 2: Content of heavy metals and radionuclide activity in soils, FYM and fly ashes

Parameters	Vertisol	FYM			Fly ash			Pond ash		
Heavy metals		2004	2005	2006	2004	2005	2006	2004	2005	2006
Total Se (ppm)	0.90	0.50	0.50	0.40	1.60	1.60	1.20	1.40	1.30	1.12
Av. Se (ppm)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Total As (ppm)	1.20	0.70	0.80	0.45	2.30	2.50	3.01	1.90	1.90	1.28
Av. As (ppm)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Total Pb (ppm)	13.90	7.50	7.90	6.10	18.40	20.20	16.10	17.20	16.40	20.5
Av. Pb (ppm)	0.18	0.06	0.05	0.10	0.03	0.04	0.09	0.03	0.03	0.02
Radio nuclides (Bq/kg)										
Gamma 40K	282.30	145.80	136.60	122.4	359.30	363.50	281.3	353.70	342.40	3000.10
Gamma 226Ra	37.50	16.90	16.60	15.8	99.70	103.20	114.50	91.80	103.20	99.2
Gamma 228 Ac	65.90	26.30	24.40	30.1	108.20	110.30	96.50	106.20	101.70	98.5

low compared to fly ash. The total content of Pb, As and Se in pond ash was 1.72, 1.9 and 1.4 ppm, respectively. The DTPA extractable micronutrients such as Cu, Fe, Mn and Zn were 0.36, 10.56, 10.23 and 1.29 mg/kg, respectively. The radionucleides *viz*., a b and g (^{40}K,^{226}Ra and ^{22}AC) were 225, 616.8, 342.4, 91.80 and 106.0 Bq/kg, respectively.

The variation in pond ash might be attributed to the composition of parent coal, condition during coal combustion, efficiency of emission control devices and handling and storage of ash.

Effect of fly ash/ pond ash on biomass yield sunflower and maize :

During *kharif* 2004, the biomass yield of sunflower was 10.6 q/ha in control, which increased significantly in treatment receiving either fly ash or pond ash . The highest biomass yield of 16.0 q/ha was recorded in T_3 treatment followed by T_4. The increase in biomass yield over control was 50.9 and 47.2 per cent, respectively. Treatments, T_2, T_5 and T_6 also recorded higher yield which were *at par* with T_3 (Table 3). Kene *et al*., 1991, also reported similar results in sunflower and millets. During *kharif* 2005, the biomass yield of sunflower in control was 24.2 q/ha which increased significantly with the application of either fly ash or pond ash. The maximum biomass yield of 37.0 q/ha was recorded in T_8 treatment followed by T_7 treatment (36.6 q/ha).The per cent increase in biomass yield over control was 52.9 and 51.2, respectively. However, the biomass yield did not differ significantly between T_3, T_4, T_6 and T_9 treatments.

During *kharif* 2006, the biomass yield of sunflower in control was 15.8 q/ha. The biomass yield of sunflower varied significantly with the application of either fly ash or pond ash. The highest biomass yield of 18.2 q/ha was noticed in T_4 treatment but it did not differ significantly between T_3, T_5, T_6, T_7 and T_8 treatments. All these treatments were found to be *at par* with each other with respect to biomass yield. Pooled analysis of the data indicated that the biomass yield of sunflower in control was 16.9 q/ha. The maximum biomass yield of 23.1q/ha was recorded in T_7 treatment. However it was *at par* with T_3 (22.3 q/ha), T_4 (22.3 q/ha) and T_8 (22.8 q/ha) treatments. The per cent increase in biomass yield over

Table 3: Bulk application of fly ash levels on biomass yield of crops in irrigated vertisols

Tr.	% difference over control	Cropping season and name of crops					
		kharif-04 sunflower	*rabi* -04 maize	*kharif* – 05 sunflower	*rabi* – 05 maize	*kharif* – 06 sunflower	*rabi* – 06 maize
T_1: Control (RDF)	Treatment Mean (q/ha)	10.6	23.1	24.2	22.8	15.8	30.5
T_2: RDF + FA @ 30t/ga every year	Treatment mean (q/ha)	15.4	29.3	27.	31.6	16.2	32.5
	% difference over control	45.3	26.8	14.5	38.6	2.53	6.5
	Significance over control	*	NS	NS	*	*	*
T_3: T2+ FYM @ 20t/ha every year	Treatment mean (q/ha)	16.0	42.5	33.2	43.1	17.8	35.5
	% difference over control	50.9	84.0	37.2	89.0	12.0	16.4
	Significance over control	*	*	*	*	*	*
T_4: RDF + FA @ 40 t/ha every year	Treatment mean (q/ha)	15.6	42.1	33.0	42.5	18.2	34.2
	% difference over control	47.2	82.3	36.4	86.4	15.2	11.8
	Significance over control	*	*	*	*	*	*
T_5: RDF + FA @ 30 t/ha once in three years	Treatment mean (q/ha)	15.0	33.1	27.00	38.9	17.3	31.9
	% difference over control	41.5	43.3	11.6	70.6	8.9	4.6
	Significance over control	*	*	NS	*	*	*
T_6: RDF + Pond ash @ 30 t/ha every year	Treatment mean (q/ha)	15.1	32.7	34.0	28.8	17.2	32.4
	% difference over control	42.5	41.6	40.5	26.3	8.9	6.2
	Significance over control	*	*	*	NS	*	*
T_7: T_6 + FYM @ 20 t/ha every year	Treatment mean (q/ha)	14.6	40.3	36.6	43.5	18.0	35.5
	% difference over control	37.7	74.5	51.2	90.8	13.9	16.4
	Significance over control	*	*	*	*	*	*
T_8: RDF + Pond ash @ 60 t/ha every year	Treatment mean (q/ha)	13.5	33.8	37.0	28.5	18.00	32.7
	% difference over control	27.4	46.3	52.9	25.0	13.9	7.2
	Significance over control	*	*	*	NS	*	*
T_9: RDF + Pond ash @ 60t/ha once in three year	Treatment mean (q/ha)	12.4	32.9	32.1	24.5	15.5	30.3
	% difference over control	17.0	42.2	32.3	7.4	10.9	-
	Significance over control	*	*	*	NS	*	NS
	C.D. (P=0.05)	1.09	6.3	6.23	7.45	1.21	1.32

control was 36.7 in T_7 treatment.

During *rabi* 2006, the biomass yield of maize in control was 23.1 q/ha. The highest biomass yield of 42.5 q/ha was recorded in T_3 treatment followed by T_4 treatment (42.5 q/ha). The per cent increase in biomass yield over control was 84.00 and 82.25 in T_3 and T_4 treatments respectively. However, both the treatments did not differ significantly with T_7 treatment (40.3 q/ha) During *rabi* 2005, the biomass yield of maize was 22.8 q/ha in control. The maximum biomass yield of 43.5 q/ha was recorded in T_7 treatment followed T_3 (43.1 q/ha) and T_4 (42.5 q/ha) treatments but all the three treatments were *at par*. The per cent increase in biomass yield over control was 90.8, 89.0 and 86.4, respectively.

During *rabi* 2006, the biomass yield in control was 30.5 q/ha which increased significantly with the application of either fly ash or pond ash. The maximum biomass yield of 35.5 q/ha was recorded in both T_3 and T_7 treatments. However, they did not differ significantly with T_4 treatment. The per cent increase in biomass yield over control was 16.4. *et al.* (1985), reported that, the increase in the biomass was due to improvement in water holding capacity of the calcareous soils.

Pooled analysis of the data showed that the biomass yield of maize in control was 25.5 q/ha. The highest biomass yield of 41.2 was recorded in T_4 followed by 40.4 q/ha in T_3 treatment. However, it was *at par* with T_7 (39.8 q/ha) treatment. Treatments T_4, T_3 and T_7 were superior to all other treatments. The per cent increase in biomass yield of maize over control was 61.6, 58.4 and 56.1 in T_4, T_3 and T_7 treatments, respectively. The residual effect of higher dose of fly ash application was comparable with the treatments receiving recommended dose of ash with FYM. The results are in agreement with the findings of (Sale *et al*, 1996).

Effect of maximum yield / dose treatment of fly ash and pond ash on the concentration of heavy metals in biomass :

Perusal of the data presented in (Table 4) revealed that the average concentration of heavy metals in sunflower and maize stover grown with RDF (control) was 0.09 and 0.09 ppm Se, 0.14 and 0.13 ppm As and 0.26 and 0.25 ppm Pb, respectively. Application of fly ash @ 30 t/ha along with FYM @ 20 t/ha significantly increased the concentration of Se in sunflower and maize biomass during all the seasons. While the concentration of As and Pb remained non-significant in most of the seasons.The extent of increase in the concentration of heavy metals in sunflower stover ranged from 11.1 to 20.0 per cent in Se, 7.4 to 12.5 per cent in Pb and 0 to 13.3 per cent in As. In maize stover, it varied from 10.0 to 22.2 per cent in Se, 8.3 to 25.0 per cent in As and 0 to 13.6 per cent in Pb. Joseph, (1987) reported the increase in concentration of Pb, Se, Cr, As in leafy vegetables.

The average concentration of heavy metals in sunflower and maize biomass, respectively, grown with RDF (control) was 0.9 and 0.1 ppm Se, 0.14 and 0.12 ppm As, and 0.26 and 0.25 Pb.(Table 5). Application of fly ash @ 40 t/ha (T_4) increased the average concentration of heavy metals in sunflower and maize biomass to 0.11 and 0.13 ppm in Se, 0.16 and 0.15 ppm in As and 0.30 and 0.29 ppm in Pb, respectively. Comparison of T_4 treatment with that of control indicated that application of fly ash @ 40 t/ha significantly increased the concentration of Se and As in sunflower and maize biomass during all the seasons, but that of Se and As except during *kharif* 2006. The extent of increase in the concentration of heavy metals varied between 22.2 and 40.0 per cent in Se, 7.1 and 20.0 per cent As and 11.1 to 20.8 per cent in Pb.

Table 4: Effect of fly ash (max. yield) on heavy metal content (ug/kg) in biomass of irrigated vertisols

Material/Element	Selenium			Arsenic			Lead		
Av. Content in FA	BDL			BDL			0.052		
Av. Content in PA	BDL			BDL			0.049		
Initial level in soil	BDL			BDL			0.182		
Cropping sequence & Name of crop	T_1 (control) Tr Mean ***	Tr. Mean***	% diff. over control	T_1 (control) Tr Mean ***	Tr. Mean***	% diff. over control	T_1 (control) Tr Mean ***	Tr. Mean***	% diff. over control
kharif 2004 sunflower	0.09	0.10	11.11**	0.14	0.14	NS	0.27	0.29	7.91**
rabi 2004 – 05 maize	0.10	0.11	10.00**	0.12	0.12	NS	0.25	0.29	NS
kharif 2005 sunflower	0.09	0.11	11.11**	0.14	0.13	NS	0.27	0.24	NS
rabi 2005-06 maize	0.10	0.11	10.00**	0.12	0.13	8.33**	0.25	0.24	NS
kharif 2006 sunflower	0.10	0.12	20.00**	0.15	0.17	13.33**	0.24	0.27	12.50**
rabi 2006-07 maize	0.09	0.11	22.20**	0.12	0.15	25.00**	0.22	0.25	13.60**

* and ** Significance of values at P=0.05 and 0.01, respectively *** Mean of three replications

Table 5 : Effect of fly ash (max. dose) on heavy metal content (ug/kg) in biomass of irrigated vertisols

Material/Element	Selenium			Arsenic			Lead		
Av .content in FA	BDL			BDL			0.052		
Av. Content in PA	BDL			BDL			0.049		
Initial level in soil	BDL			BDL			0.184		
Cropping sequence & Name of crop	T_1 (control) Tr Mean ***	Tr. Mean***	% diff. over control	T_1 (control) Tr Mean ***	Tr. Mean***	% diff. over control	T_1 (control) Tr Mean ***	Tr. Mean***	% diff. over control
kharif 2004 sunflower	0.09	0.11	22.22**	0.14	0.15	7.14**	0.27	0.33	11.11**
rabi 2004-05 maize	0.10	0.12	20.00**	0.12	0.14	16.67**	0.25	0.28	12.0**
kharif 2005 sunflower	0.09	0.09	NS	0.14	0.14	NS	0.27	0.30	11.11**
rabi 2005-06 maize	0.10	0.13	30.00**	0.12	0.16	33.33**	0.25	0.29	16.0**
kharif 2006 sunflower	0.10	0.14	40.00**	0.15	0.18	20.00**	0.24	0.29	20.83**
rabi 2006-07 maize	0.09	0.12	33.30**	0.13	0.17	30.80**	0.22	0.26	18.20**

* and ** Significance of values at P=0.05 and 0.01, respectively *** Mean of three replications

It was clear from the (Table 6) that the concentration of Se, As and Pb in sunflower and maize stover grown in control plot averaged 0.09 and 0.1 ppm Se,0.14 and 0.12 ppm As and 0.26 and 0.24 ppm Pb, respectively. Combined application of pond ash @30 t/ha and FYM @20 t/ha did not influence the concentration of Se, As and Pb significantly. However, the magnitude of increase in the concentration of heavy metals in sunflower stover varied from 0 to 22.2 per cent in Se, 0 to 16.7 per cent in As and 7.4 to 16.7 per cent in Pb. Similarly, in maize biomass, it varied between 0 and 11.1 per cent in Se and 8.0 and 18.2 per cent in Pb.

Table 6 : Effect of pond ash (max. yield) on heavy metal content (ug/kg) in biomass of irrigated vertisols

Material/Element	Selenium			Arsenic			Lead		
Av .content in FA	BDL			BDL			0.052		
Av. Content in PA	BDL			BDL			0.049		
Initial level in soil	BDL			BDL			0.184		
Cropping sequence & Name of crop	T_1 (control) Tr Mean ***	Tr. Mean***	% diff. over control	T_1 (control) Tr Mean ***	Tr. Mean***	% diff. over control	T_1 (control) Tr Mean ***	Tr. Mean***	% diff. over control
kharif 2004 sunflower	0.09	0.07	NS	0.14	0.13	NS	0.27	0.29	7.14**
rabi 2004-05 maize	0.10	0.08	NS	0.12	0.13	8.33**	0.25	0.27	8.00**
kharif 2005 sunflower	0.09	0.11	22.22**	0.14	0.14	NS	0.27	0.28	NS
rabi 2005-06 maize	0.10	0.10	NS	0.12	0.13	8.33**	0.25	0.26	NS
kharif 2006 sunflower	0.10	0.11	22.22**	0.15	0.13	NS	0.24	0.28	16.66**
rabi 2006-07 maize	0.09	0.10	11.10**	0.13	0.13	8.30**	0.22	0.26	18.20**

* and ** Significance of values at P=0.05 and 0.01, respectively *** Mean of three replications

The average concentration of heavy metals in sunflower and maize stover grown with RDF (control) was 0.09 and 0.10 ppm Se, 0.14 and 0.12 ppm As and 0.26 and 0.24 ppm in Pb, respectively (Table 7). The similar results were reported by (Kiteagishi and Yamane, 1981) in Pb and Se of celery.

Application of pond ash @ 40 t/ha in vertisols under irrigated condition significantly increased the concentration of Se in sunflower and maize stover during all the seasons, but that of As and Pb during all the seasons except in *kharif* 2005. The extent of increase in the concentration of heavy metals in sunflower stover ranged from 11.1 to 60 per cent in Se, 7.1 to 26.7 per cent in As and 11.1 to 29.2 per cent in Pb. Similarly, in succeeding maize crop, it varied between 10.0 and 20.0 per cent in Se, 8.3 and 25.0 per cent in As and 8.0 and 16.0 per cent in Pb.The level of Pb in fly ash (0.052 ppm) was comparable with that in pond ash (0.04 q ppm). But, the level of se and As was below detectable limit. It was because, Pb was relative by immobile in alkaline condition than that of Se and As.

Application of either fly ash or pond ash @ 40 t/ha in vertisols increased the concentration of heavy metals in sunflower stover and maize stover, during most of the seasons. Similar trend was observed with the application of fly ash or pond ash @ 40 t/ha under irrigated condition.

Table 7 : Effect of pond ash (max. dose) on heavy metal content (ug/kg) in biomass of irrigated vertisols

Material/Element	Selenium			Arsenic			Lead		
Av. content in FA	BDL			BDL			0.052		
Av. content in PA	BDL			BDL			0.049		
Initial level in soil	BDL			BDL			0.184		
Cropping sequence & Name of crop	T_1 (control) Tr Mean ***	Tr. Mean***	% diff. over control	T_1 (control) Tr Mean ***	Tr. Mean***	% diff. over control	T_1 (control) Tr Mean ***	Tr. Mean***	% diff. over control
kharif 2004 sunflower	0.09	0.10	11.11**	0.14	0.15	7.14**	0.27	0.30	11.11**
rabi 2004-05 maize	0.10	0.12	20.00**	0.12	0.13	8.33**	0.25	0.27	8.00**
kharif 2005 sunflower	0.09	0.12	33.33**	0.14	0.13	NS	0.27	0.28	NS
rabi 2005-06 maize	0.10	0.11	10.00**	0.12	0.15	25.00**	0.25	0.29	16.00**
kharif 2006 sunflower	0.10	0.16	60.00**	0.15	0.19	26.60**	0.24	0.31	29.16**
rabi 2006-07 maize	0.09	0.14	40.00**	0.13	0.17	30.80**	0.22	0.29	26.10**

* and ** Significance of values at P=0.05 and 0.01, respectively *** Mean of three replications

However, the concentration of heavy metals in those crops was comparable with those grown in some normal soils. Combined application of either fly ash or pond ash @ 40 t/ha or 30 t/ha and FYM @ 20 t/ha did not alter the concentration of heavy metals during most of the seasons, as compared to control. It was possibly due to decontamination of toxic elements, present in fly ash/pond ash by adsorption of the toxic metals ions to the organic legends. The results are in line with (Srivastava and Gupta, 1996 and Pichel *et al*., 1994).

Effect of fly ash and pond ash on the activity of radionuclides in biomass :

Perusal of (Fig. 1) revealed that the activity of radionuclides in sunflower and maize stover grown with RDF averaged 0.56 and 0.60 Bq/kg ^{226}Ra,0.69 and 0.86 Bq/kg ^{228}Ac and 30.47 and 32.47 Bq/kg ^{40}K, respectively. Application of fly ash @ 30 t/ha along with FYM @ 20 t/ha significantly increased the activity of ^{40}K during all the seasons except *kharif* 2004, the activity of ^{228}Ac during all the seasons except *kharif* 2005 and *rabi* 2005. While the activity of 226Ra remained non-significant during most of the seasons. The per cent increase in the activity of radionuclides in sunflower stover varied from 11.3 to 24.1 in ^{226}Ra, 11.0 to 25.0 in ^{228} Ac and 7.0 to 164.5 in ^{40}K. Similarly, in maize stover it varied between 0 and 15.4 per cent in ^{226}Ra, 8.0 and 15.4 per cent in ^{228}Ac and 13.1 and 15.3 per cent in ^{40}K.

The activity of radionuclides in sunflower and maize stover in control plot soil (Fig. 2) averaged 0.56 and 0.60 Bq/kg ^{226}Ra,0.69 and 0.86 Bq/kg ^{228}Ac and 30.47 and 32.47 Bq/kg ^{40}K. Application of fly ash @ 40 t/ha significantly increased the activity ^{40}K in both sunflower and maize biomass during all the seasons. But, the activity of ^{226}Ra remained unaffected in biomass of maize during *rabi* 2006 and that of ^{228}Ac during 1997-98 and 1998-99. The magnitude of increase in the activity of radionuclides in sunflower stover due to application of fly ash over control ranged from 16.1 to 26.9 per cent in ^{226}Ra, 19.2 to 26.0 per cent in ^{228}Ac and 9.5 to 16.1 per

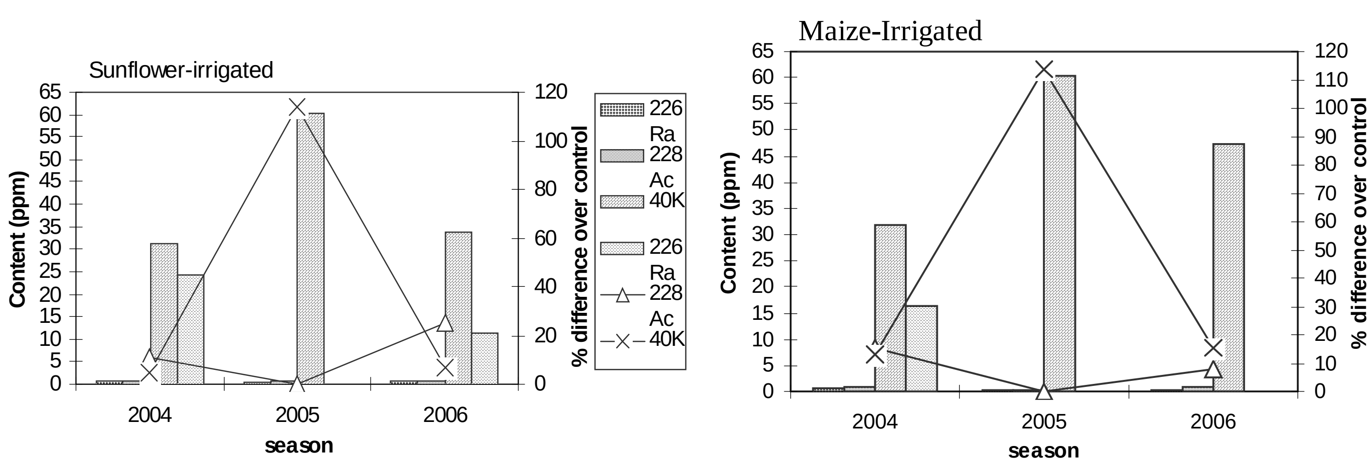

Fig.1 : Effect of fly ash (max.yield) on the radionuclide content (Bq/kg) in biomass in irrigated vertisols

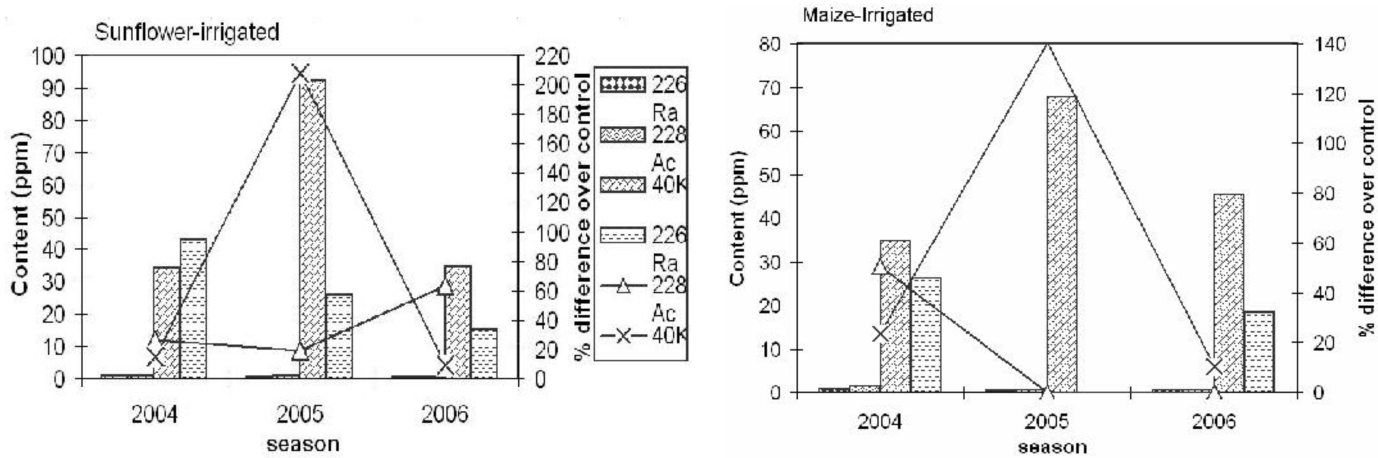

Fig. 2 : Effect of fly ash (max.dose) on the radionuclide content (Bq/kg) in biomass in irrigated vertisols

cent in ^{40}K. Similarly, in maize stover it varied from 18.4 to 26.2 per cent in ^{226}Ra, 0 to 50.5 per cent in ^{228}Ac and 10.5 to 140.4 per cent in ^{40}K.

The average activity of radionuclides in sunflower and maize stover grown with RDF was 0.56 and 0.6 Bq/kg ^{226}Ra,0.69 and 0.86 Bq/kg ^{228}Ac and 30.47 and 32.13 Bq/kg ^{40}K, respectively (Fig. 3). Application of pond ash @ 30 t/ha along with FYM @ 20 t/ha significantly increased the activity of ^{40}K in both sunflower and maize stover during all the seasons. But, the activity of ^{228}Ac remained non-significant during *rabi* 2005-06 and that of ^{226}Ra during all the three *rabi* seasons. The extent of increase over control in the activity of radionuclides in sunflower stover varied from 13.8 to 15.5 per cent in ^{226}Ra, 5.5 to 63.3 per cent in ^{40}K. Similarly, in the succeeding maize stover, it varied between 0 and 50.5 per cent in ^{228}Ac and 8.2 and 12.2 per cent in ^{40}K.

The average activity of radionuclides in sunflower and maize stover grown with RDF in black soil (Fig. 4) was 0.57 and 0.60 Bq/kg ^{226}Ra,0.69 and 0.86 Bq/kg ^{228}Ac and 30.47 and 32.47 Bq/kg ^{40}K, respectively. Application of pond ash @ 40 t/ha significantly increased the activity of ^{226}Ra and ^{228}Ac during all the seasons except *rabi* 2005-06. And the activity of ^{40}K was significant during all the seasons except *kharif* 2006. The per cent increase in the activity of radionuclides in sunflower stover varied from 15.3 to 40.7 per cent in ^{226}Ra, 27.4 to 65.0 per cent in ^{228}Ac and 2.2 to 218.1 per cent in ^{40}K. Similarly in maize stover, it ranged from 9.2 to 10.2 per cent in ^{226}Ra, 12.0 to 64.8 per cent in ^{228}Ac and 9.2 to 123.4 per cent in ^{40}K. Vijayan *et al*., (1998) reported the activity of radionuclides in rice and wheat.

The activity of radionuclides namely ^{226}Ra, ^{228}AC and ^{40}K in fly ash was 101.5, 109.3 and 361.4 Bq/kg, and the corresponding values in pond ash were 91.8, 106.0 and 342.4 Bq/kg, which was slightly lower as compared to fly ash. The effect of addition of either fly ash or pond ash at maximum dose either individually or in combination with FYM both under rainfed and irrigated conditions was assessed on the activity of radionuclides in both sunflower and maize stover over a period of 3 years. It was observed that even though application of fly ash @ 40 t/ha or @ 30

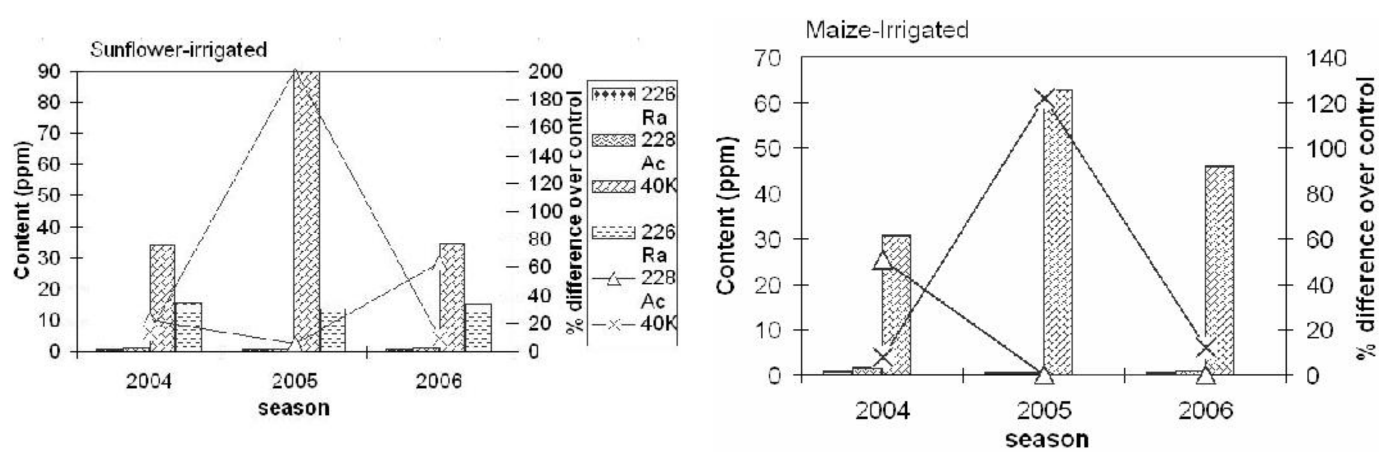

Fig. 3: Effect of pond ash (max.yield) on the radionuclide content (Bq/kg) in biomass in irrigated vertisols

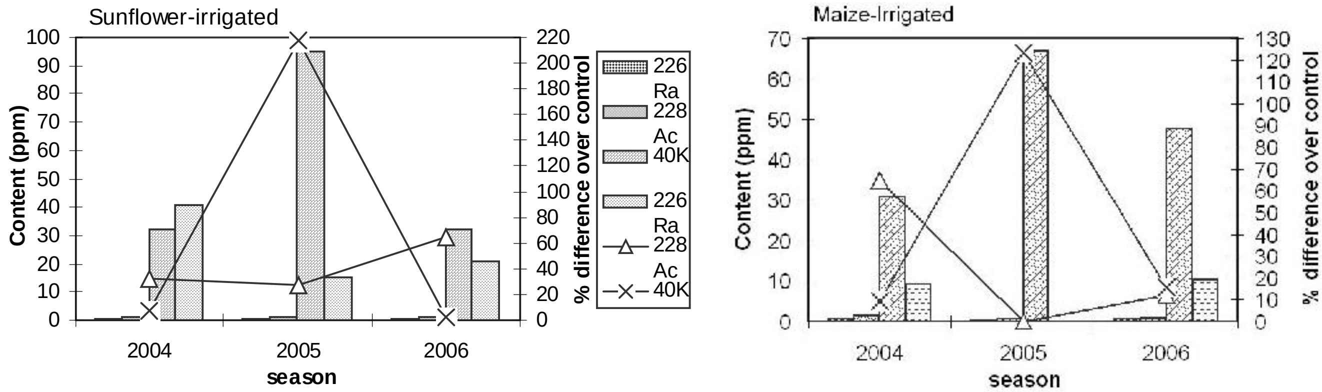

Fig.4 : Effect of pond ash (max.dose) on the radionuclide content (Bq/kg) in biomass in irrigated vertisols

t/ha increased the activity of these radionuclides in both sunflower and maize stover, the activity of these natural readionuclides are comparable with those crops grown in some normal soils. Similar effect was noticed with the application of pond ash at the corresponding level.

The effect of addition of either fly ash or pond ash at maximum dose either individually or in combination with FYM both under rainfed and irrigated conditions was assessed on the activity of radionuclides in both sunflower and maize stover over a period of 3 years. It was observed that even though application of fly ash @ 40 t/ha or @ 30 t/ha increased the activity of these radionuclides in both sunflower and maize stover, the activity of these natural readionuclides are comparable with those crops grown in some normal soils. Similar effect was noticed with the application of pond ash at the corresponding level.Application of fly ash/pond ash @ 30 t/ha under irrigated condition along with FYM 20 t/ha did not lower the activity of radionuclides in sunflower and maize stover, during most of the seasons.

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REFERENCES

Aitken, A.L., Campbell, D. and Bell. L.C. (1985). Properties of Australian fly ash relevant to their agronomic utilization. *Aust. J. Soil Res.*, **22**: 443-453.

Furry, A. K., Kelly, W. C., Bache, C. A., Gutenmann, W. H. and Lisk, D. J. (1976). Multi element uptake by vegetable and millet grown in pots on fly ash amended soils. *J. Agric. Food Chemistry*, **24**: 885.

Joseph Fail (1987). Concentration of Pb, Se, Cr and As in fly ash applied lettuce and mint. *Plant & Soil*, 101 – 149.

Kefer, R.F. and Sajwan, K. S. (1993). *Trace elements in coal and coal combination residues*, Ed. Levis Publication, Boca Raton.

Kene, D.R., Lanjewar, S.A., Ingole, B.M. and Chjaphale, S.D. (1991). Effect of application of fly ash on physico-chemical properties of soil. *Journal of Soils and Crops,* **1**(1): 11-18.

Kitagishi and Yamane, I. (1981). In: *Heavy Metal pollution in soils of Japan,* Japan Science Society Press, Tokyo, pp. 302.

Pichel, J.R., Dickk, W.A. and Sutton, P. (1994). Effect of organic amendments on availability of toxic elements in peat soils.

Sale, L.Y., Naeth, M.A. and Chanasyk, D.S. (1996). Growth response of barley on unweatherd fly ash amended soils. *J. Environ. Quality,* **25**: 684 -691.

Srivastava, P.C. and Gupta, U.C. (1996). *Trace elements in crop production.* Oxford and IBH publishing company Ltd., New Delhi.

UNSCEAR (1988). Report sources effects and risks of cornicing radiation, United Nations, New York.

Vijayan.V. and Behera, S.N. (1997) Characterization of natural radio activity of coal fly ash Proc. of Nat. Seminar on fly ash characterization and its geotechnical applications. (1999) 139 Ed. A. Sridharan, Allied Publishers Ltd., New Delhi.

Vijayan, V., Behera, S.N., Asokan, P. and Saxena Mohoini, (1998). Analysis of heavy metals and radio nuclides in crop grown on fly ash applied soils. Proc.of Nat. Seminar on fly ash characterization and its geo-technical applications, 145. Ed. A Sridharan, Allied Publishers Ltd., New Delhi.

Wong, J.W.C. and Wong, M.H. (1990). Effect of fly ash on yields and chemical composition of two vegetables (*Brassica parachiness and Chinesis*). *Agriculture Ecosystem & environment,* **30**: 251 – 264.