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Long-Term Effect of Fly Ash on Crop Yield and Soil Properties

N. A. YELEDHALLI, S. S. PRAKASH, M. V. RAVI AND K. NARAYANA RAO

Department of Soil Science and Agricultural Chemistry
College of Agriculture, Raichur - 584 101, India

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Abstract : Realizing the gravity of the situation regarding management of very huge and unmanageable quantities of fly ash being currently generated by the thermal power plants in the country and the imperative need for its safe disposal and gainful utilization in agriculture. Long term field experiments have been designed to study in depth the bulk application of fly ash/ pond ash application @ 30-40 t/ha (one time and repeat application) with recommended dose of NPK fertilizers alone or along with FYM @ 20 t/ha was used for cultivation of sunflower maize crops in irrigated vertislos in rotation. The results indicated that the total yield of 35.7 q/ha was recorded in treatment receiving pond ash @ 40 t/ha along with FYM @ 20 t/ha followed by fly ash @ 30 t/ha. The in yield over control was 53.3 and 45.00 per cent respectively. The water holding capacity of soil increased from 64 to 67.5 per cent due to pond ash @ 40 t/ha application. However, there was marginal changes in soil physico-chemical properties with respect to either fly ash or pond ash.

Key words: Fly ash/pond ash, crop yield, water holding capacity, vertisol

Introduction

In India, the generation of huge quantity of fly ash nearly 120 million tonnes/year with its overall 10-15% utilization mainly in the area of civil construction, being far below the fly ash utilization in overseas countries, if not seriously considered and taken care of the associated problems of environmental pollution and occupation of large area for its disposal seem to be much more alarming in future. Coal ashes contain not only the essential but nonessential elements. But the trace and heavy metals which can adversely affect crop, soil and perhaps ground water quality. And these need to be urgently addressed through various technologies in different sectors.

In a number of investigations on the aspect of utilization of fly ash for agricultural purposes. It has been reported that FA (Fly Ash) acts as a source of micro-nutrients essential for plant life and agricultural crops as well as in correcting the deficiency of several micronutrients and preventing the toxicity of some metal ions through the neutralization of soil acidity. The effect of fly ash addition on the uptake/enrichment of various nutrients and heavy trace elements in soil as well as various crops has been investigated with safe use of crop produce for human consumption (Page *et al.*, 1979 and Doran and Martins, 1972).

The Raichur Super Thermal Power Station (RSTPS) is located at Shaktinagar, Raichur district in Karnataka State. Coal is the main fuel at RSTPS with an ash content of 40 – 45 per cent. Nearly 18000 metric tones of coal are burnt every day, generating about 7000 metric tones of fly ash. In number of investigations on aspect of utilization of FA/PA for agricultural purposes has been reported by (Ciravolo and Adrino, 1979). The perusal of properties of both fly ash and pond ash chemically on par with each other but the pond ash contains higher percentage of larger sized particles. Further, it was suggested that pond ash has low reserve alkalinity, low soluble salt content and high water retention capacity than fly ash.

The present studies on utilization of fly ash in agriculture were under taken with a view to develop data from field experiments on the beneficial/adverse effects of fly ash/ pond ash in agriculture with special emphasis on changes in physico-chemical properties of soil due to bulk application of FA/PA on long term basis in sunflower- maize cropping sequence. Field experiments on permanent basis were laid out on vertisols under irrigated conditions.

Material and Methods

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 longitude and at an altitude of 389 meters above mean sea level (MSL). 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 RSTPS, Shaktinagar 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). The earlier experiment conducted at College of Agriculture Raichur have suggested application of fly ash / pond ash @ 30 t/ha found to be effective in increasing the crop yield and soil properties, which has been included in UAS Dharwad, package of practices for high yields. These amendment was 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. Each year during kharif season experiment was conducted to study the direct effect of application of fly ash/ pond ash on crop growth and yield and soil properties. During rabi season, the residual effect of fly ash/pond ash on the succeeding crop was evaluated

Soil, fly ash and FYM : Composite soil samples collected from the experimental site before the start of experiments were analyzed for various parameters by adopting standard methods (Jackson, 1973). The data are presented in Table 1. Fly ash, pond ash and FYM collected each year of experimentation and samples have been analyzed for their physico-chemical properties and expresses as ranges. The FYM was neutral in reaction (pH 7.1 to 7.7), low in EC (0.32 to 0.60 dS/M) and rich in available nutrients. The available N, P_2O_5 and K_2O contents varied from 310 to 355, 795 to 890 and 1020 to 1126 mg/kg respectively. The available sulphur varied from 14 to 55.3 mg/kg. The total contents of Cu, Fe, Mn and Zn varied from 30 to 40, 2800 to 11300, 20 to 30 and 20 to 80 mg/kg respectively. While the DTPA extractable micronutrient content of Cu, Fe, Mn and Zn varied from 1.5 to 2.1, 22.1 to 26.2, 10.0 to 11.2 and 2.8 to 3.3 mg/kg respectively.

Results and Discousion

Characterization of fly ash, pond ash, soil and FYM: The soil is clay in texture, alkaline in reaction, low in soluble salt and high in water holding capacity. The texture of dry fly ash represent silty clay loam with 40 per cent silt sized particles. It is highly alkaline in reaction, low in soluble salt content and water holding capacity. The texture of pond ash is silt loam with higher proportion of silt sized particles. It is alkaline in reaction, low in soluble salt but high in water holding capacity. The black soil has constraints of poor aeration for crop production. Fly ash as compared to pond ash is more alkaline and has less water holding capacity, which makes it inferior to pond ash for agriculture utilization. Similar results were also reported by Chang et al (1977), Hussian Saheb (1993) and Adrino *et al.* (1980).

A comparison between the physical characteristics of both the FA and PA and soil (Table 1) showed that (i) the vertisol and both the ashes were alkaline, (ii) BD of both the ashes were lower, while WHC and porosity were higher than the soil, (iii) silt content of both the ashes was higher than the soil.

Effect of fly ash/Pond ash on crop yield : The data furnished in Table 2 revealed that during kharif 2004, the seed yield of sunflower in control was 5.2 q/ha, it has increased significantly due to application of either fly ash or pond ash. The maximum seed yield of 9.3 and 9.2 q/ha were recorded in T_3 (which consists of fly ash @ 30 t/ha + FYM @ 20t/ha applied every year) and T_7 (pond ash applied @ 30 t/ha along with FYM @ 20 t/ha every year) treatments, respectively. The per cent increase in yield over control was 78.4 and 76.9, respectively. During kharif 2005, the seed yield of sunflower in control was 9.6 q/ha, which increased significantly due to application of either fly ash or pond ash. The maximum seed yield of 13.6 and 13.5 q/ha was obtained in T_3 and T_7 treatments, respectively, which accounts to 41.7 and 40.6 per cent increase in yield over control, respectively . During kharif 2006 also, the seed yield of sunflower varied from 6.7 q/ha in control to a maximum of 10.2 q/ha in both T_3 and T_7 treatments with an increase of 52.2 per cent over control. Lobl *et al.* (1971) reported increased seed yield of sunflower in red and black soil. It was attributed to increase in soil moisture holding capacity, friability indices and increased nutrient availability.

During rabi 2004, the yield of maize in control was 14.8 q/ha, which increased significantly due to application of either fly ash or pond ash. The maximum grain yield of 21.16 and 20.6 q/ha was recorded in T_3 treatment followed by T_7 treatment. The increase in yield over control was 48.0 and 39.2 per cent respectively . During rabi 2005, the grain yield recorded in control was 18.7 q/ha. Application of either fly ash or pond ash increased the grain yield significantly. The maximum grain yield recorded was in T_7 treatment which was accounts for 36.4 per cent higher in yield over control. During rabi 2006,the grain yield of maize in control was 17.4 q/ha which increased significantly to a maximum of 27.8 q/ha in T_7 treatment. The per cent increase in yield was 60.35 over control. Similarly, T3 recorded the grain yield of 25.85 q / ha. Similar observations were also been made by Plank *et al.* (1975) and Sajwan *et al.* (1996).

In cropping system, the grain yield of crops in control was 14.3 q/ha. Application of different levels of either fly ash or pond ash increased the grain yield significantly. The maximum grain yield of 21.30 q/ha was observed in T_7 treatment. The per cent increase in grain yield over control due to T_7 and T_3

Table 1. pH and other physical properties of soil, fly ash, pond ash and farm yard manure

Parameters	Initial	2004			2005			2006		
	Vertisol	Fly ash	Pond ash	FYM	Fly ash	Pond ash	FYM	Fly ash	Pond ash	FYM
pH	8.60	10.50	9.30	7.10	9.80	9.00	7.20	9.30	88.85	7.23
EC (dSm-1)	0.10	1.00	0.50	0.30	0.90	0.30	0.35	0.75	0.45	0.45
BD (g/cc)	1.30	0.95	1.10	0.64	1.00	1.00	0.70	0.94	1.12	0.66
WHC (%)	64.20	48.10	63.60	145.40	50.20	68.10	155.20	45.20	56.50	140.35
Porosity (%)	50.90	-	-	-	-	-	-	-	-	-
Texture										
Sand (%	9.20	21.50	36.50	-	19.80	30.20	-	19.10	32.80	-
Silt (%)	27.00	40.10	45.60	-	50.20	45.60	-	49.50	48.20	-
Clay (%)	63.80	38.40	24.20	-	30.00	24.20	-	30.20	18.60	-
Textural class	C	Sicl	Sil	-	Sicl	Sil	-	Sicl	Sil	-

Table 2. Long term effect of fly ash levels on grain yield of crops in irrigated vertisols

Treatment/ Cropping season & Name the of crop	Critical difference (@ 5 %)	T_1: control – (RDF) Treatment Mean ***	T_2: RDF + FA@30t/ha every year			T_3: T_2 + FYM @ 20 t/ha every year			T_4: RDF + FA @ 40t/ha every year			T_5: RDF + FA @ 60 t/ha once in three years		
			Tr. Mean*** (q/ha)	% diff. over control	Sig. Diff. over control	Tr. Mean*** (q/ha)	% diff. over control	Sig. Diff. over control	Tr. Mean*** (q/ha)	% diff. over control	Sig. Diff. over control	Tr. Mean*** (q/ha)	% diff. over control	Sig. Diff. over control
Kharif 2004 sunflower	0.77	5.2	8.3	6.0	*	9.2	76.9	*	8.7	67.3	*	8.4	61.5	*
Rabi 2004- 05 maize	3.28	14.8	18.4	24.3	*	21.9	48.0	*	20.0	35.1	*	19.0	28.4	*
Kharif 2005 sunflower	1.14	9.6	11.8	22.9	*	13.6	41.7	*	13.0	35.4	*	11.7	21.9	*
Rabi 2005 -06 maize	2.26	18.7	23.0	23.0	*	24.0	28.3	*	22.1	18.2	*	22.0	17.6	*
Kharif 2006-sunflower	1.82	6.7	8.0	19.4	NS	10.2	52.2	*	8.4	25.4	NS	8.7	29.9	*
Rabi 2006 -07 maize	0.74	17.4	19.4	12.1	*	25.9	49.0	*	20.2	16.2	*	17.7	1.8	NS
Pooled	1.82	14.3	18.0	26.0	*	21.0	47.1	*	19.4	31.3	*	17.8	27.3	*

Treatment/ Cropping season & Name the crop	Critical difference (@ 5 %) Mean ***	T1: control – (RDF) Treatment Mean*** (q/ha)	T6: RDF + PA @ 30 t/ha every year			T7: T6 + FYM @ 20t/ha every year			T8:RDF + PA @ 40 t/ha every year			T9: RDF + PA@60 once in three years t/ha		
			Tr. over control	% diff. . over control	Sig. Diff Mean*** (q/ha)	Tr. over control	% diff. . over control	Sig. Diff Mean*** (q/ha)	Tr. over control	% diff. . over control	Sig. Diff Mean*** (q/ha)	Tr. over control	% diff. Diff. over control	Sig
Kharif 2004 sunflower	0.77	5.2	9.10	75.0	*	9.3	78.4	*	8.1	55.8	*	9.0	73.1	*
Rabi 2004 - 05 maize	3.28	14.8	19.20	29.7	*	20.6	39.2	*	19.5	31.8	*	20.1	35.8	*
Kharif 2005 sunflower	1.14	9.6	12.50	30.2	*	13.5	40.6	*	11.5	19.8	*	11.7	21.7	*
Rabi 2005 -06 maize	2.26	18.7	23.2	24.1	*	25.5	36.4	*	24.3	29.9	*	21.4	14.4	*
Kharif 200 sunflower	61.82	6.7	8.2	22.9	NS	10.2	52.2	*	8.2	22.4	NS	7.1	8.0	NS
Rabi 2006 -07 maize	0.74	17.4	22.0	26.6	*	27.8	60.4	*	20.4	17.6	*	17.5	1.0	NS
Pooled	1.82	14.3	18.9	32.3	*	21.3	49.2	*	18.3	30.6	*	17.5	25.0	*

* Sig @ 5% NS: Non significant, *** Mean of three replications

Table 3. Effect of maximum dose (40t/ha) of fly ash and pond ash and final status of composite soil properties.

Parameters	Soil		Fly ash @ 40 t/ha		Pond ash @ 40 t/ha	
	Initial (original)	Final (after 3 years)	Treatment mean	% difference over control	Treatment mean	% difference over control
pH	8.6	8.65	8.65	-	8.6	0.57
EC (dSm^{-1})	0.14	0.22	0.25	16.44	0.24	7.31
BD (g/cc)	1.3	1.29	1.28	0.78	1.28	0.78
WHC (%)	64.2	62.67	65.04	3.78	67.40	7.52
Porosity (%)	50.9	49.5	50.9	2.83	50.9	2.83
Sand (%)	9.2	9.6	9.8	2.08	10.0	4.17
Silt (%)	27.0	28.2	28.5	1.06	28.4	0.71
Clay (%)	63.8	62.2	61.7	0.8	68.6	0.96

Table 4. Effect of maximum yield of crops due to fly ash and pond ash and final status of composite soil properties.

Parameters	Soil		Fly ash @ 40 t/ha		Pond ash @ 40 t/ha	
	Initial (original)	Final (after 3 years)	Treatment mean	% difference over control	Treatment mean	% difference over control
pH	8.6	8.65	8.61	0.46	8.57	0.92
EC (dSm^{-1})	0.14	0.22	0.288	30.54	0.25	11.87
BD (g/cc)	1.3	1.29	1.27	1.55	1.27	1.55
WHC (%)	64.2	62.67	66.07	5.43	67.12	7.10
Porosity (%)	50.9	49.5	51.70	4.44	51.7	4.44
Sand (%)	9.2	9.6	10.0	4.17	9.8	2.08
Silt (%)	27.0	28.2	28.2	0.0	28.2	0.0
Clay (%)	63.8	62.2	61.8	0.64	62.0	0.32

treatments was 49.2 and 47.1 respectively than other treatments receiving either fly ash or pond ash were at par. The pooled analysis for the cropping system has been worked out by taking the concept of equivalent yield considering the prevailing market price of commodities at harvest. The maize yield was converted to sunflower yield by multiplying by the factor 0.42..The pooled data for the cropping system indicated that the total yield of edible product in control was 14.3 q/ha which increase significantly due to application of fly ash. The highest yield of 21.34 q/ha was recorded in T_7 followed by T_3 (21.04 q/ha) treatment. The increase in yield over control was 49.23 and 47.13per cent respectively.

Application of either pond ash or fly ash increased the grain yield of both sunflower and maize significantly. However, application of ash in conjunction with FYM produced the maximum yield. There was no significant difference between fly ash and pond ash treatments on crop yield response.

Physical properties of fly ash /pond ash and soil :The effect of fly ash / pond ash application on mechanical composition was significant. The sand and silt content increased from 63.8 to 61.6 %. The pH, EC and BD of soil did not change significantly due to application of fly ash / pond ash. The porosity increased marginally 50.9 % in control to 51.7 % due to application of fly ash. The water holdingreatments (Table 3). Capacity of soil was increased to maximum of 67.4 % inT7 treatments (table 3).

Effect of fly ash application on mechanical composition of soil was significant. The sand and silt content increased from 9.2 to 10.0 per cent and from 27.0 to 28.5 per cent respectively. On the contrary, the clay content of soil decreased from 63.8 to 61.6 per cent (Table 4). The pH, EC and bulk density of soil did not change significantly due to application of either fly ash or pond ash. Soil porosity increased marginally from 50.9 per cent in control to 51.7 per cent due to application of fly ash. The WHC of black soil increased significantly. It was 64.2 per cent in control and increased to a maximum of 67.4 per cent in T_8 treatment. Application of fly ash altered the textural class of the soil towards increasing sand and silt content, consequently the soil porosity and WHC increased significantly. Application of fly ash / pond ash altered the textural class of soil towards increasing sand and silt content, consequently soil porosity and water holding capacity increased significantly.

Water retention capacity of soil : The initial content of moisture in soil (Table 5) at 30 and 1500 kPa was 36.7 and 16.4 per cent, respectively. The available water content in soil was 20.3 per cent. Similarly, the initial content of moisture in soil before the start of the experiment was 37.3 per cent of 30 kPa and 16.2 per cent at 1500 kPa and available moisture content was 24.1 per cent. Application of fly ash and pond ash either individually or in combination with FYM increased the water retention capacity of soil at both the suctions.

The moisture content of 30 and 1500 kPa in pond ash amended soils was 34.5 and 14.7 per cent, respectively. The extent of increase in moisture retention at 30 and 1500 kPa due to T_7, T_8 and T_3 treatment over control was 17.2, 8.6 and 12.8 per cent respectively. Similarly, the available water was highest in

Table 5. Effect of fly ash levels on water retention capacity of irrigated vertisols during kharif 2004 before sunflower and 2006 after maize

Treatment	Control	A= T-4(Tr Max Fly ash Dose @ 40 t/ha)								B= T8 (Tr Max Pond ash Dose @ 40t/ha)					
Cropping season& Name of crop Kharief sunflower - rabi maize	a=% at field cap(1/3 Bars)	b=% at PWP (AT 15 Bars)	1=Av. Water (a-b)	% at FC (1/3Bars)		%at PWP (at 15 Bars)			Av.water	% at FC (1/3Bars		%at PWP (at 15 Bars)			Av.water
				C=Tr Mean ***	Dif. over control & %dif over control= (c-a)	D= Tr Mean ***	Dif. over control & %dif over control= (d-b)	2= Tr Mean *** (c-d)	Dif. over control & %dif over control= (2-1)	C=Tr Mean ***	Dif. over control & %dif over control= (c-a)	f= Tr Mean ***	Dif. over control & %dif over control= (f-b	3= Tr Mean ***= e-f)	Dif. over control %dif over control= (3-1
Initial	36.7	16.4	20.3	36.7	0.00	16.4	0.00	20.30	0.0	36.7	0	16.4	0	20.3	0
Final	37.29	16.18	21.11	38.04	0.75 (2.01)	16.31	0.13 (0.8)	21.73	0.62 (2.94)	39.44	1.15 (5.77)	16.48	0.30 (1.85)	22.96	1.85 (8.62)
Treatment	Control	C= T3 (Tr Max. yield with fly ash (13.6 q/ha)								D= T7 (Tr. Max. With pond ash (13.5 q/ha)					
Cropping season& Name of crop Kharief sunflower - rabi maize	a=% at field cap(1/3 Bars)	b=% at PWP (AT15 Bars)	1=Av. Water (a-b)	% at FC (1/3Bars)		%at PWP (at 15 Bars)			Av.water	% at FC (1/3Bars)		%at PWP (at 15 Bars)			Av.water
				G=Tr Mean ***	Dif. over control & %dif over control= (g-a)	H= Tr Mean ***	Dif. over control & %dif over control= (h-b)	4= Tr Mean *** (g-h)	Dif. over control & %dif over control= (4-1)	I=Tr Mean ***	Dif. over control & %dif over control= (I-a)	J= Tr Mean ***	Dif. over control %dif over control= (J-b)	5= Tr Mean ***= I-J	Dif. over control & %dif over control= (5-1)
Initial	36.7	16.4	20.3	36.7	0.00	16.4	0.00	20.30	0.0	36.7	0	16.4	0	20.3	0
Final	37.29	16.18	21.11	38.62	1.33 (3.57)	16.13	0.05 (0.30)	22.49	1.38 (6.54)	39.48	2.19 (5.87)	16.73	0.55 (3.40)	22.75	1.64 (7.77)

the treatment T_7 – pond ash @ 30t/ha with FYM @ 20 t/ha (24.8%). The increase in available water in T_7 treatment over control was 17.2 per cent. Application of fly ash to soils would increase the available water content of soil (Chang et al., 1977 and Campbell *et al*., 1983).

The initial moisture in soil at 30 and 1500 kPa was 23.2 and 9.1 per cent and 36.1 and 16.4 per cent respectively. Hence the available water content was 20.3 per cent. It is obvious that the soil had higher available water content because of its high clay and silt content. Fly ash applied to sunflower crop during kharif 2006 season had significant residual effect on the succeeding maize crop in vertisols. The maximum grain yield of maize (27.8 q/ha) was recorded in T_7 treatment receiving pond ash @ 30 t/ha along with FYM.

The beneficial effect of fly ash on improvement of soil health in respect of physico-chemical parameters, nutritional status and microbial population may be due to the cumulative effect of improvement in individual physico-chemical characteristics. Due to the presence of CaSi minerals, having pozzolanic properties. On its addition to soil likely to improve physical properties (Fulekar and Dave, 1986). The fly ash brings about improvement in various physico-chemical properties such as BD, porosity, WHC, hydraulic conductivity etc. of soil. Likewise, since fly ash contains much silt (about 51%).

Effect of fly ash application on mechanical composition was significant. The sand and silt content increased from 9.2 to 10.0 per cent and from 27.0 to 28.5 per cent respectively. On the contrary, the clay content of soil decreased from 63.8 to 61.6 per cent. The pH, EC and bulk density of soil did not change significantly due to application of either fly ash or pond ash. Soil porosity increased marginally from 50.9 per cent in control to 51.7 per cent due to application of fly ash. The WHC of soil increased significantly. It was 64.2 per cent in control and increased to a maximum of 67.4 per cent in T_8 treatment. Application of fly ash / pond ash altered the textural class of the soil towards increasing sand and silt content, consequently the soil porosity and WHC increased significantly, which improved the root and shoot development of crops and yield.

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