FLY ASH UTILIZATION IN RICE PRODUCTION: A SUCCESS STORY

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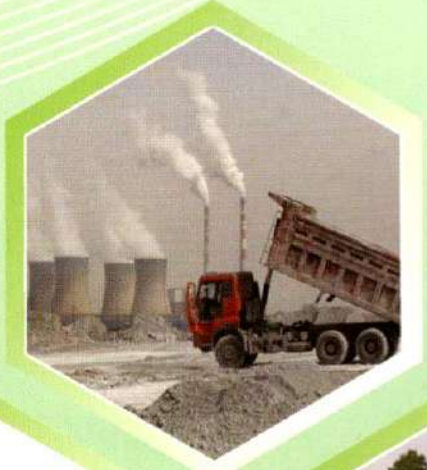

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Background

Coal is the principal energy source in India which is used for approximately 62% of electric power generation in the country. Fly ash, a finely divided residue resulting from the combustion of the coal in thermal power plant is regarded as an amorphous ferro-alumino-silicate mineral containing the naturally occurring essential elements similar to that of soil except humus and nitrogen. This has been considered as a problematic solid waste all over the world. In India the annual production of fly ash is nearly 120 million tons and likely to increase to a staggering 600 million tons per year by 2030-31 as per the estimates of Ministry of Power as well as Planning Commission. Out of 120 million tons, only 10-15% being utilized mainly in the manufacturing of cement, road construction, bricks, tiles, which is far below the fly ash utilization in overseas countries. Even if these industries become prosperous, a large portion of the ash will require other environmentally friendly uses. If not seriously considered and taken care of, the associated problems of environmental pollution and occupation of large area for disposal seem to be much more alarming in future. A great deal of research has been conducted to identify and determine the feasibility of utilizing fly ash in agricultural applications. Alkaline fly ash can be used to ameliorate the acid soils; it can also act as a soil modifier to upgrade the physical properties and improve the soil structure, upgrade the chemical and biological quality of soil, capacity of water retention, nutrient availability and thus participate in the optimization of plant growth.

Fly ash as an soil ameliorant and nutrient source for rice

Most of coal based thermal power plants are concentrated in the eastern part of the country where rice is grown as a predominant crop. Hence, fly ash disposal has natural preference for rice fields because of its inherent properties like plant nutrient content, high pH and particulate nature. On the other hand, the rice productivity in general is very low in Eastern India and the average yield of rice is about half of those in other parts of the country. Presence of extreme light textured soils as well as very heavy textured soils limits the rice crop growth and productivity in this region. The fly ash being in the intermediate particle size range of sand and clay, can improve the water and air permeability in these soils. The acid soils could be benefitted from the incorporation of fly ash having higher pH. In Odisha alone, 12.5 M ha of area (about 80% of the total geographical area) is under acid soils. Of the many possible beneficial applications, fly ash as an ameliorant can improve the physical, chemical and biological properties of rice soils and could be a source of readily available plant macro and micronutrients. Thus rice soil can serve as a sink for disposal of fly ash with additional benefit to the farmers.

Properties of fly ash used

Particulars	Content
Particle size, %	
2.0 – 0.02 mm	33.8
0.02 – 0.002 mm	55.9
<0.002 mm	10.3
Bulk density mg m^{-3}	0.99
pH (1:2)	7.65
EC, dSm^{-1}	0.40
Nitrogen, ppm	10.0
Phosphorus, %	0.05
Potassium, %	0.20
Calcium, %	2.0
Sulphur , %	0.8
DTPA Copper, ppm	2.2
DTPA Zinc, ppm	5.1
Silica (SiO_2) , %	58.5
Alumina (Al_2O_3) , %	28.8
Iron oxide (Fe_2O_3), %	6.0

Field evaluation of fly ash

The efficacy of fly ash in improving and maintaining the productivity of rice based cropping system was evaluated by conducting field experiments at Central Rice Research Institute, Cuttack under transplanted, wet direct seeded and rainfed dry direct seeded conditions. The treatments selected for the study comprised of different combinations of fly ash, FYM and chemical fertilizers *viz.*, FP (farmer's practice - 40:20:0 kg N:P:K ha^{-1}); RDF (Recommended Dose of Fertilizer- 80:40:40 kg N:P:K ha^{-1}); Lime + RDF; FA_{50} (Fly ash @ 50 tha^{-1}); FA_{100} (Fly ash @ 100 tha^{-1}); FA_{50} + $RDF_{75\%}$ + $FYM_{25\%}$ (25% of RDF through Farm Yard Manure on N basis); FA_{100} + $RDF_{75\%}$ + $FYM_{25\%}$; FA_{50} + FYM @12.5 tha^{-1} and FA_{100} + FYM @12.5 tha^{-1}. As per the treatment combinations fly ash, FYM and lime were incorporated manually 20 days before transplanting of rice with the help of a spade into the top 15 cm depth of soil. The application of lime and fly ash were one time application and has not been applied in the subsequent seasons. As per the standard practice, the crop was transplanted (varieties Gayatri in wet and Lalat in dry season)/ wet direct seeded (varieties Swarna in wet and Lalat in dry season) / dry seeded (variety Anjali). Ideal rice soil condition was maintained by providing a shallow submergence level of around 5 cm depth of water throughout the crop growth period for the transplanted and wet direct seeded rice while the dry direct seeded rice was grown purely under rainfed upland condition.

Fly ash application *versus* rice yield

Fly ash application @ 50 t recorded on par yield with that of farmers' practice and significantly lower yield than the 100% recommended dose of fertilizers under all three situations. However, application of fly ash @ 50 t ha^{-1} along with 75% RDF + 25% through FYM on N basis recorded on par yield with that of Lime + 100% RDF under transplanted as well as direct seeded conditions. No phytotoxicity symptoms were observed in any of the fly ash applied fields.

Effect of fly ash application on rice yield (t ha^{-1})

Treatment	Transplanted rice		Wet direct seeded rice		Rainfed dry direct seeded
	Wet season 2010	*Dry Season 2011*	*Wet season 2010*	*Dry Season 2011*	*Wet season 2010*
*FP (40:20:0 kg N:P:K ha^{-1})	4.37	4.02	4.42	3.11	2.58
$RDF (80:40:40 kg N:P:K ha^{-1})	5.23	4.85	5.71	4.04	3.32
Lime + RDF	5.90	5.28	6.63	4.96	3.82
Fly ash @ 50 tha^{-1} (FA_{50})	4.07	3.14	4.63	3.04	2.72
Fly ash @ 100 tha^{-1} (FA_{100})	3.73	2.83	4.07	2.67	2.66
FA_{50} + $RDF_{75\%}$ + #$FYM_{25\%}$	5.45	4.98	5.90	4.44	3.60
FA_{100} + $RDF_{75\%}$ + $FYM_{25\%}$	5.17	4.64	5.57	3.96	3.39
FA_{50} + FYM @12.5 tha^{-1}	4.81	3.67	4.93	3.38	3.14
FA_{100} + FYM @12.5 tha^{-1}	4.20	3.06	4.77	3.14	2.99
LSD (p=0.05)	0.60	0.53	0.56	0.49	0.42

*Farmer's practice; $RDF: Recommended dose of fertilizer; #$FYM_{25\%}$: 25% of RDF through Farm Yard Manure on N basis

Fly ash application *versus* soil properties

The fly ash application @ 100 t ha^{-1} improved the soil pH and was comparable with lime application. The physico-chemical properties of soil was improved due to bulk application of fly ash either alone or in combination with FYM and inorganic fertilizers. It improved the bulk density, water holding capacity, hydraulic conductivity of the soil besides increasing the available P and K compared to farmer's practice.

Effect of fly ash on the soil properties after one year of application under transplanted rice-rice system

Treatment	BD (Mg m^{-3})	HC (cm day^{-1})	WHC (%)	pH (1:2)	O.C (g kg^{-1})	Available Nutrients (kg ha^{-1})		
						N	P	K
*FP (40:20:0 kg N:P:K ha^{-1})	1.44	2.3	42.1	5.8	5.7	251.9	21.9	253.2
$RDF (80:40:40 kg N:P:K ha^{-1})	1.43	2.4	43.3	5.8	5.7	266.1	26.3	261.1
Lime + RDF	1.43	2.3	47.5	6.5	5.8	268.8	28.9	268.1
Fly ash @ 50 tha^{-1} (FA_{50})	1.41	2.5	49.7	6.0	5.6	232.5	21.9	269.3
Fly ash @ 100 tha^{-1} (FA_{100})	1.39	2.8	48.9	6.3	5.6	227.5	20.6	283.2
FA_{50} + $RDF_{75\%}$ + #$FYM_{25\%}$	1.40	2.6	50.2	6.0	5.8	245.3	26.7	280.0
FA_{100} + $RDF_{75\%}$ + $FYM_{25\%}$	1.39	2.8	51.7	6.1	5.8	240.2	22.4	282.0
FA_{50} + FYM @12.5 tha^{-1}	1.40	2.7	50.8	5.9	5.8	235.4	28.4	285.9
FA_{100} + FYM @12.5 tha^{-1}	1.39	2.9	51.2	6.1	5.7	230.5	24.3	284.3
LSD (p=0.05)	0.04	0.30	5.6	0.4	NS	24.3	5.2	12.7

BD: Bulk density; HC: Hydraulic Conductivity; WHC: Water Holding Capacity and O.C: Organic Carbon

Economics of fly ash application

Benefit Cost ratio was highest under the treatment applied with application @ 50 t ha^{-1} + 75% NPK through chemical fertilizers + 25% of RDF through Farm Yard Manure on N basis in all the three situations *viz.*, transplanted rice, wet direct seeded rice and dry direct seeded rice under rainfed upland condition during the wet season. In the subsequent dry season under transplanted

condition, comparable economic benefits were realized under the treatments Lime+RDF and fly ash @ 50 t ha^{-1} + 75% NPK through chemical fertilizers + 25% of RDF through Farm Yard Manure on N basis. If the cost of transportation of fly ash is included in the calculation (within 20-30 km radius of thermal power station or fly ash source, the same can be recovered in the first season and in the subsequent seasons net profit can be accrued to the farmers if he applies fly ash @ 50 t ha^{-1} + 75% NPK through chemical fertilizers + 25% of RDF through Farm Yard Manure on N basis).

Effect of fly ash application on yield and economic returns

Treatment	Transplanted rice		Wet direct seeded rice		Rainfed upland dry direct seeded rice
	Wet season 2010	Dry season 2011	Wet season 2010	Dry season 2011	Wet season 2010
*FP (40:20:0 kg N:P:K ha^{-1})	2.29	2.03	2.07	1.15	0.93
$RDF (80:40:40 kg N:P:K ha^{-1})	2.55	2.29	2.60	1.55	1.35
Lime + RDF	1.41	2.59	1.59	2.13	0.60
Fly ash @ 50 tha^{-1} (FA_{50})	2.44	1.65	2.57	1.35	1.29
Fly ash @ 100 tha^{-1} (FA_{100})	2.15	1.39	2.14	1.06	1.24
FA_{50} + $RDF_{75\%}$ + #$FYM_{25\%}$	2.59	2.56	2.61	1.72	1.44
FA_{100} + $RDF_{75\%}$ + $FYM_{25\%}$	2.40	2.32	2.41	1.42	1.30
FA_{50} + FYM @12.5 tha^{-1}	2.18	2.10	2.03	1.08	1.07
FA_{100} + FYM @12.5 tha^{-1}	1.78	1.58	1.93	0.93	0.98

*Farmer's practice; $RDF: Recommended dose of fertilizer; #$FYM_{25\%}$: 25% of RDF through Farm Yard Manure on N basis

Confidence building for large scale utilization of fly ash in rice cultivation

A *kisan mela* was organized at the time of maturity of the rice crop in order to sensitize the stake holders about the effect of fly ash on rice during which stake holders were exposed to on-station field experiment conducted at CRRI, Cuttack. Farmers and other stake holders from different districts of Odisha attended and participated in the discussions during the Scientist-Farmer interaction session. Twelve farmers were selected from three districts of Odisha broadly representing the major soil groups of the state and field demonstrations were conducted to observe the effect on their fields.

Conclusions

The challenge of safe disposal of ever increasing fly ash production commensurate with the increase in thermal power generation can be meet out by its utilization in rice cultivation with a value to farmers in terms of soil amelioration and nutrient addition. The rice field proximity to the source of fly ash production could be the potential sink and application of alkaline fly ash @ 50 t/ha along with 75% RDF and 25% through FYM on N basis can substitute lime - a costly material for ameliorating acid soils and increase the productivity of rice compared to farmers practice and recommended doses of fertilisers.

Financial support provided by the Department of Science and Technology, Government of India for this study is greatly appreciated.

Suggested Citation

Nayak, A.K., Raja, R., Rao, K.S., Panda, B.B. and Shukla, A.K. (2011). *Fly Ash Utilization in Rice Production: A Success Story.* Central Rice Research Institute, ICAR, Cuttack (Odisha), India. p6.

Published by:

Director

Central Rice Research Institute, Indian Council of Agricultural Research, Cuttack (Odisha) 753 006, India

November 2011

Laser typeset at the Central Rice Research Institute, Indian Council of Agricultural Research, Cuttack (Odisha) 753 006, India, and printed in India, by the Print-Tech Offset Pvt. Ltd., Bhubaneswar (Odisha) 751 024.

Layout and Design: S.K. Sinha, CRRI