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The effect of fly ash on vegetative growth and photosynthetic pigment concentrations of rice and maize

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Fly ash generated from coal based thermal power plants creates environmental problems due to improper utilization and disposal. The present study was conducted to study the effects of various concentrations of FA (20, 40, 60, 80 and 100%) on the growth and photosynthetic activity of *Oryza sativum* (rice) and *Zea mays* (maize). Plant growth was mostly enhanced in the treatments with 20–40% fly ash, being optimal at 60%. From 80% onwards, the measured parameters tended to reduce. The most economic level of fly ash incorporation was 60%, which improved the growth of maize and rice. Hence fly ash can be utilized as a substrate or as a soil ameliorating material for the growth of plants, leading to the sustainable utilization of solid waste material.

Key words: fly ash, pot culture experiment

INTRODUCTION

Fly ash is an inorganic solid residue generated from thermal power plants through the burning of coal. In India, more than 70% of energy needs is met by coal based thermal power plants. Burning of coal releases oxides of nitrogen and sulfur and an enormous quantity of fly ash, which gets deposited on soil. Fly ash (FA) is a fine, glass powder of ferrous-aluminium silicate containing all of the essential elements that occur naturally in soil except humus and nitrogen. Chemically, 90–99% of fly ash is comprised of Si, Al, Fe, Ca, Mg, Na and K with Si and Al is forming the major matrix (Rees, Sidrak, 1956; Adriano et al., 1980). Mainly it contains S, B, Ca, Mg, Fe, Cu, Zn, Mn, and P, which are beneficial for plant growth, as well as toxic metals such as Cr, Pb, Hg, Ni, V, As, and Ba (Elseew et al., 1980; Dalmau et al., 1990). About 112 million tons of fly ash are being generated annually in India by thermal power plants (Dhadhu, 2008). FA production depends on the quality of the coal, which contains a relatively high proportion of ash that leads to 10–30% FA formation (Meij, 1995; Singh, Siddiqui, 2003). The disposal of FA by conventional methods leads to degradation of arable land and contamination of ground water; hence an eco-friendly way of disposal becomes essential to derive the maximum benefit from its heterogeneous nature as it has several macro- and micronutrients (Gupta et al., 2002).

The present study deals with the effect of the application of varying levels of fly ash amended with soil on the growth of rice and maize.

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MATERIALS AND METHODS

Sample collection of fly ash

Fly ash was collected from the fly ash dump site of a coal based thermal power plant of the National Thermal Power Corporation (NTPC) located at Kaniha, Talcher, Odisha (India). The power plant is located at 25° 27'–26° 13' N latitude and 85° 27'–86° 01' E longitude. For the experimental work, soil was collected from the agricultural field up to a depth of 20 cm, after scrapping of the surface litters. Before utilization, the soil was steam sterilized keeping in gunny bags in an autoclave at 20 lb pressure for 20 minutes. The autoclaved soil was dried and then mixed with fly ash in different percentage of 20, 40, 60, 60 and 100 separately.

Physicochemical analysis of fly ash

Fly ash and soil samples were air dried and analyzed for texture (Allen, 1974). EC and pH were determined by using a Hannes electrode. The estimation of organic carbon and phosphorus was determined by a slight modification of the method (Piper, 1950; Jackson, 1973), the sample was prepared for elemental analysis and analyzed with an atomic absorption spectrophotometer (McGrath, 1986).

Experimental procedures

For the experiments, fly ash was mixed with the autoclaved soil in the following percentage:

T0 = Control (only autoclaved soil);
T1 = 20% fly ash + 80% autoclaved soil;
T2 = 40% fly ash + 60% autoclaved soil (10% level);
T3 = 60% fly ash + 40% autoclaved soil (20% level);
T4 = 80% fly ash + 20% autoclaved soil (30% level);
T5 = 100% fly ash.

Seeds of selected plants (wheat and maize) were procured from Orissa Seeds Cooperation Ltd. Seeds were treated with 0.1% mercuric chloride for 5 minutes, followed by 70% alcohol for 1 minute. The sterilized seeds were thoroughly washed with distilled water. The seeds were soaked for 48 hours before sowing. The pots were kept on the glasshouse bench at 25–27 °C. The seeds were transplanted into 15 cm diameter pots and were arranged in a randomized block design on the glasshouse bench. After a different interval of time, plants were analyzed for various parameters such as length of shoot and root; fresh wt. and dry wt.; photosynthetic pigments. The data was analyzed statistically for significance.

Analysis

Random samples of the plants were taken from each replicate pot after 15, 30 and 45 days of sowing (DAS) for the analysis of growth parameters and photosynthetic pigments. 5 plants were collected randomly from each set of the study, i. e. uprooted carefully with their roots intact. The root and shoot portions were separated and washed with de-ionized water. Samples were now made moisture free and weighed quickly to obtain fresh weight (FW) in grams. After this the plant parts (roots and shoots) were kept in an oven running at 80 °C for 24 hours and the dry weights were recorded in grams. Chlorophyll-a, chlorophyll-b, total chlorophyll, pheophytin and carotenoid content were calculated on (mg/g) of the fresh weight tissue basis (Porra, 1989).

Lengths of root and shoot were separately measured. The roots and shoots of plants were separated and oven dried at 80 °C till constant weight. Fully expanded fresh leaves of plants were sampled randomly from each replicate plot for various biochemical analyses. Pigment contents were extracted from the leaf disc with 80% acetone and quantified according to the methods given by Machlachlan and Zalik (1963); Duxbury and Yentsch (1956). The foliar protein content was analyzed according to the method of Lowry et al. (1951) using bovine serum albumin as a standard.

RESULTS AND DISCUSSION

Fly ash has an alkaline pH of about 7.98, and EC is 581 μS/cm which might be due to the presence of high concentration of oxides of Ca and

Table 1. Physico-chemical analysis

Sample name	pH	EC, µS/cm	Organic carbon	Texture		
				Sand	Silt	Clay
Fly ash	7.98	581	2.9	86.3	12.41	1.28
Soil	6.8	228	4.1	37.31	53.74	8.94

Mg (Rai et al., 2000). Organic carbon is very low as compared to that of soil.

Fly ash, a residue of coal consumption, is primarily made up of oxides of Al and Si, but also enriched with several other essential (Zn, Fe, Mn, B and Mo) and non-essential metals (Ni, Cr, Pb, Al, Si) as reflected in Table 2.

Table 2. Heavy metal analysis

Metals	Soil	Fly ash
Chromium (Cr)	0.049	0.02
Cobalt (Co)	0.0003	0.001
Iron (Fe)	3.46	12.68
Cadmium (Cd)	ND	0.005
Nickel (Ni)	0.003	2.05
Lead (Pb)	0.005	9.574
Mercury (Hg)	8.65 µg/g	10.44 µg/g
Arsenic (As)	14.64 µg/g	3.61 µg/g

Germination is a prime plant-growth process; the effect of different concentrations of fly ash blended with soil on the germination of rice and maize is presented in Fig. 1. Germination of rice occurs after 3 days of sowing in all the treatment, but in the case maize germination starts after 5 days, it might be due to a hard seed coat. Maximum germination was recorded in F3 (60% FA) in rice and in T2 (40%) in maize. A trend was observed that with an increase in the concentration of fly ash, seed germination decreases.

In the present study, no visible injury symptoms were observed in any of the treatments during the growth and development. With an increase in the concentration of fly ash, there is a gradual reduction in the growth parameters such as root and shoot length, fresh weight and dry weight (Fig. 2). Soil blended with 80 and 100% FA shows a negative effect. The retarded plant growth, as reflected by decrease in root and shoot lengths as well as fresh and dry weight, may be coupled with undesirable chemical properties of the FA, including low N and P contents (Mishra, Shukla, 1986; Wong, Wong, 1989). Reduction in root length may be due to compaction of FA particles which probably served as a physical

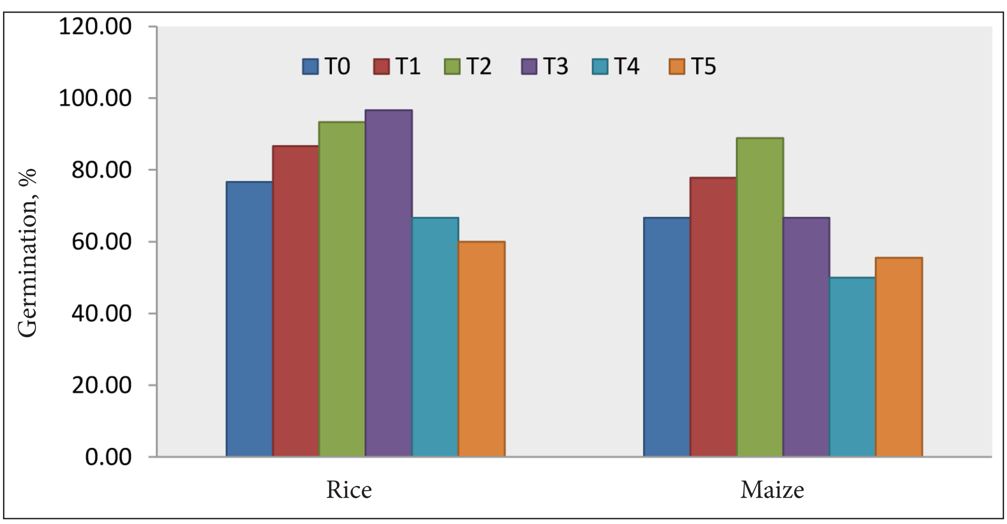

Fig. 1. Rate of germination in rice and maize

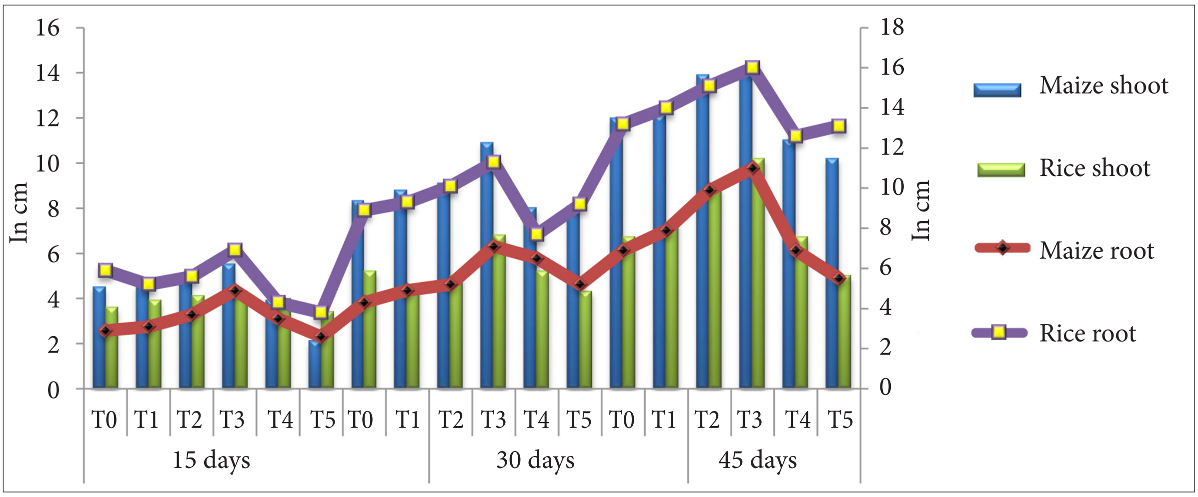

Fig. 2. Effect of different concentration of fly ash on the seedling growth, plant height in rice and maize in different intervals. Data are the mean of five replications

barrier to root elongation. Other studies have also shown that the high alkalinity affects the availability of nutrients, mainly phosphorous, which influence the plant growth adversely (Jala, Goyal, 2006).

Total chlorophyll and carotenoid contents also decreased significantly with increasing concentrations of FA as compared to that of the control at 30 DAS. Accumulation of heavy metals leads to inhibition of chlorophyll formation (Krupa, Baszynski, 1995).

Table 3. Photosynthetic pigment analysis in rice

Sample	**Photosynthetic pigments (in mg/gm) in rice**				
	Chla	**chlb**	**Total chl**	**Pheo-phytin**	**Carotenoid**
T0	2.46	2.82	5.32	0.89	0.26
T1	0.92	1.17	2.10	0.87	0.31
T2	1.80	2.15	3.98	0.76	0.42
T3	1.98	2.55	4.57	0.95	0.49
T4	1.92	2.42	4.38	0.73	0.35
T5	1.72	2.06	3.81	0.81	0.29

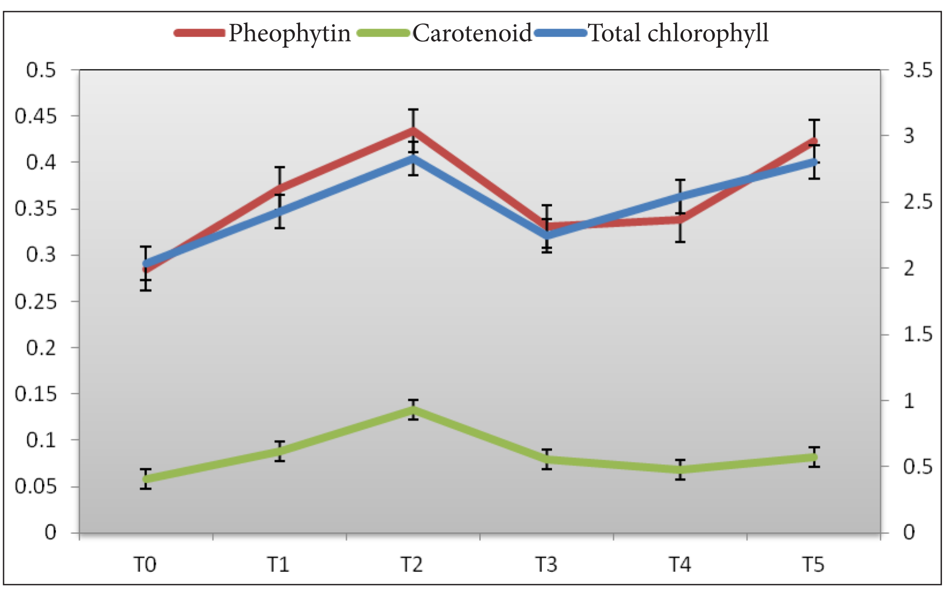

Fig. 3. Photosynthetic pigments (in mg/gm) in maize

Fly ash application in soil improved the growth of rice and maize up to certain treatments, and after that, fly ash concentration caused deleterious effects on the plant growth. In our study, 40% fly ash levels proved to be optimally useful for the plant growth. The observed responses of the plants are also supported by other workers, like Bharti et al., on green gram; Pathan et al., on *Cynodon dactylon* (L.) Pers, Cv Wintergreen; Parveen et al., on *Mentha citrata*; Hisamuddin and Singh, on *Pisum sativum*. Their findings indicated that the concentration of fly ash for better plant growth varied from plant to plant. High levels of fly ash have caused toxic effects on plant growth. According to Kumar et al. and Rai et al., fly ash can be used as a fertilizer to improve soil fertility, especially for barren lands.

CONCLUSIONS

Based on the experiment, it can be concluded that there is an ample scope for the safe utilization of fly ash in agriculture without serious deleterious effects. But fly ash varied widely in its physical and chemical composition, therefore the mode of use in agriculture is different and depends on the characteristics of soil or soil type. The present study also suggests careful investigation of the accumulation of heavy metals (present in FA) in soil vis-a-vis in the edible portions of other vegetables.

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SKRAIDANČIŲ PELENŲ POVEIKIS RYŽIŲ IR KUKURŪZŲ VEGETACINIAM AUGIMUI IR FOTOSINTETINIO PIGMENTO KONCENTRACIJAI

Santrauka

Netinkamas skraidančių pelenų (SP) iš anglimi kūrenamų šiluminių elektrinių panaudojimas ir utilizavimas kelia ekologinių problemų. Šis tyrimas skirtas įvairių koncentracijų (20, 40, 60, 80 ir 100 %) SP poveikio ryžių *Oryza sativum* ir kukurūzų *Zea mays* vegetaciniam augimui ir fotosintezės aktyvumui įvertinti. Augalai auginti pelenuose, kurių koncentracijos kas mėnesį buvo keičiamos. Didžiausias efektas nustatytas auginant 60 % pelenuose, kur ryžių ir kukurūzų augimas padidėjo. Nustatyta, kad SP gali būti utilizuoti kaip substratas ar dirvožemį gerinanti medžiaga.

Raktažodžiai: skraidantys pelenai, vazoninių kultūrų eksperimentas