Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

Vol. 8	No. 4	pp. 665-671	2009

Original Research Paper

Biomodification of Coal Fly Ash by *Eichhornia* with Respect to Improvement in Physicochemical Properties for Cultivation of Wheat

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Key Words:
Coal fly ash
Compost
Triticum aestivum
Water hyacinth

ABSTRACT

Pot and field experiments were conducted to study the effect of levels of coal fly ash (CFA) on physicochemical properties of soil, CFA amended soil and the yield parameters of wheat. The objective of the experiment was to initiate a reaction between the constituents of soil and CFA to upgrade the quality of soil to make it suitable for the cultivation of wheat. Physicochemical studies have been carried out for different composts obtained by successive replacement of CFA for soil in constituents of original and reference composts. Water hyacinth (*Eichhornia crassipes*) was used as organic manure. Physicochemical analysis was conducted after the harvest of wheat. CFA, a byproduct of Kota Super Thermal Power Station, was used. Increase in rate of growth and improvement in quality of produce was observed with the increase in percentage of CFA up to 40%. A study of graded level of CFA amended soils revealed an increase in the content of micro and macronutrients.

INTRODUCTION

Coal fly ash (CFA) is a byproduct of burning coal in thermal power stations and its large volume occupy large area of land and poses threat to environment. According to Page et al. (1979) CFA is a powdery material made up of tiny glass spheres and consists primarily of silicon, aluminium, iron and calcium oxides. CFA consists of practically all the elements present in the soil except organic carbon and nitrogen. It can act as soil ameliorating material because of its physical condition and presence of macro and micro nutrients. Its alkaline character and high concentration of mineral substances makes it suitable as fertilizer or for amendment of soil or to alter the physicochemical properties of soil. CFA may either have a positive or negative effect on plant growth and yield according to Punjab Agriculture University (1993), RRL Bhopal (1999), Singh (1989) and Kumar (1998, 1999).

The chemical properties of CFA are influenced to a great extent by those of the coal type burned and the technologies used for handling and storage. A large amount of elements (C, K, Ca, Mg, Cu, Zn and Mn) get into the soil as a result of CFA used at different doses and may probably change the physicochemical properties of soil, which in turn may determine the biological properties irrespective of the crop (Dhankhar 2003, IIT Kharagpur 1999, Kene et al. 1991, Kumar et al. 1998, 1999, Srivastava et al. 2002, Zacharia et al. 1996). Catalytic action of CFA in number of organic reactions has also been proved by Khatri et al. (2006, 2007) and Singh et al. (2006).

The present study deals with improving soil fertility for cultivation of wheat (*Triticum aestivum*), by using CFA along with water hyacinth (*Eichhornia crassipes*), which is an aquatic weed rich in potash, lime and phosphorus.

MATERIALS AND METHODS

The wheat variety, amount of seeds, fertilizers, constituents of reference compost and period for the cultivation of wheat are given below.

a. Wheat variety: 3077 (Registered seeds from Rajasthan State Seed Corporation)
a. Amount of seeds: 15-20 kg/ha
b. DAP: 150 kg/ha (at the time of sowing)
c. Urea: 240 kg/ha (at the time of sowing)
d. High zinc (Zn, Fe, B, Mg, Mn, Cu): 12 kg/ha
e. Biozyme (based on vegetable origin and sea weeds): 12 kg/ha
f. Constitution of reference compost: 3 parts of the clayey loam + 1 part of organic manure farm yard waste + High zinc + Biozyme
g. Period of the wheat cultivation: Third week of October

Different composition of composts were prepared by gradual replacement of soil by CFA (from 10% to 50%) and dried water hyacinth was mixed in reference compost. For conversion into composts these admixtures were left in separate pits (approx. 4 feet in depth) for 1.5 months.

Physical and chemical characteristics of soil were determined by standard procedures (Willard et al. 1986, Vogel 1939). The wheat was grown according to its requirements of water, support and climatic conditions. Seedlings were transplanted in pots of identical dimension packed with composts of different constitution after reaching at definite height of 5 cm. Ten pots were prepared for each composition of composts (0%, 10%, 20%, 30%, 40%, 50% CFA).

Different physicochemical parameters like WHC, porosity, density, pH, conductivity, nitrate, phosphate, sulphate, potassium, calcium, magnesium, manganese, copper, zinc, iron and organic matter were determined for reference compost, non modified mixture and modified mixtures (composts prepared). Time to time observations were recorded for growth of plants, quality and quantity of produce, frequency of diseases and pest attacks.

Experiments for the study of plant growth and quality and yield of produce were carried out in pots and fields. The plants were allowed to grow till maturity and then harvested. The grain samples were thoroughly washed and dried at 45-50°C and powdered in pestle and mortar for further analysis. Seeds were sown in control and different composts prepared with CFA. Growth parameters were observed from percent germination of seeds to complete growth of plants. Flowering occurred after 70 to 75 days of sowing. Fruits developed after 90 days of sowing. Distance between rows of plants was 7 inches. Plant height, number of branches per plant, leaf area, number of ears/balies per plant, number of seeds per ear/bali were determined. Seeds obtained, were subjected to determination of protein, fat and carbohydrates contents.

To find out utility of composts preparation (bioremediation) simultaneous experiments were carried out under similar conditions by growing the wheat directly in unmodified compost. The studies have been carried out for three successive years 2005, 2006 and 2007. In the year 2007 experiments were also carried out in field by applying selected dose from previous two years experiments.

RESULTS AND DISCUSSION

Results of the study are summarized in Tables 1 to 7 and Figs. 1 to 3. Physicochemical properties of CFA depend on their origin and the composition of coal used for combustion. The preparation of

Table 1: Physical properties of different composts prepared with CFA for cultivation of wheat.

Parameters % of Compost	Texture	Organic Matter (%)	WHC (%)	Porosity (%)	Density (g/cm^3)	pH	Conductivity (μmho/cm)
C_0	Sandy clay	0.765	43.50	44.65	1.320	5.82	144.0
C_1	Sandy clay	0.745	42.80	46.05	1.255	5.95	158.5
C_2	Clay	0.715	42.35	47.50	1.210	6.12	172.5
C_3	Loamy clay	0.680	41.50	48.70	1.190	6.20	190.0
C_4	Loamy clay	0.630	40.75	49.30	1.182	6.28	214.0
C_5	Loamy clay	0.603	42.50	48.10	1.190	6.40	224.5

% of CFA (C = compost): C_0 = 00%, C_1 = 10%, C_2 = 20%, C_3 = 30%, C_4 = 40%, C_5 = 50%

different composts by application of different percentage of CFA resulted in favourable biological and physicochemical changes with modification of soil properties with an increase in available nutrients like N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu. An improvement in fertility of soil was observed up to 40 % replacement of soil by CFA.

Physical parameters (texture, density, porosity, water holding capacity): Table 1 gives density, porosity and WHC for different composts prepared for the studies. As the composition of the mixture or compost changes, the porosity increases and density and WHC decrease with the increase in percentage of CFA in reference compost from C_0 to C_4 but from C_4 to C_5 the trend has reversed. As the CFA increases, the salt content of the mixture after reaching an optimum, decreases. Increase in porosity improves soil drainage and aeration. These changes were due to silty nature of CFA, its low density (0.98), better porosity (58.30) and other physical conditions. In control soil, the major portion was clay but on admixing with CFA, the clay content has reduced and silt percentage had increased. Texture changes from sandy clay to loamy clay.

The organic matter decreases and pH increases from C_0 to C_5 with increase in percentage of CFA in compost mixture. It may be due to the increase in basic oxides like calcium oxide (CaO) and magnesium oxide (MgO), which were contributed from the alkaline CFA and also from the neutralization of H^+ ions by more basic metallic oxides of CFA. The electrical conductivity increased due to addition of CFA with soil due to increasing quantity of soluble macro and micro nutrients (Tables 2, 3, 4) released by CFA or the interaction of inorganic constituents of CFA with soil organic matter from C_0 to C_5.

Available plant nutrients in composts prepared with CFA: With the increase in dose of CFA, the availability of macronutrients was increased. The release of the nutrients in the ionic form increasing their bioavailability can be considered by favourable results of chain of chemical reactions among constituents of composts at more suitable pH and physical conditions, i.e., better texture, reduced density, increased porosity and appropriate WHC. This helps in increasing the concentration of nutrients and conditions of the soil to assimilate the nutrients by plants following specific physiological mechanism. The available nitrogen was measured in terms of NO_3^-. The concentration of nitrate increased from C_0 to C_4 and then decreased from C_4 to C_5.

The available phosphorus was measured in terms of phosphate. The increase in concentration of phosphate may be attributed to the available phosphorus present in CFA. Plants take phosphate in HPO_4^{-2} form. The increase is due to the hydrolysis of iron, aluminium and magnesium compounds in CFA and released inorganic acids by CFA. The liberated acids help in the release of available phosphate from the unavailable form without affecting the pH as organic matter present in the soil has a

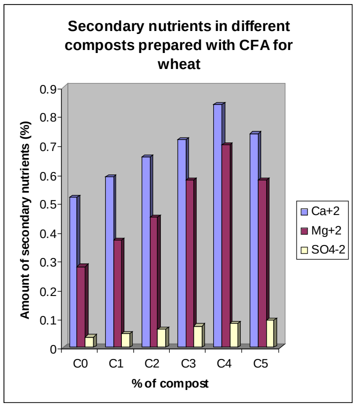

Fig. 1: Secondary nutrients in different composts prepared with CFA for wheat.

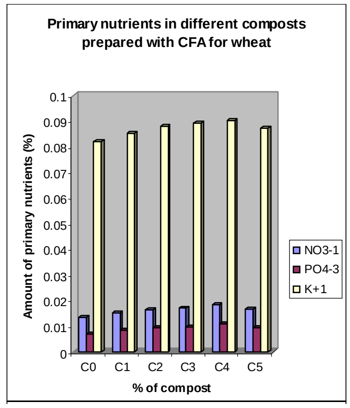

Fig. 2: Primary nutrients in different composts prepared with CFA for wheat.

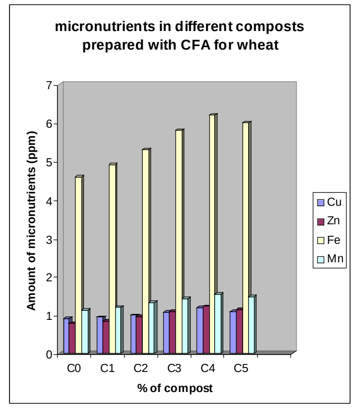

Fig. 3: Micronutrients in different composts prepared with CFA for wheat.

buffering capacity in maintaining the pH. The concentration of phosphate increases from C_0 to C_4 and then decreases from C_4 to C_5.

Potassium is measured in terms of K^+ in soil and CFA. It is present in the form of albite and mizzonite. The complex constituents present undergo probable transformations, which help in release of ions in the similar form and contributing to the soil. The availability of K^+ ions increases from C_0 to C_4 and then decreases from C_4 to C_5. Calcium and magnesium in soil and CFA are present in the form of silicates and oxides. The availability of calcium and magnesium increases on increase in percentage of CFA from C_0 to C_4 and then decreases. Like primary nutrients, the secondary nutrients (calcium, magnesium, sulphate) also play a significant role in formation of plant tissues. Sulphur is taken up by plants in SO_4^{2-} form. The availability of sulphate increases on increase in percentage of CFA from C_0 to C_5.

At higher level of CFA, the decrease in the macronutrients (primary & secondary) may be pertained due to the combined effect of imbalance clay, silt and sand content, microbial activity, organic matter, and pH. It is reported by some researchers that at higher concentration of CFA, some heavy metals become more active and hinder the microbial activity. pH plays a vital role in the release of specific nutrients. The availability of nutrients is maximum at pH 5.5 to 6.5. At higher concentration of CFA some heavy metals like molybdenum (Mo) and boron (B) become more active and form some inorganic complexes which inhibit the release of essential nutrients like nitrogen, phosphorus and potassium.

Intake of micronutrients (Fe, Mn, Zn, Cu): The phytotoxicity to the plants is due to excess of heavy metals. This occurs more in acidic medium, sandy soil or crops that have low tolerance to the heavy metals. Most of the heavy metals play a vital role in plant physiology. In soils, iron and manganese has an oxidative or catalytic effect and maintains a nutritional balance for normal growth. The availability of iron is more than manganese. The results reveal that as the concentration of CFA increases the availability of iron and manganese increases but iron did not impart any toxicity to plants. In this case firstly, manganese oxidizes ferrous (soluble) into ferric (insoluble). This reduces the availability of soluble iron which may cause toxicity. Secondly, due to the reaction taking place between the carbonate ion and iron which reduces the excess availability of iron to the plants.

Table 2: Primary nutrients in different composts prepared with CFA for wheat in %.

% of compost	NO_3^-	PO_4^{-3}	K^+
C_0	0.0135	0.0070	0.0820
C_1	0.0152	0.0082	0.0852
C_2	0.0162	0.0093	0.0880
C_3	0.0171	0.0099	0.0892
C_4	0.0183	0.0108	0.0902
C_5	0.0168	0.0095	0.0872

Table 3: Secondary nutrients in different composts prepared with CFA for wheat in %.

% of compost	Ca^{+2}	Mg^{+2}	SO_4^{-2}
C_0	0.52	0.28	0.036
C_1	0.59	0.37	0.048
C_2	0.66	0.45	0.062
C_3	0.72	0.58	0.074
C_4	0.84	0.70	0.082
C_5	0.74	0.58	0.094

Table 4: Micronutrients in different composts prepared with CFA for wheat in ppm.

% of compost	Cu	Zn	Fe	Mn
C_0	0.90	0.78	4.6	1.12
C_1	0.94	0.83	4.9	1.20
C_2	0.99	0.96	5.3	1.32
C_3	1.07	1.10	5.8	1.42
C_4	1.18	1.22	6.2	1.54
C_5	1.10	1.14	6.0	1.46

Table 5: Yield of wheat in different composts prepared with CFA in kg/m^2.

Name of crop	C_0	C_1	C_2	C_3	C_4	C_5
Wheat	0.82	0.88	0.93	0.98	1.04	1.0

Deficiency of manganese may cause chlorosis in plants. It acts as a catalyst in oxidation-reduction with iron and nitrogen metabolism. If large amount of zinc and copper is present then manganese deficiency is found in plants. In the present study no such symptom was observed although zinc and copper were higher in soil CFA mixtures. This may be due to the physicochemical properties of CFA which on mixing with soil has ameliorated the soil from sandy to silty loam and due to the presence of oxides of calcium and magnesium which maintained alkalinity (Mandal & Saxena 1998, Saxena & Asokan 1998, Saxena et al. 1998).

Copper is an essential constituent of oxidizing enzyme. It acts as an electron carrier in enzymes which bring about oxidation reduction and regulates respiratory activity in plants. It is reported that copper helps in the accumulation of calcium and magnesium. In CFA, it is present in the form of tenorite (CuO). It reacts with inorganic acids released during the hydrolysis of various compounds and helps in the release of available copper. Table 4 indicates that copper is increased with the increase in concentration of CFA but did not impart any toxicity as excess availability was hindered due to alkaline pH, organic matter and clay content. The availability of Cu, Zn, Mn and Fe increases on increase in percentage of CFA from C_0 to C_4 and then decreases.

The yield of wheat in various composts is shown in Table 5. The yield increases on increasing percentage of CFA up to 40% and then decreases. The percentage increase in yield of wheat in different composts in comparison to reference compost is given in Table 6. The heavy metal analysis of wheat obtained from compost giving best results is shown in Table 7.

Table 6: Percentage increase in yield of wheat in different composts prepared with CFA in comparison to reference compost in kg/m^2.

% of composts	% increase in yield
C_1	7.32
C_2	13.42
C_3	19.51
C_4	26.83
C_5	21.95

Table 7: Heavy metal analysis of the wheat obtained from compost giving best results in ppm.

Names of heavy metals	Wheat
Cu (Copper)	04.07
Zn (Zinc)	09.25
Cd (Cadmium)	00.03
Pb (Lead)	00.86
Fe (Iron)	39.62
B (Boron)	06.82

Present study clearly reveals that CFA works as soil modifier and nutrients supplier in the cultivation of wheat. Results obtained for different parameters indicate that CFA improved physical and morphological properties of soil and water retention capacity of soil together with increased release of nutrients such as calcium, magnesium, sulphur, potassium, copper, phosphorus, zinc, etc.

Best results in terms of plant growth, maturation period and quality and quantity of produce were obtained with composts containing 40% (v/v) of CFA. The percentage increase in amount of protein, fat and carbohydrates in the produce was found better in the compost having 40% CFA. Maximum increase in yield was 26.83% in compost having 40% CFA for the cultivation of wheat. On cultivation of wheat in this compost, the grains obtained were comparatively more in quantity and larger in size, meeting the food quality standards and consumer acceptability. It was found that heavy metal uptake was within the permissible limits.

Utilization of CFA and water hyacinth in proper amount and proper way can act as a boon in agriculture giving solution of safe and sustainable management of these wastes, which also act as soil and irrigation water savers.

CONCLUSION

From the present studies, it is concluded that CFA worked as soil modifier and nutrients supplier in cultivation of wheat. Best results in terms of plant growth, maturation period, resistance to pests and diseases, and quality and quantity of produce were obtained with composts containing 40% (v/v) of CFA, which can be advantageously applied in cultivation of wheat. Constant amount of added water hyacinth helped in increasing potassium, calcium, phosphorus and organic carbon in the mixture. The plant and the grains were observed five times less prone to the pests. Resistance to diseases and absorption of nitrogen and phosphorus increased in 40% compost. No considerable change in uptake of toxic heavy metals in seeds of plants could be observed under experimental conditions of the present study. In seeds obtained from compost containing 40% CFA, protein was increased up to 13%, fat up to 8% and carbohydrates up to 7%.

ACKNOWLEDGEMENT

The authors are thankful to Dr. M. L. Meena, Principal, and Dr. K. K. Gupta, Head of P.G. Deptt. of

Chemistry, Govt. College, Kota, Rajasthan for constant encouragement and providing necessary facilities.

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