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EFFECT OF COAL ASH ON PHYSIO-MORPHOLOGICAL AND BIO-CHEMICAL CHARACTERS OF OKRA (*ABELMOSCHUS ESCULENTUS* L. MOENCH)

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ABSTRACT

A pot culture experiment comprised of five treatments such as T1 : 100 % soil mixture + 0% coal ash, T2 : 75 % soil mixture + 25% coal ash, T3 : 50 % soil mixture + 50% coal ash, T4 : 25% soil mixture + 75% coal ash, T5 : 0 % soil mixture + 100% coal ash was laid out in completely randomized block design with 5 replications to assess the effect of varying levels of coal ash on physio-morphological and bio-chemical characters of okra. The results revealed that the combination of 50:50 soil and coal ash mixture increased the seed germination (80%) and seedling characteristics such as height (28.9 cm), collar girth (1.95 cm) and root girth (35 cm). The plant height (151.9 cm), leaf area (2508 sq cm), no. of fruits (24), fruit weight (350 g), chlorophyll content(10.25 mg/g) and biomass production(19.5 g) of the crop tested in the current investigation was found significantly maximum in the soil mixture amended with 50% coal ash. The increase in growth traits was mainly attributed to increase in nutrient acquisition of plants grown under above combination. However, 100% coal ash in the growing medium reduced seed germination, seedling vigour, growth, yield attributing characters and biomass per plant. The leaf nutrient status in relation to the macronutrients like Ca, Mg, S and the micro nutrients Zn, Mn, B, Mo, Fe and Cu were found higher in the treatments having high coal ash content in the growing medium than other treatments and the lowest was recorded in control (no coal ash). The present investigation indicated that application of 50:50 coal ashes and soil mixture was found beneficial for successful cultivation of okra under sandy loam soil.

INTRODUCTION

Disposal of non-biodegradable industrial waste is a major issue of concern in India. The major generators of non-biodegradable industrial solid waste are thermal power plants producing coal ash, integrated iron and steel mills producing blast furnace slag and steel melting slag. Such non-ferrous industries as aluminum, zinc, and copper, which produce red mud and tailings etc that are toxic to plants and animals. These heavy metals adversely affect soil productivity for extended period of times at relatively low levels of concentration. Sustainable development is very much concerned with the availability of clean environmental and natural resources in the future. The problem is much more acute in developing countries like India. The industrial wastes and by-products which are generated in large amount pose problems for safe disposal (Jabeen *et al.*, 2010). The industrialists and also the environmentalists are finding difficulty in recycling of some of the industrial wastes, one such difficult to handle industrial waste is coal ash. Coal ash is one of the major solid waste products and environmental pollutant from thermal power plant. Basically, coal ash is a heterogeneous mixture of amorphous and crystalline phases and is generally considered to be a ferro aluminosilicate element characteristically high in potassium, sodium, calcium, magnesium and sulphur content. With the promotion of more and more coal based thermal plants, the ash generation is getting multiplied geometrically. Disposal of these large amounts of ash required large patch of land causing reduction in cultivable land. There is a thumb rule that for every mega watt of power, one acre of land is required for disposal of ash accumulating to a height of 8-10 m in ash pond (Patnaik, 1992). Enormous volume of coal ash remains unutilized and its dumping has posed a threat to environment (Pathak *et al.,* 1996). There are several reports of the use of coal ash as a soil amendment to field crops. Potential of coal ash as amendment and micronutrient carrier has been identified. Coal ash amendment has been reported to modify soil pH, improve soil texture, water retention and stability and provide essential plant nutrients for increasing crop production (Ram and Reginald, 2010; Riehl *et al.*, 2010). Intensive agriculture and decreasing inputs of organic materials have led to severe degradation of soil fertility and productivity which can be replenished to some extent by application of coal ash. Efforts are being made to device strategies on purposeful use and safe disposal of huge amount of coal ash produced. However, inconsistent results on crop yield have been reported from different regions of the world. This may be due to the heterogeneity of the physical, mineralogical and chemical properties of coal ash, which in turn depend on the composition of the parent coal, combustion condition, efficiency of emission control device, handling and storage of coal ash and climate. The problem is further influenced by the type of recipient soil and plant species to be grown. Hence, favourable crop response to coal ash depends directly on the proper combination of coal ash, soil mixture and plant species to be grown. India is the largest producer of okra in the world and it has tremendous export potential as fresh vegetable. The effect of coal ash on growth and development has not been much studied. The present investigation was therefore attempted with an objective to study the effect of graded levels of coal ash on growth and bio-chemical characters of okra.

MATERIALS AND METHODS

The experiment was carried out in the Regional Research and Technology Transfer station, OUAT, Semiliguda, Koraput in the state of Odisha during spring and summer season of 2009 and 2010 with the support of National Aluminum Company (NALCO), Damanjodi Unit, Koraput, Odisha. To have control over the experiment, a pot culture trial using coal ash was carried out in okra *(Abelmoschus esculentus* L. Moench*)* var. Utkal Gaurav under open condition. The place is characterized by warm and moist climate with hot and humid summer and cool winter. Coal ash was obtained from National Aluminum Company Ltd, Damonjodi, Koraput, Odisha. The physico-chemical composition of coal ash as reported by NALCO, Damonjodi, Odisha is presented in Table 1 and 2. The mechanical composition of garden soil was estimated by Bouyoucos hydrometer method (Piper, 1996). The soil fraction of coarse sand (50.45%), fine sand (24.3%), silt (15.30%) and clay (9.45%) indicating a sandy loam texture of experimental soil. The chemical composition of garden soil such as organic carbon (0.47%), total nitrogen (0.075 %), available P (23.4 kg/ha) and available K (110 kg/ha) were determined as per standard procedures (Jackson, 1967).

The pot culture experiment was conducted in a completely randomized block design with 5 replication and 5 treatments. The treatments were randomly allocated to each replication using Fisher's random table. Sowing was done in the polythene bags of size 12 x 8 of 400 gauge with different levels of coal ash along with the mixture of garden soil + FYM + sand in 2:1:1 ratio. The soil mixture and coal ash were mixed in different proportion by volume. The treatment schedule was 100% soil mixture + 0% coal ash (T1), 75% soil mixture + 25% coal ash (T2), 50% soil mixture + 50% coal ash (T3), 25% soil mixture + 75% coal ash (T4), 0% soil mixture + 100% coal ash (T5).The observations on germination percentage, seedling characteristics and the plant growth parameters were recorded at periodic interval. Germination of okra seeds were recorded on the 10th day and expressed in percentage. The seedling characteristics such as seedling height (cm), collar diameter (cm) and root length (cm) were determined at 30th day. The various growth parameters such as plant height (cm), number of leaf, leaf area (sq.cm) were recorded at regular intervals from 50-75 DAS while the yield and yield attributing characters such as number of flowers per plant, number of fruits per plant, fruit weight per plant (g) and total biomass (g/plant) were recorded at regular intervals up to 90 DAS. The effect of coal ash on leaf bio-chemical parameters such as chlorophyll content, macro nutrient (N,P, K, Ca, Mg, S) and micro nutrient (Mn, B, Mo, Fe, Cu and Zn) status were studied at 90 DAS. The leaf chlorophyll content was calculated by using the formula recommended by Maclauchlan and Zalik (1963). The leaf nutrients were estimated as per standard procedures (Jackson, 1967; Piper, 1996). Sulphur was estimated by turbidometric method (Massoumi and Cornfield, 1963) and micronutrients employing atomic absorption

Table 1: Physico-chemical properties of coal ash

Sl. No.	Characters	Results
1.	Structure of coal ash	Amorphous
2.	Mixing Ability	Free from
3.	Colour	Gray
4.	Moisture Content	0.3 -16%
5.	Water Holding Capacity	46.58%
6.	E.C.	0.30 mS/cm
7.	pH(1:2.5, soil : water)	6.9

Table 2: Chemical composition of coal ash

Sl.No.	Chemical Constituents	Composition
1.	Si_2O_3	66.74
2.	Al_2O_3	28.87
3.	Fe_2O_3	21.94
4.	CaO	16.84
5.	MgO	2.91
6.	SO_2	1.20
7.	K_2O	1.20
8.	P_2O5	0.75
		(mg kg-1 Coal ash)
9.	B	15
10.	Ba	350
11.	Co	15
12.	Cr	100
13.	Cu	75
14.	Ga	15
15.	Li	25
16.	Mo	400
17.	Pb	15
18.	Sb	25
19.	Zn	250
20.	V	100

(Source: Annual Report-1999-2000, NALCO, Damonjodi, Odisha)

Table 3: Effect of coal ash on germination and seedling vigour of okra (pooled data of 2009 and 1010)

Treatment		Germination at 10 days after sowing(%)	Seedling vigour		
			Height (cm)	Collar girth (cm)	Root length (cm)
T1	Coal Ash:Soil (0:100)	70.0	20.5	1.50	25.0
T2	Coal Ash:Soil (25:75)	78.5	25.5	1.65	29.5
T3	Coal Ash:Soil (50:50)	80.0	28.9	1.95	35.0
T4	Coal Ash:Soil (75:25)	68.5	18.2	1.00	24.0
T5	Coal Ash:Soil (100:0)	65.0	10.0	0.85	20.0
SEm ±		1.20	1.15	0.07	2.10
LS.D. (0.05)		3.68	3.53	0.21	6.44

Table 4: Effect of coal ash on growth and yield attributing characters of okra (pooled data of 2009 and 1010)

Treatment		Plant Height (cm)	Number of leaves	Leaf area (sq. cm)	Number of flowers/plant	Number of fruits/plant	Fruit wt (g/ plant)
T1	Coal Ash:Soil (0:100)	142.5	25.0	2005	15	15	300
T2	Coal Ash:Soil (25:75)	146.5	28.0	2120	18	18	320
T3	Coal Ash:Soil (50:50)	151.9	32.0	2508	25	24	350
T4	Coal Ash:Soil (75:25)	140.2	24.0	1996	14	14	200
T5	Coal Ash:Soil (100:0)	130.0	20.0	1850	12	12	180
SEm ±		1.15	1.15	10.75	2.20	2.10	0.65
LS.D. (0.05)		3.53	3.53	33.00	6.75	6.14	1.99

Table 5: Effect of coal ash on macronutrients status of okra (pooled data of 2009 and 1010)

Treatment		Chlorophyll(mg/g)	Bio-mass (g/ plant)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)
T1	Coal Ash:Soil (0:100)	8.90	16.2	0.85	0.52	2.75	0.70	0.42	0.30
T2	Coal Ash:Soil (25:75)	9.35	18.2	0.93	0.46	4.90	0.68	0.49	0.33
T3	Coal Ash:Soil (50:50)	10.25	19.5	0.76	0.39	3.87	0.76	0.53	0.39
T4	Coal Ash:Soil (75:25)	7.60	14.0	0.78	0.31	2.65	0.83	0.58	0.43
T5	Coal Ash:Soil (100:0)	6.85	12.5	0.82	0.29	2.30	0.88	0.64	0.49
SEm ±		1.68	0.02	0.02	0.016	0.19	0.04	0.27	0.18
LS.D. (0.05)		NS	0.061	NS	0.055	0.51	0.108	NS	NS

Table 6: Effect of coal ash on micro nutrients status of okra (pooled data of 2009 and 1010)

Treatment		Mn(mg/kg)	B(mg/kg)	Mo(mg/kg)	Fe(mg/kg)	Cu(mg/kg)	Zn(mg/kg)
T1	Coal Ash:Soil (0:100)	24.90	56.00	40.20	170.0	15.3	20.30
T2	Coal Ash:Soil (25:75)	26.20	58.80	41.50	176.2	17.6	22.50
T3	Coal Ash:Soil (50:50)	28.40	60.25	43.70	182.5	18.9	24.20
T4	Coal Ash:Soil (75:25)	30.80	61.65	45.10	187.5	20.6	24.70
T5	Coal Ash:Soil (100:0)	32.00	63.00	47.00	190.2	21.3	25.10
SEm ±		0.8	1.35	1.38	1.67	0.63	0.23
LS.D. (0.05)		NS	NS	NS	5.12	1.93	NS

spectrophotometer (Jackson, 1967). Boron was estimated by employing Azomethaine-H indicator (Jackson, 1967).

The data obtained on various growth, yield, yield attributing and biochemical characters were pooled, analyzed statistically and the variances were tested at 5% level of significance, standard error of mean and least significant difference (0.05) were calculated for comparing the mean values as per Sukhatme and Amble (1995).

RESULTS AND DISCUSSION

Germination and seedling characteristics

The data presented in Table 3 revealed that significantly higher germination percentage of okra seeds were recorded in 50:50 coal ash and soil media. The minimum germination was obtained in the treatment having coal ash 100%. The study indicated that the germination percentage decreased with increase in coal ash concentration in the media soil. Increase in germination is attributed to higher moisture content in 50:50 coal ash and soil composition. The moisture content in 50:50 coal ash and soil composition promoted better germination. Treatment with 100% coal ash inhibited germination of the okra seeds which might be due to poor physical environment in the poly bags created by compactness of coal ash treatment (T5). It is a fact revealed by the earlier worker that the germination percentage varied due to soil composition. The present finding confirmed the earlier findings of Pawer *et al.* (1988), Wong and Wong (1990) and Sarangi *et al.* (1997).

The seedling characteristics determined by seeding height, collar diameter and root growth were significantly influenced by the coal ash concentration in the growing media. The 50:50 combinations of coal ash and soil in the growing media exhibited maximum seedling height and the lowest seedling height was recorded with the treatment having 100% Coal ash in the media. The similar trend was also noticed in case of other seedling characters like collar diameter and root length where higher concentration of coal ash in the medium adversely affected the root and collar growth. The coal ash concentration above 50% in the media as well as the media devoid of coal ash was not found giving favorable effect on the growth of okra seedlings. It might be due to accumulation of different nutrients which increases the collar girth in order to signify growth. The treatment 50:50 combinations of coal ash and soil have definite positive effect on increasing the girth as indicated from the result of this study. Earlier records suggests that because coal ash improves root growth without producing any toxic effect in the plant by increasing the level of trace elements in plant material or in soil solutions hence coal ash is used in land improvement. The findings are in conformity with the findings of Mishra and Shukla(1986), Pathak *et al.* (1996), Sethi (1996) and Satapathy (1997). Swain and Padhi (2011) reported that combination of 25:75 and 50:50 coal ash and soil mixture consistently increased the germination and seedling growth in jackfruit.

Growth, yield attributing characters, biomass and chlorophyll content

Coal ash had a positive effect in increasing plant height in okra over the period of study (Table 4). The data revealed a considerable variation in plant height among the treatments. It was observed that the maximum height was recorded in 50:50 coal ashes and soil combination in the growing media and the minimum height was recorded with the highest concentration of coal ash. Similar trend was also observed with number of leaf, leaf area (sq.cm), number of flowers per plant, number of fruits per plant, fruit weight per plant (g) in okra crop. It was contemplated that coal ash as a supplement with soil in the growing media improved the vegetative growth because of presence of trace elements in coal ash. The possible reason for enhancement in weight of fruit with application coal ash might be due to active participation of Zn and B in cell division, cell expansion and increased volume of intercellular space in the mesocarpic cells. Increase in cell characters particularly cell enlargement is mostly due to availability of Zn in plant stream. Zinc is known to act as a metal activator in the synthesis of auxin precursor which is solely responsible for maintenance of tissue turgor resulting in expansion of cells and the growth process as a whole. The higher synthesis of metabolites and enhanced mobilization of food and minerals from other parts of the plant towards developing fruits is mostly due to boron. No visible symptom of nutrient deficiency or phytotoxicity was observed in okra plant in all the cases of ash amended soil. These findings are in accordance with the reports of Sarkar *et al.* (1984), Sethi (1996), Sathpathy (1997). Swain *et al.* (2013) found that 50:50 coal ash and soil mixture invariably increased vegetative growth in mango.

The effect of coal ash on okra 90 days after sowing resulted in maximum biomass with 50:50 coal ash and soil combination while the minimum was recorded in soil mixture with only coal ash and no soil (Table 5). The fertility status of the soil, which was improved by addition of coal ash, might have aided higher nutrients acquisition in the plant parts thus increased the bio-mass content of the whole plant. A favourable growth response was observed in barley plant in ash amendment upto 8% (Elseewi *et al.*, 1978)). The result of present study is in close proximity with that of Dubey *et al.* (1982) and Mishra and Shukla (1986). However, the effect of coal ash on total chlorophyll content was least since the variation between the treatments was subtle.

Nutrient acquisition

Macro nutrients

The plant nutrients content have been influenced by the use of graded levels of coal ash in the growing medium (Table 5). It is indicated from the table that significant difference among the treatments was recorded in case of leaf P and K content. The level of leaf P and K content remained high under the influence of coal ash treatment at 25: 75 coal ash and soil mixture in the growing medium. Such an additive effect of coal ash might be due to efficient assimilation of P and K in the presence of certain micro nutrients in coal ash particularly Cu and Mo and activities of certain enzymes. However, no significant variation in respect of effect of coal ash on leaf N was observed among the treatments. In general the increase in leaf P and K content by application of coal ash have already been reported by others like Adriano *et al.* (1978), Sethi (1996), Sathapthy (1997), Singh *et al.* (2002) and Gond *et al.* (2011).

The data pertaining to secondary nutrient status of okra (Table 5) revealed that the maximum leaf Ca content was recorded with the treatments having 100% coal ash and the lowest was recorded with the treatment having 25: 75 coal ash and soil in the growing medium. However, no significant difference was found among the treatments with respect to leaf magnesium and sulphur content.

Micro nutrients

The leaf nutrient status in relation to the micro nutrients such as Mn, B, Mo, Fe, Cu and Zn were found to be higher in the treatments having high proportion of coal ash in the growing medium and the lowest was recorded with the treatment receiving no coal ash (Table 6). After application of coal ash in graded doses to plants, the elements are absorbed by the plants to certain extent after utilization and accumulated in the plant tissue (Sushil *et al.*, 2006 and Gond *et al* 2011). It might be due to the chemical composition of the coal ash which is rich in micronutrients. According to Wong and Wong (1990), accumulation of micronutrients were observed consistently with an increase in ash amendment in *Brassica parachinensis* and *Brassica chinensis*. The results of the present study are in conformity with the finding of Furr *et al.* (1979) who cultured a variety of vegetables, millets and apple trees on poly pots amended with coal ash showed enhanced absorption of B, Cu, Co, Fe, Mg, Mn Mo, Se and Zn. Mo is also reported to have essential role in Fe absorption and translocation in plants, the micronutrients which have its own discrete function (Padmanathan *et al.*, 2008). The leaf nutrient status in relation to the micronutrients like Zn, Mn, B, Mo, Fe and Cu were found elevated in the treatment supplemented with high coal ash content (Das *et al.*, 2011 and Swain *et al.*, 2013).

From the present study, it is ascertained that the proportion of coal ash in soil is most important and in the present context, 50:50 coal ash and soil composition consistently increased the seed germination, seedling growth, biomass, vegetative growth and chlorophyll content of okra plants while 100% coal ash in the growing media reduced the above mentioned attributes. The leaf nutrient status in relation to nutrients like Ca, Mg, S and the micronutrients Zn, Mn, B, Mo, Fe and Cu were found to be elevated in the treatments with high coal ash proportion in the growing medium and the lowest was recorded with treatment having no coal ash. The present investigation suggests that application of coal ash and soil mixture of 50:50 proportions is beneficial in terms of growth parameters and nutrient acquisition of okra in sandy loam soil and at the same time, the disposal problem of huge amount of coal ash will also be minimised.

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