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Growth performance and biochemical responses of Tomato (*Lycopersicon esculentum* Mill.) grown in fly-ash amended soil

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Abstract : *The disposal of huge amount of fly-ash from coal-fired power stations causes significant economic and environmental problems. The conventional disposal methods for fly-ash lead to degradation of arable land and contamination of the ground water. However fly-ash is a useful ameliorant that may improve the physical, chemical and biological properties of acidic soils and is a source of readily available plant macro and micronutrients. Fly-ash can enhance plant biomass production from degraded soils. In the present investigation Tomato (Pusha rubi) were grown in degraded soil of Chandrapura (as control) and various amendments (60, 120, 180 and 240) of Chandrapura Thermal Power Plant fly-ash for a period of 100 days and effect on growth and productivity of plant was evaluated vis-a-vis metal accumulation in the plants. The toxicity of fly-ash at higher concentration was reflected by the reduction in plant height and fruit weight. However, at lower concentrations (60-180), Fly-ash enhanced growth of the plants as evident by the increased growth parameters. The chlorophyll a, chlorophyll b, total chlorophyll, Carotenoid, root and shoot length showed increase in their levels up to180 t/ha fly-ash as compared to control.*

Key words : Fly-ash, Growth and Productivity, Macro and Micro nutrients, Tomato.

Introduction

Fly-ash is the portion of the combustion residue that enters the flue gas stream in power generating facilities and consists of many small, glass-like particles ranging in size from 0.01 to 100 mm (Davison *et al*., 1974). Fly-ash is a heterogeneous mixture of amorphous and crystalline phases and is generally considered to be a ferroaluminosilicate element (El Mogazi *et al*., 1988; Mattigod *et al*., 1990). Chemically, fly-ash contains oxides, hydroxides, carbonates, silicates, and sulfates of calcium, iron, aluminum, and other metals in trace amount (Adriano *et al*., 1980).

Particle size greatly influences chemical composition of fly-ash and how it may affect physical properties of soil. The mineralogical, physical and chemical properties of fly-ash depend on the nature of the parent coal, conditions of combustion, type of emission control devices and storage and handling methods. The pH of fly-ash can vary from 4.5 to 12.0 depending largely on the S content of the parent coal (Plank and Martens, 1974). Thus, anthracite, bituminous and lignite coals produce ashes of different compositions. Combustion temperature influences the degree to which many mineral elements may volatilize. Storage methods may affect weathering rates, especially under humid conditions where soluble constituents may be leached (Adriano *et al*., 1980). Eastern U.S. coals that include anthracite are generally high in S and produce acidic ashes, while western U.S. coals, which

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include lignites, tend to be lower in S and higher in Ca and produce alkaline ashes (Page *et al*., 1979). Indian fly-ash is also alkaline in nature due to lower S content. In India, coal is the most extensively used and most important source of energy, and will probably continue to be so. In India fly-ash production is 112 million tones in 2005–06 and it is expected to generate about 150–170 million tones of fly-ash per year by end of the 11th 5-year plan (MOEF, 2007).

In India, major areas for fly-ash utilization are construction and biomass production. Construction area includes cement production, brick manufacturing and road embankments while biomass production covers agricultural, forestry, and floriculture. But forestry attracts more fly-ash utilization for growing few economically important trees such as pulp and paper tree, biodiesel crops, firewood, timber wood and plywood trees. So, using fly-ash for biomass production is one of the important strategies to protect environmental degradation as well as economical importance.

The other applications of fly-ash include metals extraction, creation of cenospheres and waste-water treatment (Asokan *et al*., 2005). Enormous volume of fly-ash remains unutilized and its dumping has passed a threat to environmental problem to heavy metal content (Gupta *et al.,* 1995; Pathak *et al.,* 1996). Depending on the source of the coals fly-ash contain various levels of trace elements such as arsenic, barium, boron, cadmium, chromium, cobalt, copper, lead, mercury, and selenium (Page *et al* 1979; Khan and Khan, 1996). In controlled doses fly-ash is as an amendment for agricultural soil due to its potential to improve physical and chemical texture of problematic soils. Similarly, at 100-1000 times dilution, it does not affect the soil micro flora or enters the food chain (Carlson and Adriano, 1993, Saxena *et al*., 1998).

Fly-ash has already been recognized as a potential soil amendment for increasing the availability of mineral nutrients for plant growth (Mittra *et al*., 2005; Lee *et al*., 2007; Pandey and Singh, 2010; Singh *et al.*, 2011). Indian fly-ash has been found beneficial for the growth of plants due to the presence of several plant nutrients (Adriano *et al*., 1980). Its amendment in soil up to 40 per cent level brings about an increase in the growth and yield of cucumber, maize, okra, potato, tomato and wheat (Khan and Khan, 1996; Mishra and Shukla, 1986; Raghav and Khan, 2002).

Fly-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 (Bilski *et al*., 1995; 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, particularly in rice agriculture. Apart from plant residues, fly-ash can be also considered as a potential source of soil amendments for paddy agriculture production (Pandey and Singh, 2010). Use of fly-ash for agricultural practices have been proposed, since the hydroxide and carbonate salts give fly-ash one of its principal beneficial chemical characteristics, the ability to neutralize acidity in soils (Matsi and Keramidas, 1999; Pathan *et al*., 2003). Several field and greenhouse experiments indicate that many chemical constituents of fly-ash may benefit plant growth and can improve agronomic properties of soil (Elseewi *et al*.,1980; Singh and Singh, 1986;Wong and Wong, 1989; Sikka and Kansal, 1995). The present investigation was, therefore, conducted to study the direct and residual effect of fly-ash applied alone in an integrated manner on crop productivity, restoration of soil fertility and nutrient status in plant in tomato sequence.

Materials and Methods

Study area : Chandrapura Thermal Power Station is situated in the Bokaro district of

Fig 1. Location of study area

Jharkhand state (Fig. 1), India. It is 50 km from the Dhanbad and 1 km from the Chandrapura railway station and situated at Dhanbad–Bokaro roadway. Chandrapura located 23°75' on the North and 86°7' E. The capacity of thermal power plant is 750 MW. The power plant has an ash pond near the fly ash disposal site.

Physico-chemical analysis of different amendment and soil : Fly ash and soil samples were collected randomly from dumping sites of Chandrapura Thermal Power Station in large plastics bags and brought to the CIMFR field laboratory. The fly ash and soil were dried 5 days and passed through 2 mm sieve before making various amendments (manually) plots were 1 x 1m size with 15 cm uniform spacing between plots and 30 cm ridges between adjacent plots and five treatments i.e. 0, 60,120, 180 and 240 t/ha respectively were taken.

Physico-chemical analyses were carried out in triplicate in soil and their different amendments with fly-ash before the growth of *Lycopersicon esculentum* Mill. The pH of the different amendment was measured in 1:2.5 soil water suspension using pH meter (Consort C831), electrical conductivity (EC) of soil and amendments samples was determined by digital conductivity meter (Consort C831).

Organic carbon values of 5 days old soil and amended samples were determined by oxidation with potassium dichromate in acid medium (Walkley and Black, 1934). Total concentrations of trace elements were determined with Hydrogen fluoride, Nitric acid and Perchloric acid (7:3:1) using through with ICP-MS - Perkin Elmer Sciex ELAN DRC II.

Experimental design : Certified seed of *Lycopersicon esculentum* (Pusha rubi) were obtained from Birsha Agricultural University, Jharkhand, India. All the seed were sterilized with 0.1 % mercuric chloride for 5 min to avoid fungal contamination and washed with distilled water three times and soaked in water for 5 h. The soaked seed were evenly sown in pot (10 inch diameter), which were filled with different amendments (60, 120, 180, and 240 t/ha) along with one set of control (soil) each in pot to a depth of 0.5 cm and watered daily till seed germination. The plants were irrigated with tap water at regular interval (300 ml), avoiding leakage of water from the pots and root and shoot lengths were measured.

Leaves of plants 40 and 100 days after germination were used for photosynthetic pigment (Chlorophyll a, Chlorophyll b, Total Chlorophyll and Carotenoid) measurement (Arnon, 1954). 0.1 gm of (fresh weight) of leaves (three replicates) samples were crushed with 10 ml of 80 % acetone v/v. After centrifugation at 10000 rpm for 10 min, optical densities of acetone soluble pigments were determined at 643 and 645 nm. Total concentrations of trace elements were determined with nitric perchloric acid (3:1) using through with ICP-MS - Perkin Elmer Sciex ELAN DRC II.

A two way ANOVA in complete randomized block design was used to confirm the validity of data. Comparison from control and between the means of treatment was done by Duncan's multiple range test (DMRT) using SPSS 16.

Results and Discussion

The physico-chemical characteristic of soil and their amendment with fly-ash were reported in Table 1. The moisture content varied from 2.85-4.43 % in respective amendments. Addition of fly-ash increased pH (6.15-7.05) in amended soil. Electrical conductivity value was almost doubled at the level of 240 metric tons fly-ash 55.47-73.46 (µS/cm). Values of organic carbon and organic matter were increased with the addition of fly-ash. The concentration of organic carbon and organic matter was absorbed from 0.75 %-0.86 % and 1.30-1.47% approximately. This was more than normal soil (ICAR, 1996). The application of graded levels of fly-ashes resulted in an increase in available macro and micro nutrient (P, K, Cr, Co, Ni, Zn, Cu, Fe, Al, Pb, Cd, Mo, As, Se and V) in the soil whereas addition of fly-ash concentration of N were reported in decreasing trend (Table 1).

The accumulation of trace elements in (mg/kg) edible parts after 100 days of treatment in different amendments of fly-ash was reported in Table 2. The plants grown in soil have accumulated appreciable amounts of these metals in the edible part. The plants growing in soil and 180 t/ha showed a different trend of accumulation of trace elements as Fe> Al> Zn> Cu> Cr> Ni> Co> Pb> Mo> Cd> Se> As and V. Although the plants grown in fly-ash accumulated significant amounts of these metals, general vigour of plant was not affected. The accumulation of toxic metal, Cr was found to be higher in the plant grown in soil. Mishra and Shukla (1986) also reported the enrichment of soils and plants with trace elements by fly-ash application.

The data represented in Tables 3 and 4 showed that all the plant growth parameters and photosynthetic pigments (root length, and fresh weight edible part of brinjal) were significantly increased at all amendment in fly-ash combinations as compared to control set. The plant growth was better in 60, 120, 180 and 240 combinations irrespective of control, maximum being at 120 -180 t/ha level of fly-ash. The photosynthetic pigments (chlorophyll a chlorophyll b, total chlorophyll and carotenoid) were significantly increased in the treatments with 120 to 180 t/ha fly-ash as compared with soil. The beneficial effect of fly-ash at lower levels have already been observed on many crops - soybean, cabbage, chickpea, cucumber, lentil, maize, potato, wheat, tomato

Table 1. Physico-chemical properties in different amendments of fly-ash with soil

	Soil	60 t/ha	120 t/ha	180 t/ha	240 t/ha
W. Holding capacity (%)	$42.11^{d} \pm 0.55$	$52.64^{d} \pm 0.04$	$63.15^{c} \pm 0.04$	$65.70^{b} \pm 0.02$	$65.76^{a} \pm 0.02$
Moisture content (%)	$2.85^{b} \pm 0.15$	$2.58^{b} \pm 0.26$	$3.94^{a} \pm 0.20$	$4.43^{a} \pm 0.20$	$3.76^{a} \pm 0.11$
Specific gravity (g/cm^3)	$1.21^{b} \pm 0.02$	$1.17^{c} \pm 0.02$	$1.31^{b} \pm 0.01$	$1.43^{a} \pm 0.04$	$1.10^{c} \pm 0.03$
Bulk density (g/cm3)	$1.24^{a} \pm 0.01$	$1.22^{a} \pm 0.02$	$1.24^{a} \pm 0.01$	$1.28^{a} \pm 0.04$	$1.24^{a} \pm 0.03$
pH	$6.15^{d} \pm 0.10$	$6.45^{d} \pm 0.15$	$6.70^{c} \pm 0.23$	$6.95^{b} \pm 0.25$	$7.05^{a} \pm 0.30$
EC(µS/cm)	$55.47^{d} \pm 0.12$	$56.79^{d} \pm 0.04$	$60.65^{c} \pm 0.02$	$62.04^{b} \pm 0.04$	$73.46^{a} \pm 0.01$
OC(%)	$0.75^{c} \pm 0.02$	$0.83^{c} \pm 0.02$	$0.89^{a} \pm 0.03$	$0.90^{a} \pm 0.01$	$0.86^{b} \pm 0.02$
OM(%)	$1.30^{b} \pm 0.02$	$1.43^{c} \pm 0.02$	$1.53^{a} \pm 0.03$	$1.57^{a} \pm 0.01$	$1.47^{b} \pm 0.02$
Ca(mg/kg)	$2.77^{d} \pm 0.01$	$6.74^{d} \pm 0.02$	$7.18^{c} \pm 0.01$	$8.20^{b} \pm 0.01$	$9.15^{a} \pm 0.02$
Mg(mg/kg)	$17.70^{c} \pm 0.02$	$16.42^{d} \pm 0.02$	$17.38^{c} \pm 0.01$	$19.87^{b} \pm 0.01$	$20.25^{a} \pm 0.02$
N(kg/ha)	$296.94^{a} \pm 25.76$	$290.66^{a} \pm 37.83$	$242.62^{c} \pm 21.04$	$232.77^{d} \pm 32.17$	181.63^{d} 15.87
P(kg/ha)	$9.63^{d} \pm 0.15$	$9.67^{d} \pm 0.02$	$10.35^{c} \pm 0.02$	$11.09^{a} \pm 0.02$	$10.59^{b} \pm 0.02$
K(kg/ha)	$111.60^{a} \pm 1.99$	$111.16^{d} \pm 0.22$	$111.44^{c} \pm 0.23$	$112.22^{a} \pm 0.11$	$111.44^{c} \pm 0.14$
Trace elements (mg/kg)					
Cr	$79.36^{c} \pm 1.99$	$108.76^{c} \pm 1.96$	$128.32^{a} \pm 1.00$	$114.6^{b} \pm 0.86$	$136.51^{a} \pm 1.15$
Co	$11.16^{c} \pm 0.32$	$13.64^{c} \pm 0.02$	$17.12^{a} \pm 0.02$	$17.04^{a} \pm 0.02$	$12.53^{b} \pm 0.01$
Ni	$25.09^{c} \pm 0.30$	$34.72^{b} \pm 0.60$	$43.94^{a} \pm 1.09$	$45.02^{a} \pm 1.17$	$37.28^{b} \pm 1.19$
Cu	$50.28^{b} \pm 0.60$	$78.58^{a} \pm 1.22$	$62.47^{a} \pm 1.95$	$67.19^{a} \pm 2.03$	$59.89^{a} \pm 2.00$
Zn	$681.33^{a} \pm 6.92$	$601.40^{b} \pm 3.00$	$452.22^{d} \pm 2.01$	$576.94^{c} \pm 3.00$	$477.31^{d} \pm 3.00$
Fe	$22404^{a} \pm 360$	$19227^{a} \pm 262$	$24326^{a} \pm 375$	$25190^{a} \pm 429$	$23208^{a} \pm 360$
Mo	$36.79^{a} \pm 0.01$	$34.81^{a} \pm 0.02$	$36.71^{a} \pm 0.02$	$25.34^{b} \pm 0.02$	$28.41^{b} \pm 0.01$
Al	$80.75^{c} \pm 1.99$	$71.90^{d} \pm 1.97$	$108.51^{a} \pm 1.01$	$87.39^{b} \pm 1.15$	$54.10^{d} \pm 0.87$
Pb	$77.11^{a} \pm 1.99$	$70.24^{b} \pm 1.94$	$50.84^{c} \pm 1.01$	$71.73^{b} \pm 1.17$	$73.32^{a} \pm 0.84$
Cd	$3.56^{c} \pm 0.05$	$4.01^{d} \pm 0.02$	$5.63^{c} \pm 0.02$	$5.80^{b} \pm 0.02$	$7.43^{a} \pm 0.02$
As	$3.95^{a} \pm 0.03$	$4.01^{a} \pm 0.06$	$4.30^{a} \pm 0.09$	$5.17^{a} \pm 0.09$	$5.24^{a} \pm 0.08$
Se	$1.30^{b} \pm 0.01$	$2.31^{a} \pm 0.02$	$4.03^{a} \pm 0.02$	$3.37^{a} \pm 0.01$	$4.39^{a} \pm 0.02$
V	$64.38^{c} \pm 1.96$	$97.34^{c} \pm 1.99$	$97.84^{c} \pm 1.97$	$122.86^{a} \pm 2.03$	$115.43^{b} \pm 2.01$

Values are mean (n=3) SD, ANOVA $p < 0.05$, different superscripts denote significant differences ($p < 0.05$) between means in a column for each parameter according to DMRT.

etc. (Mishra and Shukla, 1986; Khan and Khan, 1996; Raghav and Khan, 2002).

It has been confirmed from this study that amendment of fly-ash at lower levels (60-180 t/ha) with soil was found beneficial for the plant growth and yield of tomato. However, higher levels of fly-ash addition in soil showed reduced growth and yield of tomato. The study also showed that the available nutrients present in fly-ash were beneficial for certain levels for utilization of a particular plant species and improve physico-chemical characteristic of acidic soil. Therefore, fly-ash can be used as an eco-friendly, non-conventional fertilizer at 60

Table 2. Accumulation of trace elements (mg/kg) of *Lycopersicon esuulentum* Mill. growing in different fly-ash amendment

	Soil	60 t/ha	120 t/ha	180 t/ha	240 t/ha
Cr	0.75^{a}±0.36	0.73^{a}± 0.06	0.74^{a}±0.05	0.69^{b}± 0.07	0.62^{c}± 0.02
Co	0.05^{a}±0.02	0.03^{a}±0.02	0.05^{a}±0.02	0.04^{a}±0.02	0.03^{a}± 0.02
Ni	0.72^{a}± 0.01	0.71^{b}± 0.03	0.57^{b}±0.06	0.49^{c}±0.01	0.44^{d}± 0.02
Cu	5.12^{a}± 2.53	4.05^{a}± 2.01	3.37^{a}±2.00	2.39^{a}±2.01	3.00^{a}± 2.01
Zn	19.89^{c}± 2.01	25.20^{b}±2.01	30.35^{a}±3.06	18.23^{c}±2.01	16.17^{c}±2.01
Fe	68.47^{a}±11.51	54.09^{b}±1.16	66.64^{a}±2.32	41.56^{c}±1.16	36.15^{d}±1.16
Mo	0.81^{c}± 0.02	1.70^{c}± 0.01	2.83^{a}± 0.14	1.94^{b}± 0.53	4.29^{a}± 0.01
Al	31.70^{a}± 2.01	18.55^{c}±2.01	28.93^{a}±2.58	28.93^{a}±2.01	8.51^{c}± 2.01
Pb	7.80^{a}± 0.01	2.56^{b}± 0.02	2.85^{b}± 0.02	0.75^{c}± 0.02	0.69^{c}± 0.02
Cd	0.06^{a}± 0.01	0.04^{a}± 0.02	0.05^{a}± 0.02	0.04^{a}± 0.02	0.04^{a}± 0.02
As	0.75^{a}± 0.02	0.39^{d}± 0.02	0.53^{c}± 0.03	0.32^{d}± 0.02	0.62^{a}± 0.02
Se	0.15^{d}± 0.02	0.80^{c}± 0.02	1.14^{b}± 0.08	0.77^{c}± 0.02	1.24^{a}± 0.02
V	0.49^{a}± 0.02	0.31^{d}± 0.02	0.39^{c}± 0.12	0.27^{d}± 0.12	0.44^{b}± 0.02

Values are mean (n=3) SD, ANOVA $p < 0.05$, different superscripts denote significant differences ($p < 0.05$) between means in a column for each parameter according to DMRT.

Table 3. Effect of various fly-ash amendments on shoot length of *Lycopersicon esuclentum* Mill. (inch) at different durations (40 and 100 days) and edible fresh weight(g/plant)

	40 days	100 days	40 days	100 days	Edible
	Root length(inch/plant)		Shoot length (inch/plant)		Weight(g/plant)
Soil	6.38^{b}±0.74	9.57b±0.95	9.68^{b}±1.06	23.82^{b}±2.06	774.21^{b}±41.13
60 t/ha	7.10^{a}±0.77	10.64^{b}±1.01	11.43^{a}±0.98	24.56^{b}±0.76	896.08^{b}±43.26
120 t/ha	7.62^{a}±1.20	11.44^{a}±1.97	12.52^{a}±1.90	26.69^{a}±1.12	935.77^{a}±45.35
180 t/ha	7.95^{a}±1.01	11.92^{a}±1.11	12.75^{a}±1.65	25.38^{a}±0.98	994.65^{a}±48.52
240 t/ha	6.25^{b}±0.70	9.37^{b}±0.89	12.57^{a}±1.63	23.33^{b}±1.02	848.13^{b}±39.58

Values are mean (n=3) SD, ANOVA $p < 0.05$, different superscripts denote significant differences ($p < 0.05$) between means in a column for each parameter according to DMRT.

Table 4. Effect of various fly-ash amendments on photosynthetic pigments (mg/g) of *Lycopersicon esuulentum* Mill. at 40 and 100 days

	40 days	100 days	40 days	100 days	40 days	100 days	40 days	100 days
	Chlorophyll a		Chlorophyll b		Total Cholorophyll		Carotenoid	
Soil	0.90^{b}± 0.09	0.97^{b}± 0.09	0.54^{b}± 0.06	0.62^{b}± 0.06	1.44^{b}± 0.25	1.59^{b}± 0.16	0.27^{b}± 0.01	0.54^{b}± 0.02
60 t/ha	1.02^{a}± 0.09	1.06^{a}± 0.10	0.69^{a}± 0.08	0.73^{a}± 0.06	1.70^{a}± 0.40	1.79^{a}± 0.43	0.30^{a}± 0.01	0.61^{a}± 0.02
120 t/ha	1.01^{a}± 0.13	1.09^{a}± 0.10	0.66^{a}± 0.10	0.82^{a}± 0.05	1.68^{a}± 0.46	1.91^{a}± 0.46	0.45^{a}± 0.02	0.74^{a}± 0.03
180 t/ha	0.89^{b}± 0.17	1.23^{a}± 0.12	0.57^{b}± 0.06	0.94^{a}± 0.07	1.46^{b}± 0.87	2.17^{a}± 0.87	0.47^{a}± 0.02	0.84^{a}± 0.03
240 t/ha	0.98^{b}± 0.57	1.01^{a}± 0.10	0.57^{b}± 0.05	0.71^{b}± 0.07	1.55^{a}± 0.54	1.72^{a}± 0.54	0.26^{b}± 0.01	0.55^{b}± 0.02

Values are mean (n=3) SD, ANOVA $p < 0.05$, different superscripts denote significant differences ($p < 0.05$) between means in a column for each parameter according to DMRT.

and 180 t/ha levels respectively because they will improve the growth and yield of certain crops. At the same time, the disposal problem of huge amount of fly-ash will also be minimized.

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