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FLY ASH AS A POTENTIAL SOURCE OF SOIL AMENDMENT IN AGRICULTURE AND A COMPONENT OF INTEGRATED PLANT NUTRIENT SUPPLY SYSTEM

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ABSTRACT

The present study investigates the effect of fly ash amended soil on the growth and photosynthetic pigment content of *Capsicum annuum*. A pot culture experiment comprising four treatments such as 5%, 10%, 15% and 20% were carried out with a control pot. The different photosynthetic pigments like chlorophyll a, chlorophyll b, total chlorophyll, carotenoid and physical parameters like total length of plant, root length and shoot length were studied on different experimental days, i.e. 10^{th} day, 20^{th} day, 30^{th} day, 40^{th} day, 50^{th} day and 60^{th} day. The different physico-chemical characteristics of soil before and after the experiment were analyzed. Photosynthetic pigments like chlorophyll a, chlorophyll b, total chlorophyll and carotenoid were found to be highest in 5% fly ash amended soil on 40^{th} days of growth followed by a decline trend. One way ANOVA test for those pigments between different days of growth and also within different fly ash amendment soils showed a significant difference ($P < 0.05$). Further, the physical parameters like root length, shoot length and total length of the plant were studied on each experimental days. One way ANOVA test for those parameters between different days of growth and also within different fly ash amendment soils were not found to be significant. The change in soil physico-chemical parameter such as pH, conductivity (µs/cm), moisture content (%), OC (g%), OM (g%), N (mg/kg), P (mg/kg), Cu (mg/kg), Zn (mg/kg), Fe (mg/kg), Cr (mg/kg) were also analyzed from each culture pot after the end of the experiment. It was observed that except N, P, K all other parameter have increased with increase in fly ash amendment.

INTRODUCTION

Fly ash is a residue of burning of coal and lignite, the organic sources of energy. Now-a-days fly ash disposal into the environment is one of the major concerns throughout the world mainly in developing countries. The micro and macro nutrients present in coal get generally concentrated in the ash. Fly ash has great potentiality in agriculture due to its efficacy in modification of soil health and crop performance.

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Unlike the waste water (Dash and Mishra, 1996a, 1996b, 1998, 1999, Dash, 2012, Pradhan *et al*., 2013, Dash and Pradhan, 2013) fly ash has been found to be beneficial for plant growth due to the presence of several plant nutrients (Adriano *et al*., 1980). Chemically, 90-99% of fly ash is comprised of Si, Al, Fe, Ca, Mg, Na and K with Si and Al forming the major matrix (Adriano *et al*., 1980). These elements increase the yield of many agricultural crops. It is substantially rich in trace elements like lanthanum, terbium, mercury, cobalt and chromium (Adriano *et al*., 1980). Many trace elements including As, B, Ca, Mo, S, Se and Sr (Page *et al*., 1979) in the ash are concentrated in the smaller ash particles (Adriano *et al*., 1980). Fly ash improves the nutrient status of soil (Rautaray *et al*., 2003). The utilization of fly ash as a soil amendment has been so far tested for *Helianthus annus* (Pandey *et al*., 1994), *Lycopersicon esculentum*, (Khan *et al*.,1996), *Beta vulgaris*, *Triticum aestivum* L., *Esculenta moench*, *Oryza sativa* L. and *Zea mays* L. (Kalra *et al*.,1997), *Cassiasiamea* (Tripathy *et al*., 2005), *Prosopis juliflora* L., (Rai *et al*., 2004). Agricultural utilization of fly ash has been proposed because of its considerable content of K, Ca, Mg, S and P (Kalra *et al*., 1997; Singh *et al*., 1997). Fly ash addition generally increases plant growth and nutrient uptake (Aitken *et al*.,1984). Weinstein *et al*., 1989 reported that fly ash increased crop yield of alfalfa (*Medicago sativa*), barley (*Hordeum vulgare*), Bermuda grass (*Cynodon dactylon*) and white clover (*Trifolium* repens). Furr *et al*., 1977 demonstrated that alfalfa, sorghum (Sorghum bicolor), field corn (*Zea mays*), millet (*Echinochloa crusgalli*), carrots (*Daucas carota*), onion (*Allium cepa*), beans (*Phaseolus vulgaris*), cabbage (*Brassica oleracea*), potatoes (*Solanum tuberosum*) and tomatoes (*Lycopersicon esculentum*) could be grown on a slightly acidic soil (pH 6.0) treated with 125 mt ha^{-1} of unweathered fly ash. In the present research, an attempt has been made to study the effect of different fly ash amendment soil on the growth and physiological parameters of *Capsium annuum* under pot culture.

MATERIALS AND METHODS

Fly ash and soil samples

Fly ash and soil samples used for the experiment were sun dried for five days and pass through 2mm sieve before used for experimental purpose. The different physico-chemical parameters of soil like pH, conductivity, moisture content, organic carbon (g %), organic matter (g %), nitrogen, phosphorous, potassium, iron, chromium, cadmium and zinc were analyzed. The detailed physico-chemical analysis of both fly ash and soil used for the experiment are given in Table 1 and Table 2 respectively.

Table 1. Physico-Chemical Analysis of Fly Ash

Analysis	Result
Color	Greyish
Moisture (%)	0.21
Particle Size (45 micron) (%)	26.62
Bulk Density (g/mL)	1.00
Fineness (%)	412.45
pH	6.85
Silica as SiO_2 (%)	75.39
Mercury (as Hg)(mg/kg)	<0.50
Lead (as Pb) (mg/kg)	5.73
Phosphates as P_2O_5 (%)	0.27
Iron as Fe (%)	0.36
Iron Oxide as Fe_2O_3 (%)	0.51
Calcium as Cao (%)	0.17
Magnesium as MgO (%)	0.07
Chromium (as Cr)(mg/kg)	4.21
Copper (as Cu)(mg/kg)	8.17
Zinc (as Zn) (mg/kg)	12.04
Aluminium as Al_2O_3 (%)	22.26
Total alkalis (as $Na_2O+0.658K_2O$) % (w/w)	0.52
Compressive strength for 28days N/sq.mm	84.6
Sulphur trioxide (as SO_3) % (w/w)	0.11

The test plant species - *Capsicum annuum*

Capsicum annuum belongs to the Kingdom – Plantae, Order - Solanales and Family - Solanaceae. The plant genus Capsicum is native to Southern North America and Northern South America. This species is the most common and extensively cultivated as the five domesticated capsicums. Capsinoid chemicals provide the distinctive tastes in *Capsicum anunuum* variants.

Experimental design for pot culture study

Fifteen cemented pots of size 50 cm (L) X 50 cm (B) and 60 cm (H) were used for the experiment. Different concentrations fly ash (control (0%), 5 %, 10 %, 15 % and 20 %) were maintained in the respective experimental pots. For each concentration, three replicate pots were kept. To each concentration, seven seedlings of *Capsicum annuum* were planted. In order to avoid crowding effect, the saplings were planted almost equal distance in-between. Normal water was irrigated to each pot every day. In the present study, photosynthetic pigments and physical parameters of *Capsicum annuum*

Table 2. Physico-Chemical Characteristics of Soil Prior to Experiment

Clay	Silt	Fine sand	Coarse sand	pH	EC µS /cm	Mois-ture content	OM%	OC%	N (mg/ kg)	P (mg /kg)	K (mg /kg)	Na (mg /kg)	Cr (mg /kg)	Ni (mg /kg)	Zn (mg /kg)
7.25 ±0.26	12.65 ±0.87	26.79 ±1.57	53.31 ±3.82	6.79 ±0.04	37.0 ±0.34	2.85 ± 0.15	3.9 ±0.31	2.3 ±0.18	0.2 ±0.02	0.02 ±0.002	0.55 ±0.05	3.18 ±0.26	2.3 ±0.16	6.5 ±0.26	11.0 ±1.26

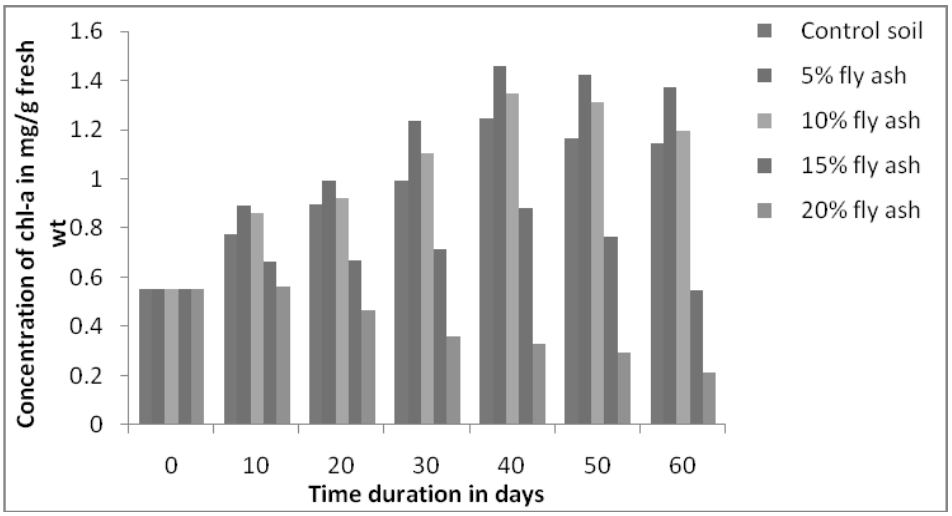

Fig. 1 Chlorophyll a (mg/g) content of *Capsicum annuum* in fly ash amendment soil

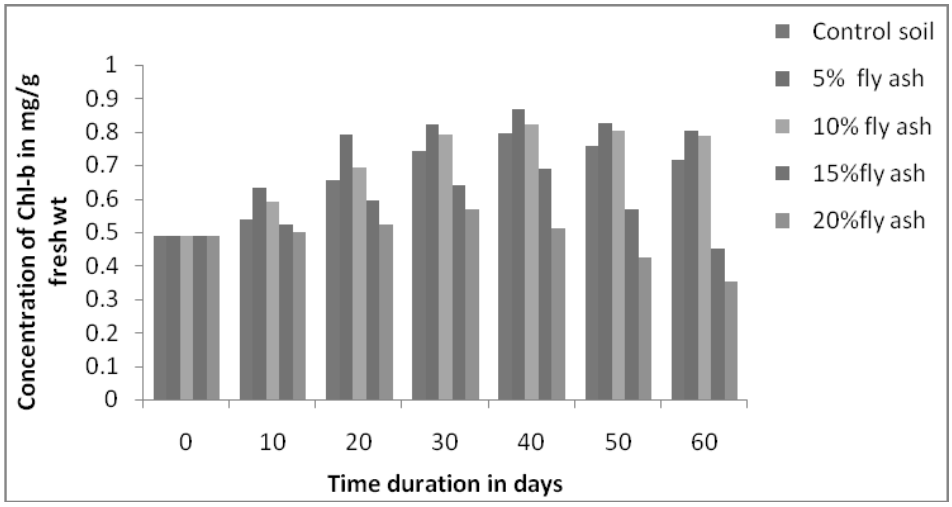

Fig. 2 Chlorophyll b (mg/g) content of *Capsicum annuum* in fly ash amended soil

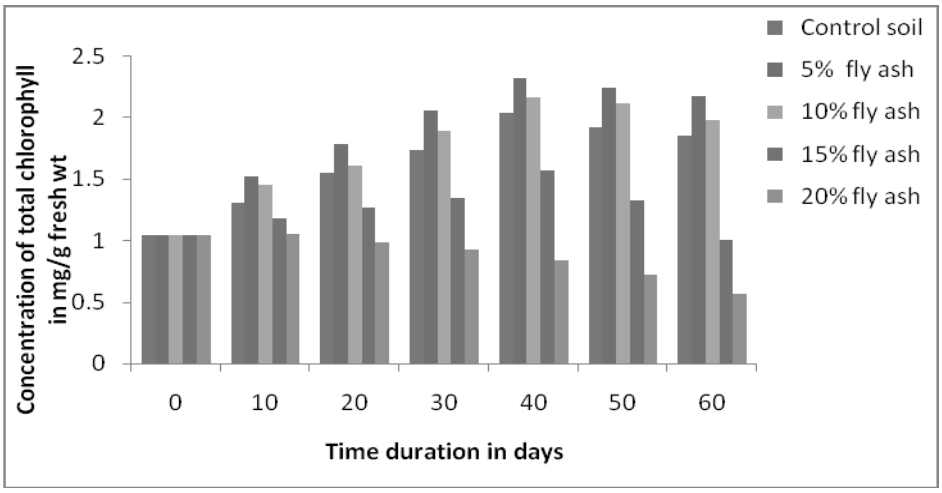

Fig. 3 Total chlorophyll (mg/g) content of *Capsicum annuum* plant in fly ash amended soil

were studied for a period from 0 day up to 60 days growth in different fly ash amendment soils.

Estimation of photosynthetic pigment content

The photosynthetic pigments such as chlorophyll *a*, chlorophyll *b*, total chlorophyll and carotenoid content of fresh leaf sample were measured at 10 day interval starting from 0 day up to 60 days of growth following the methods of Arnon, 1949. 100 mg of fresh plant samples were grinded with 80% chilled acetone and then centrifuged at 10000 rpm for 10 minutes. Then the absorbance of the suspension was taken at 475, 645 and 663 nm and the calculation was made as per the following equations;

a. Chlorophyll a (mg/ g fresh wt. tissue) = $12.7\ A_{(663)} - 2.69\ A_{(645)} \times V / (1000 \times W)$

b. Chlorophyll b (mg / g fresh wt. tissue) = $22.9\ A_{(645)} - 4.68\ A_{(663)} \times V / (1000 \times W)$

c. Carotenoid (mg / g fresh wt. tissue) = $A_{(475)}\ 10 \times V / (2500 \times W)$

Where;
A = Absorbance at a specific wavelength,
V = Final volume of the extract
W = Fresh weight of leaves taken for extraction

Measurement of morphological parameters of plant

The morphological parameters such as root length, shoot length and total length of plant from different treatment pots were measured at 10 days interval by simply extracting the plant from the pot. Three replicate were studied for each concentration and mean value were taken for calculation.

Analysis of soil physico-chemical parameters

The soil physical parameters like clay, silt, fine sand and coarse sand were measured by using different size of sieve and was expressed in percentage. For pH a soil suspension was prepared using distilled water in 1:20 ratio and pH of the unfiltered soil suspension was measured by a digital pH meter. For Electrical Conductivity also a soil suspension was prepared with distilled water in 1:20 ratio and electrical conductivity was measured by a conductivity meter and was expressed in terms of m mho/cm. Moisture content of the soil was calculated by taking the difference in the initial weight of soil sample and after keeping it in the oven for 24 hr at 105°C and was expressed in percentage. Organic Matter and Organic Carbon was estimated as per Walkley and Black's, 1934. Rapid titration method was followed to determine the organic carbon content of the soil. Percentage of Organic Matter (OM) was calculated as; OM % = 1.724 × per cent carbon (C %). Nitrogen content of soil was estimated as per Raveh and Avnimlech, 1979 and was expressed in g %. Sodium and Potassium were determined by a flame photometer using ammonium acetate extract directly and were expressed in mg/ kg of soil. Available phosphorous of soil was determined by using ammonium molybdate solution and was expressed as mg/kg of soil. Heavy metals like, Cu Ni, Zn, Fe and Pb were done by Atomic Absorption Spectrophotometer by acid digestion method. Statistical analyses (ANOVA) of the data were made according to Snedecor and Cochran, 1967.

RESULTS AND DISCUSSION

Chlorophyll a content of *Capsium annuum*

The chlorophyll a was measured on the 0th day which was found to be 0.554 (mg/g fresh wt. of leaf). Gradually the chlorophyll a content increases with respect to increase in percentage of fly ash amendment up to 5% after which it shows a decline trend. Further, the chlorophyll a content also increases from 0 day up to 40 days of growth after which it gradually decreases. On 40th day the chlorophyll a content was 1.245 (mg/g) in control, 1.456 (mg/g) in 5%, 1.345 (mg/g) in 10%, 0.879 (mg/g) in 15% and 0.330 (mg/g) in 20% fly ash amend soils. In the experiment the lowest chlorophyll a was recorded in 20% fly ash amended soil on 60th day of growth. One way Analysis of Variance (ANOVA) between different concentrations of fly ash amendment soil as well as within different days of growth for chlorophyll a content showed a significant difference ($F=11.25$; $p < 0.05$). Figure 1 shows the chlorophyll a content of *Capsicum annuum* in different fly ash amended soil on different days of growth. The percentage increase/decrease of chlorophyll a content over control on a particular day was calculated which shows that, there is an increase up to16.94 % on 5% amendment soil and decrease up to 73.49% on 20% amendment soil on 40th days of growth.

Chlorophyll b content of *Capsicum annuum*

The chlorophyll b content of *Capsicum annuum* also shows a similar trend with that of chlorophyll a. The Chlorophyll b content on 0th days was 0.489 (mg/g) which gradually increases with increase in fly ash amendment up to 5%. The maximum chlorophyll b was recorded on 40th days of growth in 5% fly ash

amendment soil (0.866 mg/g) which was found to be 0.513 (mg/g) in 20% amendment soil on the same day. After 40th days of growth in all the concentrations, gradually chlorophyll b content decreases. In the experiment the lowest chlorophyll b (0.352mg/g) was recorded on 60th days of growth in 20% fly ash amendment soil. One way ANOVA between different concentrations of fly ash amendment soil as well as within different days of growth for chlorophyll b content shows a significant difference ($F= 6.99$; $p < 0.05$). Figure 2 shows the chlorophyll b content of *Capsicum annuum* in different fly ash amended soils on different days of growth. The percentage increase/decrease of chlorophyll b content in different concentrations of fly ash amendment soils with respect to control in a particular day shows that, on 40th days of growth there is an increase of 9.06% in 5% amendment soil and there is a decrease of 35.39% in 20% fly ash amendment soil on the same day.

Total chlorophyll content of *Capsium annuum*

The total chlorophyll content of *Capsicum annuum* also follows the similar trend with that of chlorophyll a and chlorophyll b. The maximum total chlorophyll was recorded in 5% fly ash amendment soil (2.322 mg/g) on 40th days which was 0.843 (mg/g) in 20% amendment soil on the same day of growth. In the present study, the lowest total chlorophyll (0.564 mg/g) was on the 60th days in 20% fly ash amended soil. One way ANOVA between different concentrations of fly ash amendment soil as well as within different days of growth for total chlorophyll content showed a significant difference ($F= 10.19$; $p < 0.05$). Figure 3 shows the total chlorophyll content of *Capsicum annuum* in different fly ash amended soil on different days of growth. Further the percentage increase/decrease of total chlorophyll over control on a particular day shows that there is an increase of 13.87 % in 5% fly ash amendment soil and there is decrease of 58.65 % in 20% fly ash amendment soil on 40th days of growth. The maximum decrease of total chlorophyll was recorded on 60th days of growth in 20% fly ash soil (69.64 %).

Carotenoid content of *Capsium annuum*

The carotenoid content of *Capsium annuum* was measured up to 60th days of growth in all the amendments, i.e. from 5% up to 20% fly ash amendment soil including control. On 0th day carotenoid was recorded to be 0. 285 (mg/g). The carotenoid content of *Capsium annuum* gradually increases with increases in days of growth up to 40th days of growth and also with an increase in percentage of fly ash amendment up to 5% after which it gradually decreases. The maximum carotenoid was recorded to be 0.799 (mg/g) in 5% fly ash amendment soil and least carotenoid of 0.355 (mg/g) was recorded in 20% fly ash amendment soil on 40th days of growth. In the experiment, lowest carotenoid was recorded to be 0.212 (mg/g) in 20% fly ash amendment soil on 60th days of growth. Figure 4 shows the total carotenoid content of *Capsicum annuum* in different fly ash amended soil on different days of growth. One way ANOVA between different concentrations of fly ash amendment soil as well as within different days of growth for carotenoid shows a significant difference ($F= 5.176$; $p < 0.05$). Further, the

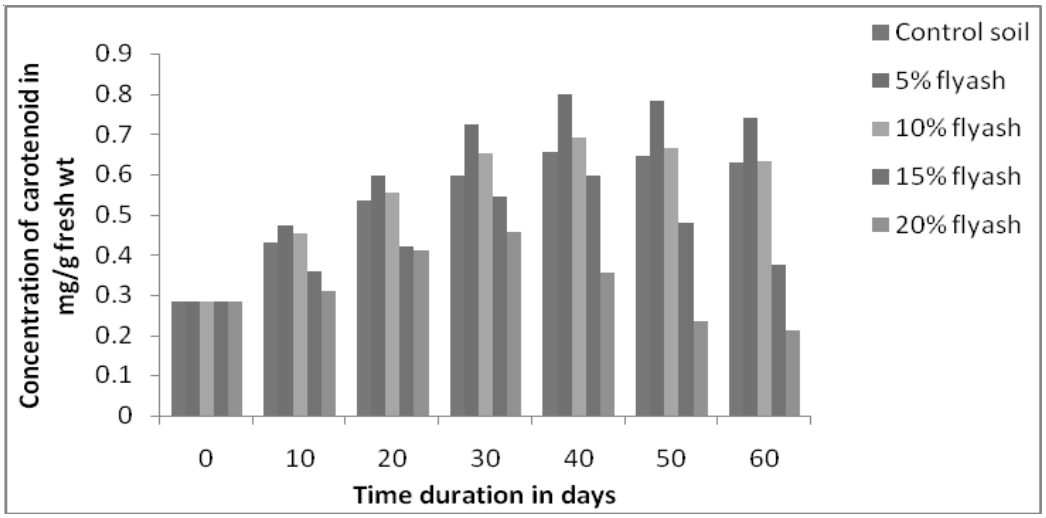

Fig. 4 Carotenoid (mg/g) content of *Capsicum annuum* plant in fly ash amended soil

percentage increased/decreased of carotenoid over control for different concentrations of fly ash amendment soil on a particular day of growth shows that, there is an increase of 21.61 (mg/g) in 5% fly ash amendment soil which gradually decreases up to 45.96% in 20% fly ash amendment soil on 40th days of growth. The maximum decrease was noticed on 60th days in 20% amended soil.

The beneficial effect of fly ash at lower level have been reported in soybean, cabbage, chickpea, maize, tomato, ground nut, etc. (Basu *et al.*, 2007; Merajul *et al*., 2010). The decreased in pigment content and the growth rate of *Capsicum annuum* at higher concentrations also supported by other workers (Krupa and Baszynski, 1995). Mishra and Shukla, 1986 also conducted an experiment on application of fly ash on agriculture and concluded that, application of fly ash also enhances growth and metabolic rates, as well as increasing the photosynthetic pigments of crops like maize and soybean. This might be due to the increase in different concentrations of plant nutrients and toxic heavy metals present in the fly ash in high concentrations of fly ash amendment experimental plots. Kenneth *et al.,* 2000 reported similar trend for carotenoid with an explanation that it might be due to a defence mechanism of plant against metal stress.

The root length, shoot length and total length of *Capsicum annuum*

The physical parameters like root length (Figure 5), shoot length (Figure 6) and total plant length (Figure 7) of *Capsicum annuum* were also individually measured and was expressed in cm. It was noticed that, all the three physical parameters increases with increase in fly ash concentration up to 5% after which it follows a decline trend on a particular day of growth. Further, with increase in days of growth up to 50 days there is a gradual increase in the above three parameters in all the amendments after which it almost stabilizes. The one way ANOVA test between different concentrations of fly ash amendment soil as well as within different days of growth for the above three parameters shows an insignificant difference ($F = 1.39$; $P < 0.05$ for root length, $F = 0.63$; $P < 0.05$ for shoot length and $F = 0.752$; $P < 0.05$ for total plant length). Further, percentage of increase or decrease of root length shows that, there is an increase of 7.45% in 5% fly ash amendment soil which gradually decreases to 33.16% in 20% fly ash amendment soil on 40th days of growth. Similarly shoot length shows that there is an increase of 14.95% in 5% fly ash amendment soil and decrease of 30.51% in 20% fly ash amendment soil while compared with control on 40th days of growth. In case of total plant length, there is an increase of 13.2 % in 5% fly ash amendment soil and decrease of 31.11 % in 20% fly ash amendment soil while compared with control on 40th days of growth. Application of 5-20% fly ash on w/w basis in the plough layer (0-15 cm) increased both grain and straw yield of pearl millet (*Pennisetum* sp.) followed by wheat (Grewal *et al*., 2001). Lau and Wong (2001) reported that weathered coal fly ash at 5% resulted in higher seed germination rate and root length of lettuce (*Lactuca sativa*).

Soil physico-chemical characteristics after the experiment

Table 3 shows the physico-chemical characteristics of soil after experiment with different percentage of

Table 3. Physico-Chemical Characteristics of Soil after the Pot Experiment

Parameters	Percentage of Fly ash amended on soil				
	Control soil	5%	10%	15%	20%
pH	6.66 ± 0.11	6.91 ± 0.12	7.13 ± 0.11	7.33± 0.12	7.42 ± 0.13
Conductivity(µS/cm)	51.47 ± 1.5	55.23 ± 2.1	61.34 ± 2.2	73.34 ± 1.8	85.78 ± 1.9
Moisture content (%)	2.68 ± 0.15	2.78 ± 0.18	3.89 ± 0. 17	4.56 ± 0.16	4. 98 ± 0.19
OC (g%)	2.33 ± 0.18	2. 64 ± 0.16	2. 81 ± 0.21	2. 99 ± 0.24	3.33 ± 0.22
OM (g%)	4.0 ± 0.45	4.57 ± 0.34	4.83 ± 0. 43	5.13 ± 0.52	5.58 ± 0.44
N (mg/Kg)	20.24 ± 1.4	18.23 ± 1.0	16 .33 ± 1.5	14.36 ± 1.2	12.23 ± 1.0
P (mg/Kg)	2.16 ± 0.12	1.45 ± 0.11	1.4 ± 0.12	1.35 ± 0.13	1.25 ± 1.0
K (mg/Kg)	5.45 ± 0.34	5.77 ± 0.44	5.88 ± 0.67	5.32 ± 0.75	5.21 ± 0.84
Cu (mg/Kg)	8.18 ± 1.4	11.78 ± 1.3	14.55 ± 1.2	17.42 ± 1.8	20.67 ± 1.6
Zn (mg/Kg)	33.0 ± 1.6	41.9 ± 1.89	50.45 ± 1.77	62.34 ± 2.45	77.45 ± 2.65
Fe (mg/Kg)	2.5 ± 0.23	3.58 ± 0.44	4.93 ± 0.34	5.27 ± 0.42	5.63 ± 0.32
Ni (mg/Kg)	14.09 ± 0.34	18.55± 0.44	23.44 ± 0.54	34.34 ± 0.56	37.23 ± 0.56

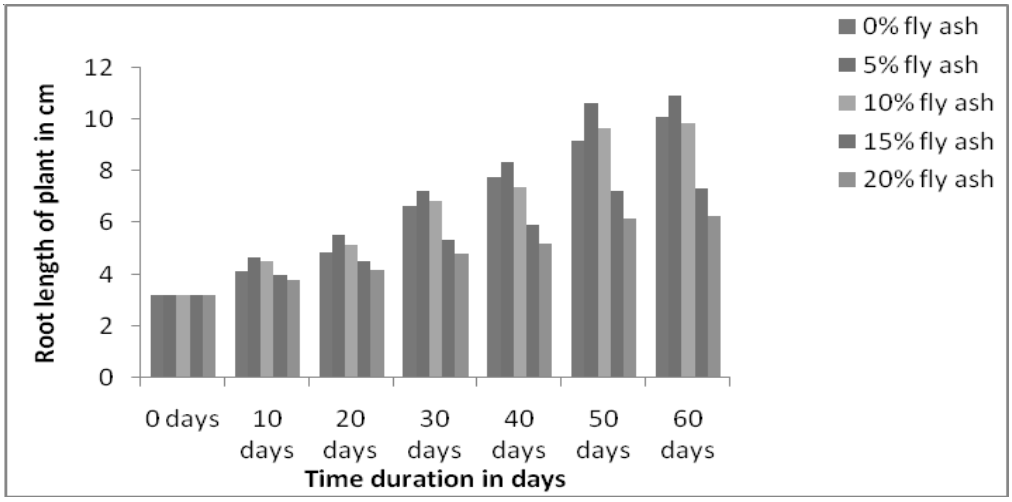

Fig. 5 Root Length (cm) of *Capsicum annuum* in fly ash amended soil

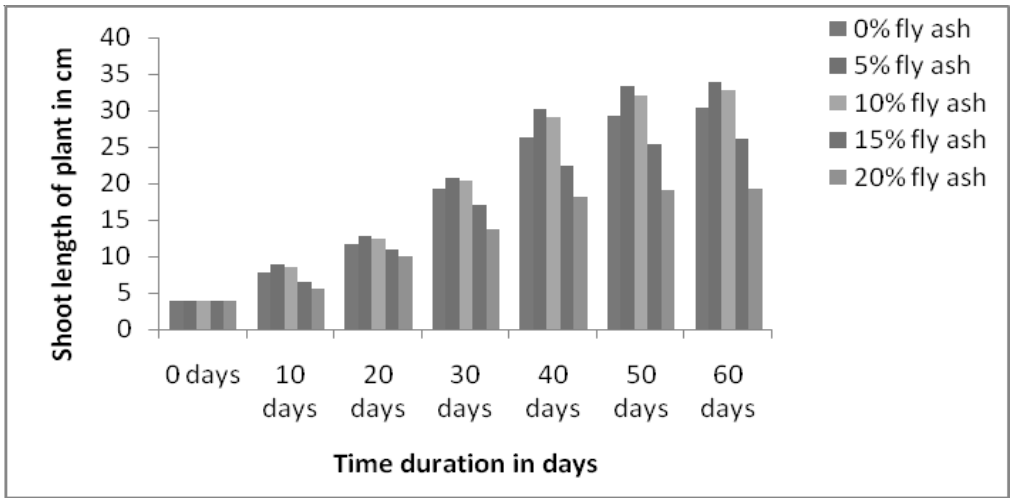

Fig. 6 Shoot Length (cm) of *Capsicum annuum* plant in fly ash amended soil

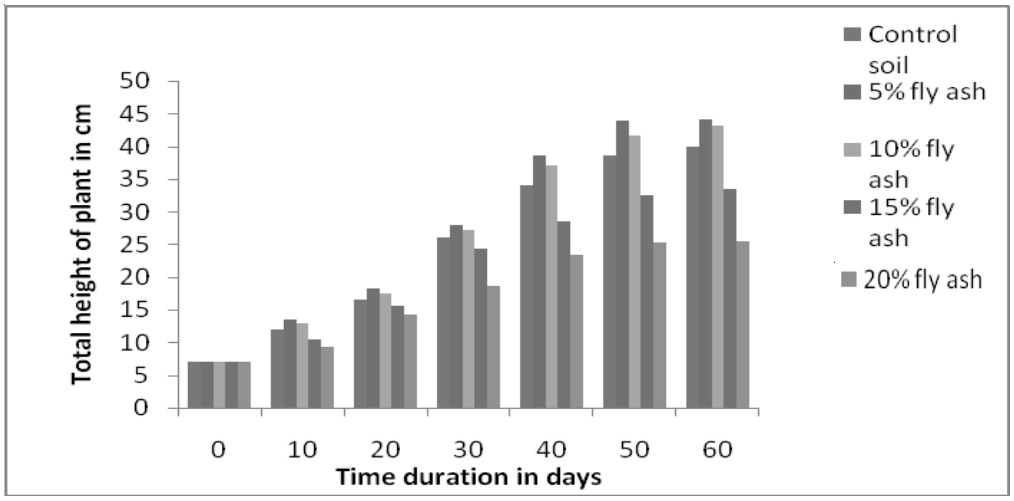

Fig. 7 Total length (cm) of *Capsicum annuum* plant in fly ash amended soil

fly ash. It reveals that, the pH of the soil was changed from slightly acidic to alkaline (6.66-7.42) in different percentage of fly ash amendment. The conductivity increases from 51.47 µS/cm - 85.78 µS/cm in higher percentage of fly ash treatment. The moisture content of the soil was 2.68 (g %) in control soil but it ranged from 2.78- 4.98 (g %) in 5%- 20 % fly ash amended soil. Organic carbon (2.33 g% - 3.33 g %) and organic matter (4.0 g% - 5.58 g %) content of soil showed an increased trend but the nitrogen (20.24 mg/g- 12.23 mg/g), potassium (5.45 mg/g – 5.21 mg/g) and phosphorous (2.16 mg/g - 1.25 mg/g) of the soil showed a decreased trend in higher percentage. The heavy metals like Cu, Zn, Fe and Ni showed an increased in concentrations at higher percentage of fly ash amendment.

CONCLUSION

Fly ash can be used as a potential nutrient supplement for soil thereby solving the solid waste disposal problem to some extent. However, the bioaccumulation of toxic heavy metals and their critical levels for human health in plant parts and soil should be investigated. From the above research it was noticed that, application of fly ash up to 5% favors the growth of *Capsicum annuum* in terms of photosynthetic pigments (chlorophyll a, chlorophyll b, total chlorophyll and carotenoid) and vegetative parameters (root length, shoot length and total length). The decrease in growth at higher concentrations of fly ash might be due to the over nutrient conditions of soil and accumulation of higher concentrations of heavy metals present in fly ash. Further the effect of integrated application of farmyard manure such as cow-dung, crop-residue etc. on plant growth should be carried out.

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