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Effect of fly ash on growth and yield of sunflower (*Helianthus annuus* L.)

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Key words: FA= Fly ash, FAA=Fly Ash Amendment, DAS=Days After Sowing.

Abstract

Fly ash, the notorious waste product of coal based thermal power plants, rich in micro and macronutrients and has the potential to improve the physical and chemical properties of soil. With this concept, a field experiment was carried out to find out the efficacy of the fly ash for agriculture. Fly ash from NALCO CPP, Angul, Odisha was used for amending soil at levels equivalent to 0%, 25%, 50%, 75% and 100% in which sunflower was grown. The growth parameters of the plants and seeds were enumerated. Fly ash amendments caused significant improvement in soil quality and germination percentage of sunflower seeds. Growth of plant, seed yield and oil content of seed increased with 25% FA amendment. Basing on the data obtained it was observed that soil amended with 10 metric tons (25%) FA ha $^{-1}$ not only improved the physical properties of soil but also contributed to better yield of seed and oil content in sunflower. Fly ash addition to soil in 25% doses improves various physical, chemical and biological properties of soil and thereby is also beneficial for sunflower plant growth with increased seed yield. Soil amended with 25% fly ash increased the main unsaturated fatty acid (Linoleic acid) in oil of the seed. Hence it concludes that though fly ash is a waste of concern but now has become a boon for sustainable agriculture.

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Introduction

Helianthus annuus L. of Asteraceae family is an annual herb, photo-insensitive plant that was native to North-America and is cultivated in temperate regions worldwide as edible oil seed crop. Sunflower plant with thick , erect stem, leaves are usually alternate but opposite on lower stem, large ovate, cordate with long petioles. The plant produces seeds (achenes) in capitulum from which edible oil is extracted.

Fly ash is a resultant waste produced from the combustion of coal in thermal power plants. In India alone, more than 112 million tons of fly ash is generated annually and projections also show that the production (including both fly ash and bottom ash) may likely to exceed 170 million tons per annum by the year 2015 (Pandey *et al*, 2009; Pandey and Singh 2010). The management of this huge amount of solid waste, at both regional and global level is a prime concern for the present and coming future (Ahmaruzzaman 2010, Kishore *et al*, 2010). The elemental composition (both nutrient and toxic elements) varies due to types and sources of used coal (Camberato *et al.* 1997). FA consists of plant macro-nutrients Na, K, P and Fe and micro-nutrients Co, B, Zn, Cu and Mn. The elements Pb, Ni, Cr, Cd and a few more also occur abundantly and have the potential to cause contamination/toxicity (Fytianos *et al.* 2001). Further, plant micro-nutrients at high concentrations can cause toxicity (Miller *et al.* 2000). Fly ash use in agriculture is mainly based on its limiting potential and supply of nutrients which promote growth of plants and alleviate the condition of nutrient deficiency in soils (Singh *et al.* 2008, Pandey *et al.* 2009, Singh and Agrawal 2010). Fly ash can be used as a liming agent not only in mono but also in dicotyledons plants for better crop yields (Ahmed *et al.*,1986; Sarangi and Mishra, 1998; Singh and Siddhiqui, 2003).

Several researches have already proposed that low dose of fly ash amendments improves the physico-chemical properties of the soil such as pH, texture, water holding capacity, electrical conductivity etc. (Kishore *et al.* 2010, Sajwan *et al.* 2003, Siddique, 2004, Lee *et al.* 2006).

Enriching soil with fly ash increased the plants growth and yield of vegetables oils and cereal crops like tomato, potato, cabbage, pea, wheat, mustard, oats and sun flower (Mittra *et al.* 2005 , Saxena *et al.* 2005). Khandakar, 1990 reported high yield of rice, soya bean and black gram in fly ash amended soil. Rajiv *et al.*(2012) reported that black gram grown on fly ash amended soils resulted in a considerable increase in carotenoid content of leaves though chlorophyll a and b content were not greatly affected. Pandey *et al.* 1994 reported that sunflower plants treated with fly ash exhibited improved growth. However, there is no report on growth, yield or leaf metabolism and heavy metal uptake in sunflower plant due to FA amendment.

Keeping all these in mind, the present experiment has been designed to study the impact of varied levels of fly ash amendments (FAA) on the growth, yield, and grain/ seed quality of high yielding sunflower cultivar PAC-36.

Materials and methods

Physico- chemical properties of fly ash

FA in an unweathered condition (sample-lots less than 30 days old) obtained from NALCOCPP, Angul, (Odisha) consists of the following (%) by weight sand 56, silt 30 and clay 14 with pH 6.9. The chemical composition (%) of fly ash : SiO_2 – 55.60, Al_2O_3 34.80, Fe_2O_3 4.92, Cao 2.69, MgO- 1.75, K_2O 1.09, TiO_2 1.14, Na_2O 0.70 and the trace elements (mg/kg) : Cu 78.7, Zn 86.9, Mn 650, Mo 2.6, As 3.0, Se 2.1, Pb 53.7, Ni 45.31, Cr 1.90, Co 12.19, Cd 0.46, B 1.5 by analysis with an absorption spectrophotometer (Model AA1475 at IMMT, Bhubaneswar).

Experimental field design

Experimental fields were prepared on randomized block design with 3 replications for each FAA. Fields were prepared by ploughing to a depth of 1ft and the cultivation was done by following standard agronomic practices. Fly ash was uniformly mixed in soils as 0%, 25%, 50%, 75%, and 100% (w/w) and designated as T1, T2, T3, T4 and T5 respectively. After complete dryness, the soil was homogeneously mixed with previously air dried fly ash as per selected ratio. For 25% FAA, 50 kg of fly ash was mixed with 150 kg of air dried soil, for 50% FAA, 100 kg FA was mixed with 100 kg of soil and for 75% FAA, 150 kg of FA was mixed with 50 kg of soil. On average, the weight of total soil for the experiment plot of 1m² area was found to be 200 kg. The fly ash mixed soil was then properly poured back into the respective experimental plots.

Seeds of sunflower (*Helianthus annuus* L) cultivar PAC36 was collected from OUAT, Bhubaneswar and used as test sample in the present experiment.

Growth response, oil and chlorophyll estimation

Growth parameters such as root and shoot lengths, number of leaves, leaf area, fresh and dry biomass were measured at 30,60 and 90 DAS. Yield parameters were determined as the capitulum diameter, number of seeds per capitulum, test weight (weight of 1000) seeds. Gas chromatography was done for quantification of fatty acids of seeds. The leaf samples from each treatment were taken for chlorophyll and carotenoid estimation. 500 gm of leaf sample was taken for each treatment, homogenized with 80% acetone. Then the homogenized sample was centrifuged at 4000 rpm. The supernatant was preserved. The residue was extracted two or more times with 80% acetone and centrifuged till it becomes completely free of chlorophyll. All the supernatants were combined and the volume was made up to 10 ml. Absorbance of the acetone extract was read at 480 nm, 645 nm and 663 nm using spectrophotometer (Perkin Elmer uv-vis spectrophotometer Lambda 25).

Estimation of chlorophyll was due as per the formula of Arnon (1949) and was expressed as microgram chlorophyll per gram fresh weight.

Chlorophyll a = $(12.7 \times A_{663} - 2.69 \times A_{645}) \times V/1000 \times W$

Chlorophyll b = $(22.9 \times A_{645} - 4.68 \times A_{663}) \times V/1000 \times W$

Total Chlorophyll = $(8.02 \times A_{663} + 20.21 \times A_{645}) \times V/1000 \times W$.

Estimation of carotenoid was done using the formula of Kirk and Allen (1965) and expressed in absorbance units as Acar 480 per gram fresh weight.

Acar/ 480 per leaf segment = $A_{480} + 0.114.A_{663} - 0.638 \times A_{645}) V/1000 \times W$

Where A480, A645 and A663 are the absorbances of the acetone extract at 480 nm, 645 nm and 663 nm respectively.

V= Volume of acetone extract.

W= Weight of leaf (gram fresh weight).

Results

In the present experiment we observed that most of the growth parameters showed optimal response at 25% FAA in sunflower cultivars. Dwivedi *et al.*(2007) found optimum growth response in different rice cultivars with 25%FAA in their study at open field condition.

Table 1. Effect of fly ash on germination percentage of *Helianthus annuus* L. cv. PAC 36.

Treatment	Germination %`
T1 Control	82.63 ± 1.84
T2 FA:Soil = 1:3	86.96 ± 2.45
T3 FA:Soil = 1:1	69.80 ± 1.76
T4 FA:Soil = 3:1	64.86 ± 1.70
T5 Fly ash	56.50 ± 1.10

Germination Percentage

The germination percentage of sunflower as affected by different concentration of fly ash are furnished in Table 1,Fig.1 and Fig.5. Germination percentage of sunflower decrease gradually with increase of fly ash concentration in soil. The maximum germination percentage (86.96%) was recorded at 25% FAA (T2) in a 7 days study. The minimum percentage of germination (56.50%) was recorded in T_5 (100% fly ash).

Table 2. Effect of fly ash on root length of *Helianthus annuus* L. cv. PAC 36.

Treatment	Root Length (cm)		
	30 DAS	60 DAS	90 DAS
T1 Control	8.7 ±0.16	19.3 ±0.20	21.5 ± 1.23
T2 FA:Soil = 1:3	9.3 ±0.22	22.8 ±0.25	24.5 ± 1.58
T3 FA:Soil = 1:1	8.5 ±0.09	18.6 ±0.32	19.5 ± 1.65
T4 FA:Soil = 3:1	8.2 ±0.18	16.8 ±0.18	17.3 ± 1.21
T5 Fly ash	8.0 ±0.14	13.8 ±0.23	14.4 ± 1.54

DAS (Days After Sowing).

Root and Shoot Length

The root and shoot length of sunflower showed an increasing trend at 25% FAA. Effect of fly ash amendment on root and shoot length were observed maximum in T2 (FA : Soil = 1:3) as recorded on 30, 60 and 90 days of experiment.(Table 2 and Table 3, Fig.2 , Fig.6 and Fig.7).The highest root length (24.5) was observed in T_2 (FA : Soil = 1:3) followed by T_1 (21.5), T_3 (19.5), T_4 (17.3) and T_5 (14.4) at 90 DAS.

The maximum shoot length (131.40) at 25% FAA in T2 (FA : Soil = 1:3) and the minimum shoot length (77.70cm) was observed in T_5 (fly ash)at 90 DAS. The shoot length in T1 (Soil) was 120.5cm.

Table 3. Effect of fly ash on plant height of *Helianthus annuus* L cv. PAC 36.

Treatment	Plant Height(cm)		
	30 DAS	60 DAS	90 DAS
T1 Control	20.2 ± 0.04	116.50 ± 0.28	120.50 ± 0.25
T2 FA:Soil = 1:3	25.36 ± 0.15	126.43 ± 0.12	131.40 ± 0.04
T3 FA:Soil = 1:1	18.56 ± 0.18	110.76 ± 0.08	113.36 ± 0.15
T4 FA:Soil = 3:1	16.33 ± 0.32	91.30 ± 0.20	96.80 ± 0.39
T5 Fly ash	13.43 ± 0.09	72.70 ± 0.12	77.70 ± 0.27

DAS(Days After Sowing).

Number and Area of leaves

Effect of fly ash amendment was studied with respect to number of leaves and area of leaves is represented in table 4 and Fig.3.From the result it is revealed that the number of leaves per plant at 60 DAS was highest (32.66) in T_2 (FA :Soil = 1:3) and lowest number of leaves (18.66) was observed in T5(fly ash).The highest leaf area (2210 cm^2) was recorded in T2 (25% FAA) and lowest leaf area (1012cm^2) was recorded in T5 (fly ash).

Table 4. Effect of fly ash on number and area of leaves of *Helianthus annuus* L.cv. PAC 36.

Treatment	Number of Leaves			Area of Leaves (cm^2)
	30 DAS	60 DAS	90 DAS	90 DAS
T1 Control	12.66 ± 0.27	26.66 ± 0.27	21.00 ± 0.47	2090 ± 4.71
T2 FA:Soil = 1:3	15.90 ± 0.13	32.66 ± 0.27	26.00 ± 0.34	2210 ± 5.65
T3 FA:Soil = 1:1	11.9 ± 0.12	24.33 ± 0.26	18.00 ± 0.40	1886 ± 3.39
T4 FA:Soil = 3:1	10.08 ± 0.09	22.5 ± 0.23	17.66 ± 0.27	1630 ± 4.32
T5 Fly ash	8.66 ± 0.27	18.66 ± 0.27	13.33 ± 0.27	1012 ± 5.81

Fresh and dry weight of the plant

The effect of the fly ash on the fresh and dry weight of sunflower in different fly ash amendment is presented in Table-5.Highest shoot fresh weight (425 gm/plant) was recorded in T2(FA:Soil=1:3) and lowest shoot fresh weight (185gm/plant) was recorded in T5(fly ash).Highest shoot dry weight (67 gm/plant) was recorded in T2 (FA:Soil=1:3) and lowest shoot dry weight (34gm/plant) was recorded in T5(fly ash). Similar result was observed in fresh weight and dry weight of root. The highest fresh weight of root (52gm/plant) was recorded in T2 (FA:Soil=1:3) and lowest fresh weight (31gm/plant) in T5 (fly ash) was recorded.The highest dry weight of root(12gm/plant) was recorded in T2(FA:Soil=1:3) and lowest dry weight (7.8 gm/plant) in T5 (fly ash) was recorded.

Biomass accumulation in any plant can be an important parameter for analyzing the performance of a plant under the prevailing condition. In this experimental result, total recorded biomass, in sunflower cultivar PAC36 was significantly affected by different FAA and highest value was recorded at 25% FA amendment.

Table 5. Effect of fly ash on fresh and dry weight of *Helianthus annuus* L. cv. PAC 36.

Treatment		Fresh weight(gm/plant)		Dry weight (gm/plant)	
		Shoot	Root	Shoot	Root
T1	Control	380± 10.23	40 ± 7.12	60 ± 7.12	10 ± 0.72
T2	FA:Soil = 1:3	425 ± 10.98	52± 7.11	67± 7.05	12± 1.05
T3	FA:Soil = 1:1	372 ± 10.56	41 ± 8.23	57 ± 7.21	10.2 ± 1.21
T4	FA:Soil = 3:1	310± 11.54	38± 8.95	46± 8.11	9.5± 1.35
T5	Fly ash	185± 11.32	31 ± 8.21	34 ± 7.36	7.8 ± 0.85

Chlorophyll

The chlorophyll is one of the important biochemical content which is used as a capability of the plant growth. The chlorophyll a, b, total chlorophyll and carotenoid content were increased at 25% FAA (T2).The effect of fly ash on photosynthetic pigments of sunflower leaves at 30,45 and 60 DAS is presented in Table-6.

Table 6. Effect of fly ash on chl.a, chl.b and carotenoid content of leaves of *Helianthus annuus* L. (PAC 36).

Soil Type	30 Days After Sowing				45 Days After Sowing			
	Chl.a	Chl.b	Total Chlorophyll	Carotenoid	Chl.a	Chl.b	Total Chlorophyll	Carotenoid
T_1	0.266 ± 0.008	0.248 ± 0.007	0.514 ± 0.006	0.365 ± 0.013	0.230 ± 0.009	0.212 ± 0.011	0.442 ± 0.013	0.201 ± 0.017
T_2	0.312 ± 0.007	0.286 ± 0.009	0.598 ± 0.018	0.410 ± 0.017	0.262 ± 0.007	0.235 ± 0.006	0.497 ± 0.014	0.304 ± 0.015
T_3	0.258 ± 0.008	0.239 ± 0.007	0.497 ± 0.014	0.346 ± 0.010	0.230 ± 0.009	0.218 ± 0.011	0.448 ± 0.013	0.273 ± 0.013
T_4	0.231 ± 0.008	0.227 ± 0.007	0.458 ± 0.014	0.291 ± 0.009	0.204 ± 0.005	0.195 ± 0.006	0.399 ± 0.011	0.251 ± 0.009
T_5	0.220 ± 0.009	0.201 ± 0.011	0.421 ± 0.013	0.243 ± 0.007	0.175 ± 0.008	0.162 ± 0.005	0.337 ± 0.010	0.180 ± 0.007

Biochemical analysis of leaves of sunflower was done at 30, 45 and 60 DAS. Leaves were used for measurement of acetone soluble pigments. At 30 DAS Chl.a contents of detached leaves showed an increased value from 0.266 to 0.312 mg g^{-1}at 25% FAA showing 17.3 % increased value over control. Chl.b contents increased progressively from 0.248(control) to 0.286 mg g^{-1}at 25% FA amendment showing 15.3% increased value over control. Carotenoid content too increased from 0.365 mg g^{-1}(control) to 0.410 mg g^{-1}(25% FAA) showing 12.3% increased value over control.The values of chl.a, chl.b and carotenoid increased in leaves of sunflower plants showing highest values at 25% FAA. Further increase of FA in soil retarded levels of chl.a, chl.b and carotenoid content of leaves. Higher FA doses resulted in progressive retardation of pigments in leaves of sunflower.

Table 7. Effect of fly ash on yield parameters of *Helianthus annuus* L.cv.PAC36.

Treatment	Diameter of Capitulum(cm)	No. of seeds /Capitulum	Weight of 1000 seeds (gm)	Oil content %
T1 Control	12.5±0.15	492 ±4.10	36.0±2.35	40
T2 FA:Soil = 1:3	14.2±0.17	578 ±3.09	42.5±2.85	41
T3 FA:Soil = 1:1	11.8±0.23	438 ±2.86	34.8±2.25	38
T4 FA:Soil = 3:1	10.0±0.25	386 ±3.74	32.5±2.30	37
T5 Fly ash	8.2±0.32	266 ±4.02	31.8±2.13	35

Yield parameter

Effect of fly ash amendment on yield of sunflower(number of seeds/ plant, weight of 1000 seeds, oil content of seeds) of different treatments are presented in Table-7, Fig.4 and Fig.8.The highest diameter of capitulum (14.2 cm), highest number of seeds/capitulum (578), highest weight of 1000 seeds (42.5gm) was recorded in T2 (25% FAA).

Oil content and Fatty acid composition

Effect of fly ash amendment on oil yield of sunflower is presented in Table-7 and highest oil content (41%) was recorded in T2 (FA:Soil=1:3).The palmitic acid, stearic acid and linoleic acid content of seeds of T1, T2 and T5 treatments basing on Gas Chromatography are presented in Table-8.

Table 8. Effect of fly ash on Palmitic, Stearic and Linoleic acid content of seeds of *Helianthus annuus* L cv. PAC 36.

Ttreatment	Palmitic acid (%w/w)	Stearic acid (%w/w)	Linoleic acid (%w/w)
T_1=Soil	0.5	0.3	4.4
T_2=FA:Soil= 1:3	0.5	0.3	4.6
T_5=Fly ash	0.4	0.3	3.7

Gas chromatographic analysis of the oils of sunflower seeds showed that the palmitic acid and stearic acid content remains same in seeds of T1 (Control) and T2(25% FAA). But the main unsaturated fatty acid (Linoleic acid) content in T2 was (4.6 %w/w) and in T1(Control) it was (4.4% w/w).The Linoleic acid content in seeds of T2 (25% FAA) showed an increased value of 4.5% as compared to T1 (Control). Increasing fly ash concentration, the palmitic, stearic and linoleic acid content showed decreased value.

Discussion

Fly ash amendment significantly increased the alkalinity, electrical conductivity (EC) and water holding capacity (WHC) of the present experimental soil. Fly ash amendment was found to enhance the pH of soil which could be due to high content of CaO and MgO with acid neutrality properties (Tripathy *et al.*

2005). According to Khan and Khan (1996),the increase in soil pH might be due to the neutralization of H^+ by alkali salts and also due to solubilization of basic metallic oxides of fly ash in soil. Both Kalara *et al.* (2003) and Pandey *et al.*(2009) found similar trends in higher pH, EC and WHC and lower bulk density (BD) in FAA soil at their experiments with mustard , maize , wheat and mung beans.

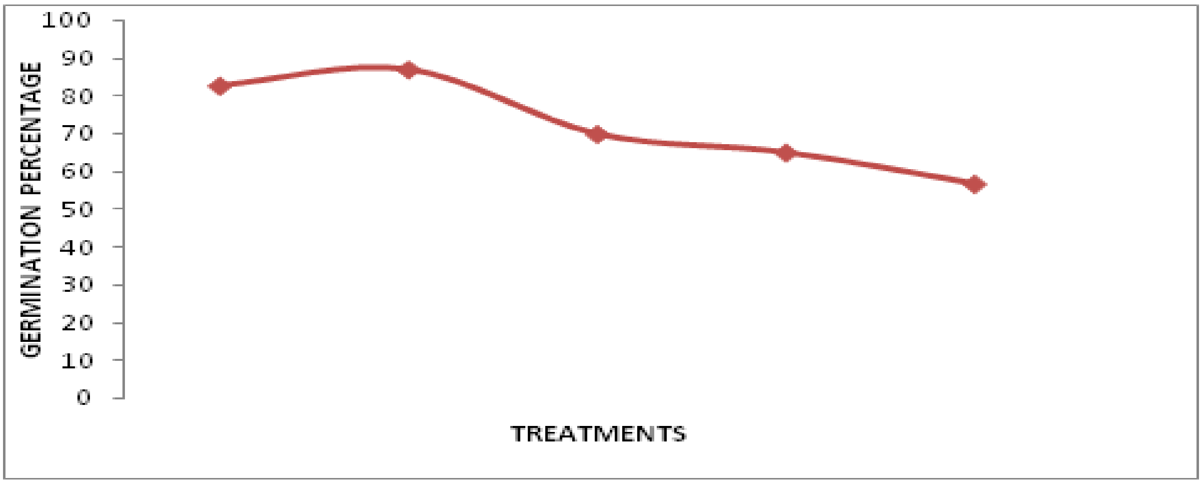

Fig. 1. Effect of fly ash on germination % in *Helianthus annuus* L. cv.PAC 36 in T1,T2,T3,T4 and T5.

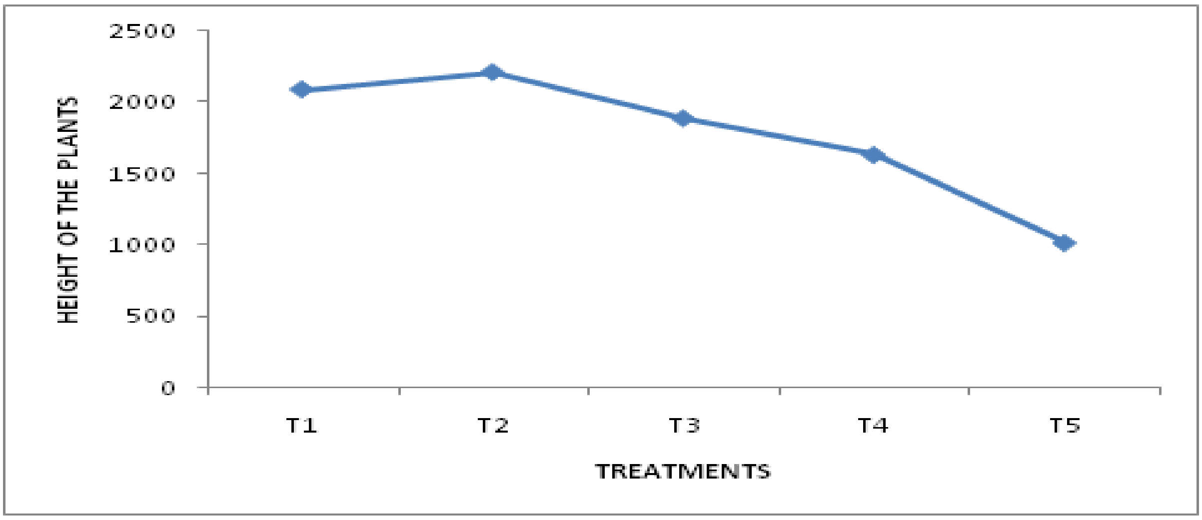

Fig. 2. Effect of fly ash on Height of *Helianthus annuus* L.cv.PAC36 in T1,T2,T3, T4 and T5.

Even the high EC values in FAA soil can be correlated with the higher availability of Ca, Fe, K, Na, and Mg as compared with control soil. Increase in EC values due to FA could suggest that the binding of metal ions occurred readily to soil particles, causing the availability of metal nutrients to growing plants. Fly ash is also a rich source of free and toxic heavy metals. Several studies conducted so far showed that long term use of fly ash in agricultural fields can modify the soil heath as well as heavy metal uptake too and also affect the plant growth, physiology and crop quality (Pandey and Singh.2010, Singh *et al.* 2010).The high phosphate content of fly ash as compared to soil may be one of the reasons of an increased productivity of plants upon fly ash amendment.

Calmano *et al.* (1993) explained that increase in growth and yield of sunflower in FA amended soil was due to the ready supply of some excess plant nutrients without any interference of the higher pH range to soil- plant relationship. This finding is encouraging for an agro- friendly disposal of this potential pollutant in agriculture for cultivation of sunflower and as fertilizer. However, care is needed while using fly ash as a source of nutrients since over application could results phytotoxicity of various trace elements due to their chemical limitations.

The availability of plant nutrients (N, P,K, S, Ca, Mg, Cu, Fe, Mn and Zn) in fly ash amended soil samples were significantly different from the control.

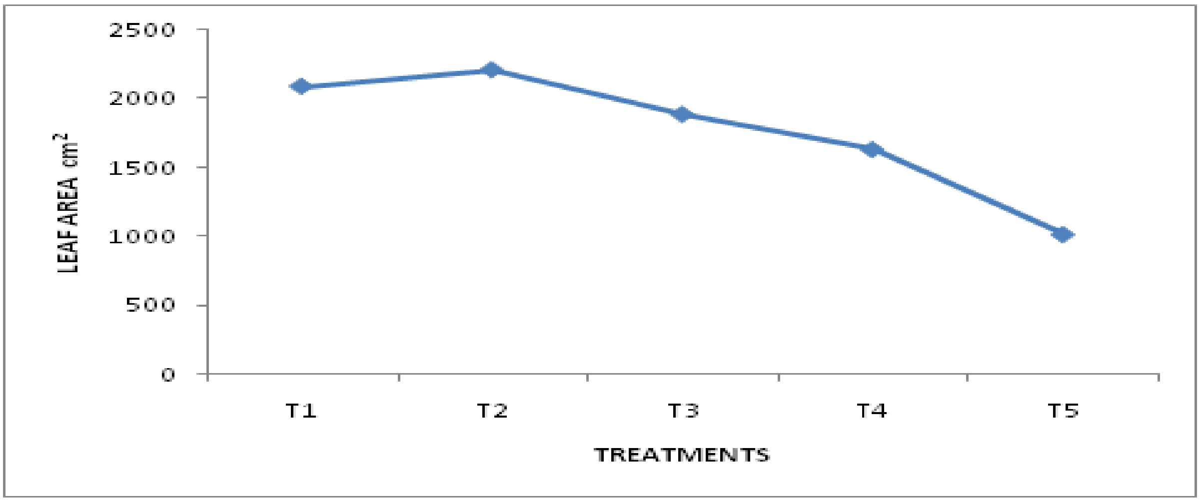

Fig. 3. Effect of fly ash on Leaf area (cm^2) in *Helianthus annuus* L.cv.PAC36 in T1,T2,T3,T4 and T5.

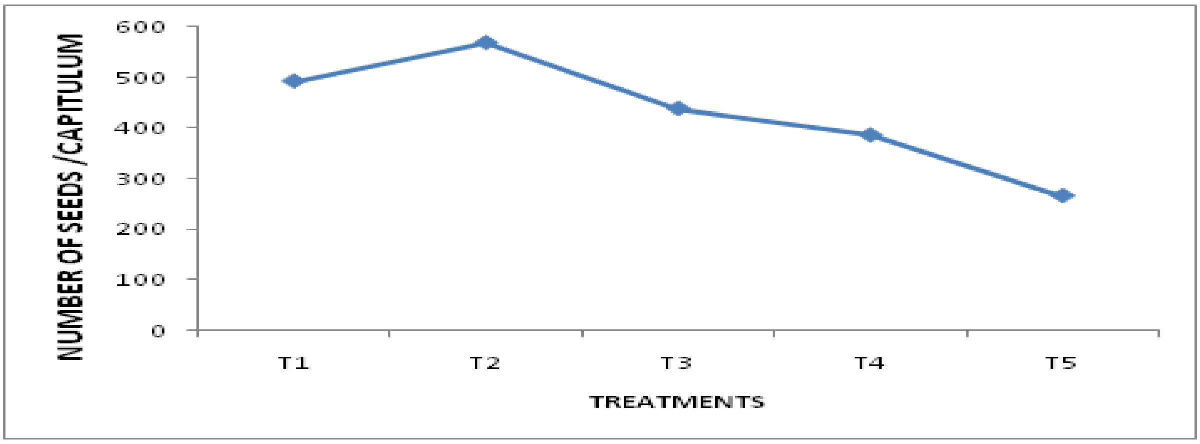

Fig. 4. Effect of fly ash on number of seeds/capitulum in *Helianthus annuus* L. cv. PAC36 in T1,T2,T3,T4 and T5.

About 50% nutrients are released soon after FA application and the presence of weathering may cause slow release of rest elements (Warren and Dudas, 1988).The morphological characteristics e.g. root length, shoot length, fresh and dry weight, number of leaves, number of seeds/capitulum and oil yield of *Helianthus annuus* L.in different concentrations of fly ash reveals an overall increasing pattern from control to T2(25% fly ash)beyond which these parameters decreased.This result coincides with the findings of Niaz *et al.*(2008) on *Eclipta alba*.The present study revealed that the fly ash could be beneficial in improving the soil quality and plant growth.The most suitable treatment for improved plant growth and crop yield for oil yielding plant *Helianthus annuus* L. is 25% fly ash with soil as it gives maximum crop yield.

In this investigation, it could be concluded that oil content of seeds significantly increased in response to 25% fly ash amendment as being compared to control (Table-7).

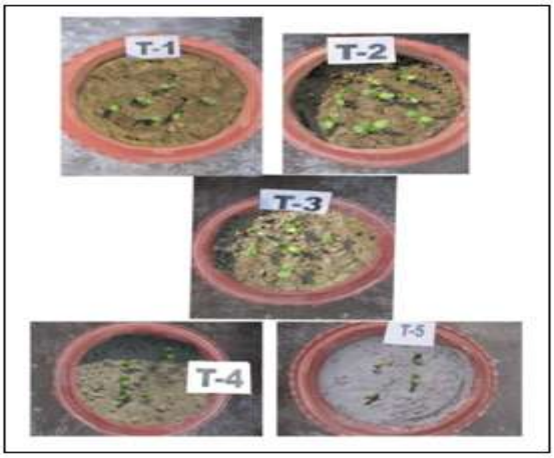

Fig. 5. Germination % of *Helanthus annuus* L.cv.PAC36 in T1,T2,T3,T4 andT5.

Fats are classified into saturated and unsaturated. The most common saturated fatty acids found in plant lipids contain 16 or 18 carbon atoms. Palmitic acid (C16) and stearic acid (C18) are present in significant amount and account for only 20% of the total fatty acid content of most plants while those with one or more double bonds (unsaturated fatty acids) account for the remaining 80%.In many fatty seeds oleic (C9) and linoleic (C12) acids account for more than 70% of the fatty acid content (>90% in sunflower) (Anderson and Beardall,1999).

Gas chromatographic analysis of the oils of sunflower seeds showed that the main unsaturated fatty acid (Linoleic acid) in seeds of T2 showed an increased value of 4.5% as compared to T1 (Soil).

Thus the yield oil of T2 (25%FAA) becomes safer for human consumption.

Fig. 6. Growth pattern and flowering condition in *Helianthus annuus* L.cv.PAC36 (in pots) in T1,T2,T3,T4 and T5.

Fig. 7. Growth pattern and flowering conditions in *Helianthus annuus* L.(in groups) in T1,T2,T3,T4 and T5.

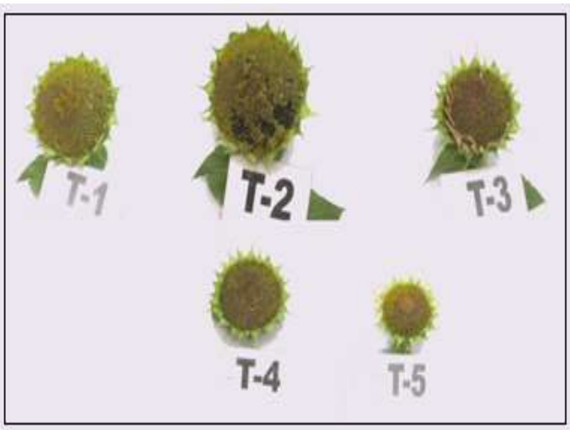

Fig. 8. Capitulum of *Helianthus annuus* L.cv,PAC36 grown in T1, T2, T3, T4 and T5.

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