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# Study of Plant Growth and Yield of Underground Stem Crops in Fly Ash Amended Soil

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**Abstract:** In the present study, the effect of different fly ash levels in soil were observed on plant growth and yield of underground stem crops viz. potato, onion and garlic. Plant growth and yield were increased significantly in 10 and 20% fly ash amended soils. However, in higher levels of fly ash (40, 60, 80 and 100%), plant growth and yield were reduced significantly. The suppressions in plant growth and yield were maximum in 80% and 100% fly ash levels. In general, when fly ash levels increased gradually, all the growth and yield parameters declined gradually. In the present study, the ideal level of 20% fly ash was found to be for the better plant growth and yield of potato, onion and garlic crops.

**Key words:** Coal, crop, fly ash, improvement, level, pollutant, reduction.

## Introduction

In India thermal power plants using coal as fuel are the source of fly ash. A thermal power plant is located in Kasimpur in Aligarh district of Uttar Pradesh. This power plant burns 3192 metric tons of coal daily, and thus releases fly ash in huge amount that cause air and soil pollution at and around Kasimpur. Fly ash contents of Indian coal ranges between 28-42% and about 12% of the total ash content in coal escapes as smoke, fly ash or aerosols (Asthana and Asthana, 1998). Disposal of fly ash is another great problem because of the quantum of daily coal utilization by this power plant. This bulky material, which is accumulated as lagoons or land hills, may require careful and special management and conservation measures in order to protect the surrounding environment. Although fly ash is considered as a particulate air pollutant, it has been found beneficial for the growth of the plants due to the presence of several essential plant nutrients (Mishra and Shukla, 1986; Martins and Beahm, 1987). Tree and shrub-seedlings grow well in fly ash amended soil (Scanlon and Duggan, 1979). Recently, fly ash was applied to soil for better growth and yield of tomato and soybean (Singh et al., 1994; Khan et al., 1997). In the present study, an attempt has been made to evaluate its potential and find the suitable level on plant growth and yield of potato, onion and garlic, the underground stem crops under glasshouse conditions.

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## Materials and Methods

### Amendment of Soil with Fly Ash

The sandy loam soil mixed with compost manure (soil+manure = 3:1) was autoclaved. This soil was mixed with fly ash in the following proportions to make seven treatments (*T*) for each crop:

$T_1$ = 100 g soil (control)
$T_2$ = 900 g soil + 100 g fly ash (10% fly ash in soil)
$T_3$ = 800 g soil + 200 g fly ash (20% fly ash in soil)
$T_4$ = 600 g soil + 400 g fly ash (40% fly ash in soil)
$T_5$ = 400 g soil + 600 g fly ash (60% fly ash in soil)
$T_6$ = 200 g soil + 800 g fly ash (80% fly ash in soil)
$T_7$ = 1000 g fly ash (100% fly ash)

After proper mixing the soil with fly ash, five pots of 25 cm height were filled with each type of mixture for each crop. In total 105 pots were prepared for the experiments (seven treatments × five replicates × three crops). Treatment without fly ash ($T_1$) served as control.

**Culturing of Plants**

All three crops, potato (*Solanum tuberosum* L.) cv. Kufri Badshah; onion (*Allium cepa* L.) cv. Poona Red and garlic (*Allium sativum* L.) cv. Aligarh Local were grown in the month of November, 2003 applying separate methods of sowing.

*(a) Potato*

For the experiment, small pieces (size 2.5 $cm^3$) of potato were cut in such a way that each piece had atleast one eye. The pieces were surface sterilized (dipped in 0.01% $HgCl_2$ for 15 min) before sowing. A small pit (4 cm deep) was formed in the centre of each pot. One potato piece was kept into the pit of each pot in such a way that eye was always towards upper side. Pots were arranged in randomized block design and placed on glasshouse bench at 25°C. Pots were wet with required amount of water after the lapse of 3-4 days. Plants were uprooted after 90 days just 15 days before maturation, for taking the plant growth. Roots and potato tubers were thoroughly washed under tap water to avoid soil particles and debries. Plant growth (length, fresh weight and dry weight of shoots and roots) and yield (number of tubers, maximum and minimum size and weight of tubers, total weight of tubers) were taken. Data were analyzed statistically for significance.

*(b) Onion*

Seeds of onion cv. Poona Red were sown in clay pot (25 cm diameter × 30 cm deep) containing autoclaved soil. Two weeks old seedlings were transplanted in 25 cm height clay pots (one seedling/pot) containing different soil and fly ash mixtures. Each treatment was replicated five times (seven treatments × five replicates = 35 pots). Pots were kept in randomized block design and placed on glasshouse bench at 25°C. Pots were watered after the lapse of 3-4 days. Plants were grown for 80 days, just 10 days short in maturation. After harvesting, roots and bulbs were carefully washed under tap water to remove the adhered soil particles. Bulbs were separated out by cutting shoot and root portions. Plant growth in terms of weight, circumference and diameter (diameter was taken by cutting the T.S. of bulb passing through the centre) of bulb was measured. Mean of each treatment was taken. Data were analysed statistically for significance.

*(c) Garlic*

A healthy garlic bulb cv. Aligarh Local was broken into cloves and one healthy clove was directly sown in each clay pot containing fly ash mixture. Each treatment was replicated five times (seven treatments × five replicates = 35 pots). Pots were arranged in randomized block design on glasshouse bench at 25°C. Pots were wet with required amount of water after the lapse of 3-4 days. Plants were harvested (after 80 days) just before maturation, for taking the plant growth. Roots and bulbs were washed carefully under tap water to remove soil particles. Bulbs were separated by cutting aerial parts and roots. Plant growth in terms of circumference, clove number/bulb and weight was measured. Mean of each treatment was taken. Data were analyzed statistically for significance.

## Results

*(a) Potato*

Data presented in Table 1 show that fly ash affected the plant growth of potato. Length of shoot and root were increased significantly in 10% and 20% fly ash mixture at both levels ($P = 0.05$ and $P = 0.01$) as compared to control maximum being at 20% level. However, in higher ratios of fly ash mixtures (40, 60, 80 and 100%), length of shoot and root reduced significantly at both levels ($P = 0.05$ and $P = 0.01$). Similar results were obtained for fresh weight and dry weight of shoot and root. In general, when fly ash levels increased gradually, all the growth parameters declined gradually. Highest reductions were found at 80% and 100% fly ash levels (Table 1). Yield of potato in terms of number, minimum and maximum size, minimum and maximum weight and total weight of tubers were significantly increased in 10 and 20% fly ash levels when compared to control, maximum being at 20% level. But, at 40, 60, 80 and 100% levels, the yields of potato plants were suppressed significantly in comparison to control. The suppressions in yield were maximum in 80% and 100% fly ash levels (Table 1).

*(b) Onion*

Fly ash affected the plant growth of onion. All the parameters of plant growth (length, fresh weight and dry weight of shoot and root) were increased at 10 and 20% levels as compared to control maximum being at 20% level. However, at higher levels (40, 60, 80 and 100%), the growth of plants was suppressed in comparison to control. Highest suppression in growth parameters were observed in 80% and 100% fly ash amended soils. All L.S.Ds were significant (Table 2). Lowest levels (10 and

20%) of fly ash increased the yield of onion in terms of circumference, diameter and weight of bulbs significantly. Highest increase was obtained at 20% level. Progressive reductions occurred in all yield parameters with an increase in fly ash levels (40, 60, 80 and 100%). Suppressions were more at higher levels (80 and 100%). All L.S.Ds were significant (Table 2).

*(c) Garlic*

Data presented in Table 3 reveal that all growth characters like length, fresh weight and dry weight of shoots and roots were increased significantly at 10 and 20% fly ash amended soils. Significant reductions were, however, observed in all above 20% levels, like 40, 60, 80 and 100% fly ash treatments. Highest reductions on plant growth were found in 80% and 100% fly ash levels. Maximum yield (circumference, clove number/bulb and weight of bulbs) of garlic was observed at 20% fly ash level. Higher amounts 40, 60, 80 and 100% fly ash caused stepwise suppressions in yield. At 100% fly ash level, yield reduced maximum. All L.S.Ds were significant (Table 3).

**Table 1: Effect of fly ash on plant growth and yield of potato (*Solanum tuberosum* L.) cv. Kufri Badshah**

| *Treatment (%)* | *Plant growth* | | | | | | *Yield* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Length (cm)* | | *Fresh weight (g)* | | *Dry weight (g)* | | *Tuber no.* | *Size (cm)* | | *Weight (g)* | | *Total weight (g)* |
| | *Shoot* | *Root* | *Shoot* | *Root* | *Shoot* | *Root* | | *Min.* | *Max.* | *Min.* | *Max.* | |
| Control | 18.5 | 20.1 | 15.0 | 5.2 | 1.8 | 0.61 | 3 | 1.2 | 3.8 | 3.6 | 35.0 | 95.7 |
| 10 | 20.3 | 22.1 | 17.2 | 5.7 | 2.0 | 0.69 | 4 | 1.5 | 4.0 | 3.9 | 38.2 | 99.8 |
| 20 | 24.7 | 24.0 | 19.1 | 6.1 | 2.1 | 0.76 | 5 | 1.7 | 4.5 | 4.2 | 40.2 | 105.0 |
| 40 | 16.2 | 18.0 | 10.0 | 4.2 | 1.1 | 0.51 | 3 | 1.0 | 3.5 | 3.0 | 26.0 | 80.3 |
| 60 | 14.5 | 17.0 | 9.2 | 3.1 | 1.0 | 0.38 | 1 | - | 3.7 | - | 33.0 | 34.0 |
| 80 | 11.2 | 11.1 | 7.2 | 3.0 | 0.8 | 0.37 | 1 | - | 3.5 | - | 30.0 | 30.0 |
| 100 | 9.5 | 11.1 | 5.5 | 3.0 | 0.68 | 0.33 | 1 | - | 3.1 | - | 29.2 | 29.0 |
| L.S.D. ($P = 0.05$) | 1.11 | 0.89 | 2.45 | 0.77 | 0.44 | 0.06 | 0.44 | 0.08 | 0.06 | 0.02 | 1.33 | 4.44 |
| L.S.D. ($P = 0.01$ | 1.58 | 1.26 | 3.48 | 1.10 | 0.62 | 0.09 | 0.62 | 0.12 | 0.09 | 0.03 | 1.89 | 6.32 |

#Each value is a mean of five replicates.

**Table 2: Effect of fly ash on plant growth and yield of onion (*Allium cepa* L.) cv. Poona Red**

| *Treatment (%)* | *Plant growth* | | | | | | *Yield* | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Length (cm)* | | *Fresh weight (g)* | | *Dry weight (g)* | | *Bulb circumference (cm)* | *Bulb diameter (cm)* | *Bulb weight (g)* |
| | *Shoot* | *Root* | *Shoot* | *Root* | *Shoot* | *Root* | | | |
| Control | 36.0 | 39.2 | 24.60 | 14.50 | 2.70 | 1.60 | 8.0 | 2.0 | 31.6 |
| 10 | 40.2 | 47.1 | 26.21 | 18.33 | 3.00 | 2.00 | 8.3 | 2.5 | 33.9 |
| 20 | 42.5 | 56.0 | 30.93 | 22.70 | 3.40 | 2.50 | 8.5 | 3.0 | 35.7 |
| 40 | 30.0 | 32.4 | 15.15 | 12.37 | 1.80 | 1.40 | 7.5 | 2.0 | 21.3 |
| 60 | 27.2 | 26.0 | 12.26 | 9.65 | 1.36 | 1.07 | 7.0 | 1.8 | 17.1 |
| 80 | 27.0 | 25.0 | 10.62 | 7.20 | 1.18 | 0.80 | 5.5 | 1.5 | 10.3 |
| 100 | 20.0 | 24.2 | 7.54 | 6.63 | 0.83 | 0.73 | 4.0 | 1.0 | 9.5 |
| L.S.D. ($P = 0.05$) | 1.98 | 5.06 | 2.42 | 0.92 | 0.70 | 0.08 | 0.17 | 0.08 | 2.66 |
| L.S.D. ($P = 0.01$) | 2.79 | 7.13 | 3.41 | 1.30 | 0.99 | 0.12 | 0.05 | 0.12 | 3.79 |

# Each value is a mean of five replicates.

**Table 3: Effect of fly ash on plant growth and yield of garlic (*Allium sativum* L.) cv. Aligarh Local**

| *Treatment (%)* | *Plant growth* | | | | | | *Yield* | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Length (cm)* | | *Fresh weight (g)* | | *Dry weight (g)* | | *Bulb circumference (cm)* | *Clove/ bulb* | *Bulb weight (g)* |
| | *Shoot* | *Root* | *Shoot* | *Root* | *Shoot* | *Root* | | | |
| Control | 52.3 | 40.0 | 10.8 | 9.0 | 1.20 | 1.10 | 7.5 | 14 | 5.7 |
| 10 | 53.1 | 42.1 | 11.3 | 9.4 | 1.30 | 1.20 | 7.8 | 16 | 6.2 |
| 20 | 55.5 | 45.0 | 12.8 | 10.5 | 1.40 | 1.30 | 8.0 | 18 | 6.8 |
| 40 | 49.5 | 36.0 | 9.9 | 7.4 | 1.10 | 0.80 | 6.0 | 13 | 4.6 |
| 60 | 46.0 | 31.5 | 7.2 | 4.1 | 0.80 | 0.50 | 5.5 | 12 | 3.3 |
| 80 | 33.5 | 28.0 | 5.2 | 3.8 | 0.65 | 0.35 | 5.0 | 12 | 2.5 |
| 100 | 30.0 | 25.0 | 3.6 | 2.3 | 0.40 | 0.25 | 4.5 | 10 | 2.3 |
| L.S.D. ($P = 0.05$) | 1.76 | 2.64 | 1.32 | 0.13 | 0.06 | 0.08 | 0.04 | 0.02 | 0.13 |
| L.S.D. ($P = 0.01$) | 2.48 | 3.72 | 1.86 | 0.18 | 0.09 | 0.12 | 0.06 | 0.03 | 0.18 |

# Each value is a mean of five replicates.

## Discussion

The usable parts of potato, onion and garlic are underground stems. These underground stems in form of tuber and bulbs are used as vegetables and in medicines. In the present study the plant growth parameters and yields of these crops were found significantly better at very low (10 and 20%) levels of fly ash amended soils (Tables 1-3). All the essential plant nutrients are found in fly ash (Druzina et al., 1983) and its addition to soil enriches the macro- and micro-nutrients which have favourable effect on crop productivity (Martens and Beahm, 1987). Amendments of fly ash to soil also neutralizes soil acidity and increase ion exchange capacity, water holding capacity and pore size (Elseewi et al., 1981). These factors might have played some important role in improving the growth and biomass of potato tubers, onion and garlic bulbs. The improvement in plant growth and yield have also been observed on several vegetables, pulse, cereal and other crops in soils amended with fly ash (Wong and Wong, 1989; Singh, 1989; Mishra and Shukla, 1986; Singh et al., 1994; Khan et al., 1997). Low fly ash amendment at 3% improved young seedling growth in *Brassica parachinensis* and *B. chinensis* (Wong and Wong, 1989). Pasha et al. (1990) observed that amendment of soil with fly ash (10 and 20%) improved plant growth, yield and chlorophyll contents of cucumber. Singh et al. (1994) reported that soybean plants grown in 25% and 50% fly ash showed significant improvement in plant growth, yield, leaf pigment, protein and oil contents of seeds. Similar observations have been made by Singh (1989) on chickpea and lentil crops and Khan (1989) on tomato. Tree and shrub seedlings grew well in fly ash amended soil (Scanlon and Duggan, 1979).

Further increase in the fly ash levels from 20% onwards caused suppression in yield and plant growth parameters of potato, onion and garlic. It indicates that the changes exerted by fly ash at 20% level in the physico-chemical properties of soil were optimal for these crops. Being underground stems, tubers and bulbs develop and remain inside the soil. That is why they were directly affected with fly ash, because fly ash contains some toxic compounds like, dibenzofuran and dibenzo-p-dioxime (Helder et al., 1982). Besides these, fly ash contains very small fraction of nitrogen (0.2%) (Wong and Wong, 1986, 1989). At 40, 60, 80 and 100% fly ash levels, concentrations of these substances might have decreased or exceeded threshold limits for these crops (Potato tubers, onion and garlic bulbs) and caused adverse effects on yield and plant growth parameters. High alkalinity and excess of salts and nutrients in soils (Adriano et al., 1980) may have also contributed towards the poor performance of potato tubers, onion and garlic bulbs from 40% fly ash level onwards. Inconsistent effects of fly ash on plant growth, yield, leaf pigment and protein contents have been reported on several crops. Singh (1989) reported that plant growth and yield of chickpea and lentil gradually declined at higher levels from 60-100%. Khan (1989) and Pasha et al. (1990) observed reduction in plant growth, yield and chlorophyll contents of leaves of tomato and cucumber respectively at higher levels (50-100%) of fly ash. Singh (1989) observed inhibition and seed germination and post emergence mortality in seedlings of chickpea and lentil in fly ash amended soils. Recently Singh et al. (1994) and Khan

et al. (1997) recorded reduced plant growth, yield, leaf pigment and protein of soybean and tomato with increased fly ash levels.

Perusals of literature eminates that lower levels (below 50%) of fly ash were beneficial for plants while higher levels (above 50%) were harmful to plants. The ideal level observed in general was 40% for many crops. However, in the present study the ideal level of 20% fly ash was found to be for better growth and yield of potato, onion and garlic crops. This shows that crop responses are concentration dependent as well as types of plant species involved.

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