EFFECT OF FLY ASH AND AM FUNGUS *(GLOMUS FASCICULAUM)*
ON GROWTH OF FOUR FIBER YIELDING PLANTS.

INTRODUCTION

Fly ash is a particulate residue of thermal power plants. The safe disposal, effective and economic utilization of fly ash voluminously generating from various coal based thermal power stations and strict compliance of the environmental regulation are of immense concern. The chemical properties of fly ash are influenced to a great extent by those of the coal type burned and the technologist used for handling and storage. As a soil pollutant fly ash is highly alkaline and rich in salts (Adriano *et al.*, 1998). Fly ash affected the growth, productive and reproductive abilities of a number of plants (Satyanarayan and Pushpalata, 1991; Saquib and Khan, 1999). A large amount of elements (C, K, Ca, Mg, Cu, and Zn) (Raularay *et al.*, 2003, Lee *et al.*, 2006 and Tiwari *et al.*, 2008) get in to the soil as a result of fly ash used at different doses and may probably change the physiochemical properties of soil, which in turn may determine the biological properties soil, which in turn determine the biological properties irrespective of the crop (Dhankar, 2003; Kumar *et al.*, 1999, Srivastva *et al.*, 2002). Fly ash studies show that one can grow commercially important plant species in fly ash covered area (Adholeya, 2000).

Arbuscular mycorrhizal fungi, through their mycelia net work accumulate heavy metals from fly ash and retain them with in their cells or carry them on their body surface when they form association with the plants. These mycelia threads, along with dense root biomass assist in binding ash particles. AM fungi have been used as bioremediation agents (Leyval and Haselwander, 1997) and biofertilizers for agricultural, horticultural and silvicultural plant species in polluted area (Anonymous 2001; Lakshman, 2009). AM fungi helps in binding the fine particles of ash and arrests the uptake of heavy metals by host plants (Sarangi and Mishra, 1998) Experiments were conducted to study the effect of fly ash with
AM fungi inoculation on growth response of Corchorus *capsularis* L., *Crotalaria juncea* L., *Gossypium hirsutum* L., and *Hibiscus cannabinus* L. Root colonization, and spore count of AM fungi in plant rhizosphere was also consideration.
REVIEW OF LITERATURE

Remediation of contaminated sites may be facilitated by selection of tolerant plant species as well as microorganisms which play a critical role to establish early ecosystem development, due to functional abilities such as nitrogen fixation, organic matter turnover, mycorrhizal symbiosis, and potential facilitation of plant establishment (Hodkinson et al., 2002; Walker et al., 2003). Among soil microorganisms, arbuscular mycorrhizal (AM) fungi play relevant roles for establishment, survival of plant species, and improved soil properties in stressed environments (Ortega-Larrocea et al., 2010). Arbuscular mycorrhizal fungi also alter the soil microbial communities in rhizosphere directly or indirectly through changes in root exudation patterns (Barea et al., 2005) and enhance the soil enzyme activities (Wang et al., 2006). The effects of selected isolates of AM fungi play an important role on the plant growth, nutrient uptake, and aggregation of fly ash (Enkhtuya et al., 2005; Wu et al., 2009). However, spontaneous selection of infective and effective AM fungi is a long process in fly ash ponds. It has also been demonstrated that the use of adapted AM fungal strains, in restoration and bioremediation studies, is more effective than applying non-adapted strains (Vivas et al., 2005).

Oliveira et al. (2010) reported that AM fungi quickly lose their symbiotic efficacy when cultivated without edaphic stresses of the environment from where they are originally isolated. They also recommended that the inoculum should be produced with original edaphic stresses especially for AM isolates from extreme environments. We have isolated AM fungi from the plants growing in fly ash pond and multiplied in pots using fly ash to maintain its adaptation. Many fungi can survive and grow at high concentrations of toxic metals and the genus Aspergillus play multi-fascinated roles such as P solubilization, heavy metal bioleaching, plant growth promotion, and synergetic effects with mycorrhizal fungi (Medina et al. 2006; Yang et al., 2009). The selection of A. tubingensis in this study is based on its
ability to solubilize the insoluble phosphates and improvement of growth of plants under stress conditions (Krishna et al. 2005).

(Kalra et al., 1997; Singh et al., 1997), reported that agricultural utilization of fly ash has been reported because of its considerable content of K, Ca, Mg, S and P. 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). Addition of unweathered western US fly ash up to 8% (w/w) to either calcareous or acidic soils resulted in higher yield of several agronomic crops (Page et al., 1979) mainly due to increased availability of S to plants. 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. These plants exhibited higher contents of As, B, Mg and Se. Also winter wheat (Triticum aestivum) grown on a deep bed of fly ash produced grains containing higher Se (Stoewsand et al., 1978). Greenhouse experiments conducted by Sikka and Kansal (1994) showed that application of 2-4% fly ash significantly increased N, S, Ca, Na and Fe content of rice (Oryza sativa) plants. The foliar application of fly ash also enhances growth and metabolic rates, as well as increasing the photosynthetic pigments of crops like maize and soybean (Mishra and Shukla, 1986).

Fly ash contains many essential plant nutrients and their availability to the plant may be problematic as reported by different authors (Pandey et al., 1994; Singh et al., 1997). However, inoculation of AM fungi supports the growth and nutrient uptake of plants and aggregation of fly ash (Enkhtuya et al. 2005; Wu et al., 2009). The AM fungi may enhance
plant P nutrition and increase the plant growth by diluting metal effect in host plant or by binding of the metal to the fungal mycelium and immobilize them in rhizosphere or roots (Chen et al., 2001).
MATERIALS AND METHOD

The used soil for the experiments was sandy loam having pH 7.0, organic carbon 0.84%, Nitrogen 1.41 mg/kg, Potassium 2.41 mg/kg, phosphorus, 0.18 mg/kg, zinc, 202 mg/kg, copper, 1.04 mg/kg, magnesium 1.42 mg/kg and E.C 10.17m mho/cm. The soil was steam sterilized for one hour on two consecutive days. The physicochemical property of the soil was determined as per Jackson (1973). Per cent of organic matter was determined according to Piper (1950). Electric conductivity was measured using Bridge meter and pH by 1:1 (w/v) soil to water ratio. The fly ash was collected from poly fiber industry Harihar in Davangeri district of Karnataka (India).

Experimental design

The experimental pots were filled with growth media (Soil: Sand in 3:1.) each experimental potting mixture was amended with three different levels of fly ash (1%, 3% and 5%) with provided with 10 g of AM fungal inoculum. (*Glomus fasciculatum*). The control treatment was maintained with out AM fungal inoculum and fly ash. The treatments maintained for each plants species were as follows.

1) Control (Uninioculated)
2) Mycorrhiza (*Glomus fasciculatum*) inoculated
3) Mycorrhiza (GF) + 1% fly ash (100g/10kg soil)
4) Mycorrhiza (GF) + 3% fly ash (300g/10kg soil)
5) Mycorrhiza (GF) + 5% fly ash (500g/10kg soil)

All the experimental pots were arranged incompletely randomized block design with triplicate per treatment. The experimental pots were kept free of weeds, insects, pets, rodents etc. the pots were watered every alternate day and 10 ml of Hoagland solution without P was given to each seedling at the interval of 15 days.
Analysis of growth parameters:

Plants were harvested after 60, 90 and 120 days after sowing. The plants parameters like shoot and root length, fresh weight of shoot and root, shoot and root dry weight, stem diameter and number of leaves, the per cent root colonization, spore number per 50 g soil, and phosphorus uptake in shoot were recorded. After the harvest, experimental plants shoot and root was oven dried at 70°C until a constant weight was obtained to determine the dry weight.

Root colonization

The per cent root colonization was evaluated microscopically followed by clearing of roots in 10% KOH and staining with 0.05% trypan blue in lactophenol according to method described by Phillips and Hayman (1970). The following formula was used to calculate the root colonization (Giovannetti and Mosse, 1980).

\[
\text{Percent mycorrhizal colonization} = \frac{\text{Number of root segments colonized}}{\text{Total number of root segments examined}} \times 100
\]

Determination of AM fungal spores

Spores were separated from the soil by wet sieving and decanting technique (Gerdemann and Nicolson, 1963). 50 g of soil was mixed with water. The mixture was pour through different sieve size (250, 106, 45µm). After several times of sieve washing, the supernatant was collected in petridish and spores counted under binocular-microscope.

Determination of Fiber content

Smallholder plots are usually harvested by hand. The plants are cut at 2 to 3 cm above the soil and left on the ground to dry. The cut Corchorus capsularis L., Crotalaria juncea L.,
and *Hibiscus cannabinus* L., is laid in swathes to dry for up to four days. This was followed by water retting (the bundled hemp floats in water) and the fiber yield in *Gossypium hirsutum* L., was measured by taking dry weight of fruits.

**Phosphorus content:**

The phosphorus content in the shoots was determined by the vanado-molybdate phosphoric acid yellow color method outlined by Jackson (1973).

**Statistical Analysis**

Analysis of variance (ANOVA) was performed on all data and the means were separated using Duncan’s multiple Range Test (DMRT), by the help of SPSS student version-9 software.
RESULTS

The different dosages of fly ash with AM fungus *Glomus fasciculatum* inoculated to test the effect of fly ash on mycorrhizal and four fiber yielding plants. All the plant species inoculated with 3% fly ash with AM fungus have shown increased growth parameters over the other treatments and control plants (Plate XV- XVI). The experimental results revealed that, not only the growth parameters of four experimental plants were increased but also the nutrient uptake and mycorrhizal status was significant compared to plants provide with high levels of fly ash.

The growth parameters of all the experimental plants were determined at 60, 90 and 120 days after sowing. The greater values for growth parameters such as shoot length, fresh weight of shoot, dry weight of shoot, root length, fresh weight of root, dry weight of root, stem diameter, number of flowers, numbers of fruits and increased “P” uptake were recorded in experimental plants with 3 % fly ash and AM fungus *Glomus fasciculatum* over the reaming treatments. Where as, plants provided with 5% fly ash have shown to be less significant (Fig. 4.1-4.10). The intermediate growth rate had been recorded in plants provided with 1% fly ash in presence of AM fungus. (Table 4.1-4.4).

Mycorrhizal parameters like per cent colonization, and spore number were determined at 60, 90 and 120 days. The mycorrhizal root colonization was found to be varied in each experimental plant. It was less in beginning (at 45-60 days) but steadily increased after 90 days. It was observed that at 120 there was maximum colonization in the experimental plants roots grown with 3% fly ash over control plants. The maximum per cent mycorrhizal colonization (PMC) was recorded in *Crotalaria juncea* L., and very least PMC was observed in the roots of *Hibiscus cannabinus* L., whereas, intermediate PMC was recorded in remaining two experimental pants. (Fig 4.5 and 4.6)
AM fungal spore number was recorded in all experimental plants. It was found to be highest at 120 days and least was noticed at 60 days, with increase in duration the spore number was increased. Maximum AM fungal spore number was observed in the rhizosphere soils of the experimental plants inoculated with *Glomus fasciculatum* and 3% fly ash. It was least in plants inoculated with *Glomus fasciculatum* and 5% fly ash whereas, moderate spore number was noticed in plants provided with 1% fly ash (Fig. 4.7 and 4.8).

The plants were also analyzed for its nutrient continent in shoot, particularly phosphorus. Maximum increased P uptake was observed in plants inoculated with *Glomus fasciculatum* in presence of 3% fly ash (Fig 4.9 and 4.10) The moderately increased P Uptake in shoots was estimated in plants grown with 1% fly ash and it was least in plants with 5% fly ash in the potting mixture. The fiber content in all the experimental plants was measured (Table. 4.5). The fiber content in the mycorrhizal plant with 3% fly ash was more when compared to control plants and mycorrhizal plants with 5% fly ash (Fig. 4.11).

It can be evident from the above results that, AM fungus *Glomus fasciculatum* with 3% fly ash was found to be the more efficient treatment of the enhancement of plant growth and fiber yield in four experimental plants.
PLATE XV

1. Effect of different levels of fly ash on *Corchorus capsularis* L. inoculated with AM fungus.
   A. Control (Uninoculated).
   B. *Glomus fasciculatum*.
   C. *Glomus fasciculatum* + 1% fly ash.
   D. *Glomus fasciculatum* + 3% fly ash.
   E. *Glomus fasciculatum* + 5% fly ash.

2. Effect of different levels of fly ash on *Crotalaria juncea* L. inoculated with AM fungus.
   A. Control (Uninoculated).
   B. *Glomus fasciculatum*.
   C. *Glomus fasciculatum* + 1% fly ash.
   D. *Glomus fasciculatum* + 3% fly ash.
   E. *Glomus fasciculatum* + 5% fly ash.
PLATE XVI

1. Effect of different levels of fly ash on *Gossypium hirsutum* L. inoculated with AM fungus.
   
   A. Control (Uninoculated).
   
   B. *Glomus fasciculatum*.
   
   C. *Glomus fasciculatum* + 1 l fly ash.
   
   D. *Glomus fasciculatum* + 3 l fly ash.
   
   E. *Glomus fasciculatum* + 5 l fly ash.

2. Effect of different levels of fly ash on *Hibiscus cannabinus* L. inoculated with AM fungus.
   
   A. Control (Uninoculated).
   
   B. *Glomus fasciculatum*.
   
   C. *Glomus fasciculatum* + 1 l fly ash.
   
   D. *Glomus fasciculatum* + 3 l fly ash.
   
   E. *Glomus fasciculatum* + 5 l fly ash.
Table 4.1: Effect of *Glomus fasciculatum* and fly ash different levels treatments on the growth of *Corchorus capsularis* L., plants at different interval (60, 90 and 120 days).

<table>
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<tr>
<th>Treatments</th>
<th>SL</th>
<th>FWS</th>
<th>DWS</th>
<th>RL</th>
<th>FWR</th>
<th>DWR</th>
<th>STD</th>
<th>PMC</th>
<th>NFL</th>
<th>NFR</th>
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<td>2.000 ±0.057e</td>
<td>2.066 ±0.057e</td>
<td>1.133 ±0.066e</td>
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<td>0.000 ±0.000e</td>
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<td>3.600 ±0.303d</td>
<td>1.466 ±0.033d</td>
<td>51.33 ±0.881d</td>
<td>0.000 ±0.000e</td>
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<td>121.6 ±1.201d</td>
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<td>0.120 ±0.000b</td>
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Note: SL: Shoot length, FWS: Fresh weight of Shoot, DWS: Dry weight of Shoot, RL: Root Length, FWR: Fresh weight of Root, DWR: Dry weight of Root, STD: Stem Diameter, PC: per cent of mycorrhizal colonization, NFL: Number of Flowers, NFR: Number of fruits, SP: Spore Number, P: Phosphorous. Values represent the mean ± SD. Means followed by the same letter within a column are not significantly P= 0.05 according to DMRT.
Table 4.2: Effect of *Glomus fasciculatum* and fly ash different levels treatments on the growth of *Crotalaria juncea* L., plants at different interval (60, 90 and 120).

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<th>DWS</th>
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<th>FWR</th>
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<td>±0.152a</td>
<td>25.76</td>
<td>±0.088a</td>
<td>16.70</td>
<td>±0.152a</td>
<td>24.63</td>
<td>±0.088a</td>
<td>6.466</td>
<td>±0.033a</td>
<td>3.100</td>
<td>±0.057a</td>
</tr>
<tr>
<td>GF+5%FA</td>
<td>40.70</td>
<td>±0.152c</td>
<td>18.43</td>
<td>±0.088c</td>
<td>10.96</td>
<td>±0.185c</td>
<td>20.13</td>
<td>±0.033c</td>
<td>5.666</td>
<td>±0.066c</td>
<td>2.033</td>
<td>±0.120c</td>
</tr>
<tr>
<td><strong>90 DAYS</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>CN</td>
<td>36.80</td>
<td>±0.057e</td>
<td>16.10</td>
<td>±0.100e</td>
<td>10.30</td>
<td>±0.152e</td>
<td>15.80</td>
<td>±0.057e</td>
<td>3.733</td>
<td>±0.166e</td>
<td>1.966</td>
<td>±0.088e</td>
</tr>
<tr>
<td>GF</td>
<td>55.13</td>
<td>±1.334d</td>
<td>23.63</td>
<td>±0.120d</td>
<td>14.26</td>
<td>±0.120d</td>
<td>28.60</td>
<td>±0.057d</td>
<td>9.033</td>
<td>±0.066d</td>
<td>4.533</td>
<td>±0.120d</td>
</tr>
<tr>
<td>GF+1%FA</td>
<td>64.80</td>
<td>±0.057b</td>
<td>32.73</td>
<td>±0.088b</td>
<td>20.23</td>
<td>±0.202b</td>
<td>32.66</td>
<td>±0.120b</td>
<td>12.60</td>
<td>±0.115b</td>
<td>6.566</td>
<td>±0.088b</td>
</tr>
<tr>
<td>GF+3%FA</td>
<td>72.76</td>
<td>±0.088a</td>
<td>39.40</td>
<td>±0.057a</td>
<td>24.73</td>
<td>±0.088a</td>
<td>36.83</td>
<td>±0.033a</td>
<td>15.66</td>
<td>±0.120a</td>
<td>8.600</td>
<td>±0.115a</td>
</tr>
<tr>
<td>GF+5%FA</td>
<td>61.66</td>
<td>±0.120c</td>
<td>29.70</td>
<td>±0.100c</td>
<td>17.93</td>
<td>±0.145c</td>
<td>30.03</td>
<td>±0.272c</td>
<td>10.43</td>
<td>±0.033c</td>
<td>5.866</td>
<td>±0.145c</td>
</tr>
<tr>
<td><strong>120 DAYS</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CN</td>
<td>49.53</td>
<td>±0.033e</td>
<td>28.73</td>
<td>±0.088e</td>
<td>13.06</td>
<td>±0.033e</td>
<td>27.43</td>
<td>±0.120e</td>
<td>10.90</td>
<td>±0.173e</td>
<td>5.700</td>
<td>±0.100e</td>
</tr>
<tr>
<td>GF</td>
<td>69.76</td>
<td>±0.088d</td>
<td>38.76</td>
<td>±0.133d</td>
<td>25.10</td>
<td>±0.057d</td>
<td>38.76</td>
<td>±0.088d</td>
<td>16.70</td>
<td>±0.115d</td>
<td>10.43</td>
<td>±0.033d</td>
</tr>
<tr>
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<td>81.20</td>
<td>±0.230b</td>
<td>46.66</td>
<td>±0.120b</td>
<td>30.43</td>
<td>±0.088b</td>
<td>42.60</td>
<td>±0.173b</td>
<td>18.73</td>
<td>±0.088b</td>
<td>11.96</td>
<td>±0.033b</td>
</tr>
<tr>
<td>GF+3%FA</td>
<td>96.83</td>
<td>±0.033a</td>
<td>55.86</td>
<td>±0.033a</td>
<td>36.83</td>
<td>±0.088a</td>
<td>49.76</td>
<td>±0.145a</td>
<td>20.63</td>
<td>±0.208a</td>
<td>13.90</td>
<td>±0.088a</td>
</tr>
<tr>
<td>GF+5%FA</td>
<td>76.33</td>
<td>±0.240c</td>
<td>42.56</td>
<td>±0.202c</td>
<td>27.60</td>
<td>±0.057c</td>
<td>39.60</td>
<td>±0.264c</td>
<td>17.10</td>
<td>±0.020c</td>
<td>10.66</td>
<td>±0.284c</td>
</tr>
</tbody>
</table>

Note: SL: Shoot length, FWS: Fresh weight of Shoot, DWS: Dry weight of Shoot, RL: Root Length, FWR: Fresh weight of Root, DWR: Dry weight of Root, STD: Stem Diameter, PC: per cent of mycorrhizal colonization, NFL: Number of Flowers, NFR: Number of fruits, SP: Spore Number, P: Phosphorous. Values represent the mean ± SD. Means followed by the same letter within a column are not significantly P= 0.05 according to DMRT.
Table 4.3: Effect of *Glomus fasciculatum* and fly ash different levels treatments on the growth of *Gossypium hirsutum* L., plants at different interval (60, 90 and 120).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>SL</th>
<th>FWS</th>
<th>DWS</th>
<th>RL</th>
<th>FWR</th>
<th>DWR</th>
<th>STD</th>
<th>PC</th>
<th>NFL</th>
<th>NFR</th>
<th>SP</th>
<th>P-uptake</th>
</tr>
</thead>
<tbody>
<tr>
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<td>±0.081e</td>
<td>±0.088e</td>
<td>±0.033e</td>
<td>±0.088e</td>
<td>±0.000e</td>
<td>±0.033e</td>
<td>±0.000e</td>
<td>±0.000e</td>
<td>±0.000e</td>
<td>±0.000e</td>
<td>±0.000e</td>
<td>±0.040</td>
</tr>
<tr>
<td>60 DAYS</td>
<td>CN</td>
<td>29.53</td>
<td>15.76</td>
<td>6.966</td>
<td>10.76</td>
<td>2.900</td>
<td>1.466</td>
<td>4.400</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000 e</td>
</tr>
<tr>
<td></td>
<td>GF</td>
<td>40.63</td>
<td>26.56</td>
<td>15.96</td>
<td>20.43</td>
<td>8.666</td>
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<td>1.133</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>110.3</td>
</tr>
<tr>
<td></td>
<td>GF+1%FA</td>
<td>49.76</td>
<td>33.46</td>
<td>21.51</td>
<td>26.53</td>
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<td>1.333</td>
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<td>0.000</td>
<td>125.6</td>
</tr>
<tr>
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<td>GF+3%FA</td>
<td>56.73</td>
<td>36.76</td>
<td>24.86</td>
<td>30.56</td>
<td>15.86</td>
<td>7.533</td>
<td>1.333</td>
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<td>0.000</td>
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</tr>
<tr>
<td></td>
<td>GF+5% FA</td>
<td>44.76</td>
<td>29.43</td>
<td>17.90</td>
<td>23.13</td>
<td>10.56</td>
<td>5.900</td>
<td>1.250</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>117.6</td>
</tr>
<tr>
<td>90 DAYS</td>
<td>CN</td>
<td>34.70</td>
<td>18.70</td>
<td>10.70</td>
<td>13.80</td>
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<td>2.100</td>
<td>1.033</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000 e</td>
</tr>
<tr>
<td></td>
<td>GF</td>
<td>60.40</td>
<td>36.76</td>
<td>24.66</td>
<td>22.30</td>
<td>12.06</td>
<td>8.133</td>
<td>1.433</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>162.6</td>
</tr>
<tr>
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<td>GF+1%FA</td>
<td>74.83</td>
<td>42.76</td>
<td>29.83</td>
<td>24.70</td>
<td>13.40</td>
<td>9.100</td>
<td>1.766</td>
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<td>0.000</td>
<td>0.000</td>
<td>177.3</td>
</tr>
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<td>GF+3%FA</td>
<td>80.63</td>
<td>50.56</td>
<td>34.73</td>
<td>29.60</td>
<td>15.56</td>
<td>10.80</td>
<td>2.066</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>196.0</td>
</tr>
<tr>
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<td>GF+5% FA</td>
<td>70.70</td>
<td>40.33</td>
<td>27.43</td>
<td>22.26</td>
<td>12.76</td>
<td>8.933</td>
<td>1.566</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>172.0</td>
</tr>
<tr>
<td>120 DAYS</td>
<td>CN</td>
<td>45.66</td>
<td>25.83</td>
<td>17.50</td>
<td>15.83</td>
<td>6.833</td>
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<td>1.833</td>
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<td>0.000</td>
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</tr>
<tr>
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<td>GF</td>
<td>74.86</td>
<td>40.66</td>
<td>27.80</td>
<td>15.86</td>
<td>15.86</td>
<td>9.766</td>
<td>2.066</td>
<td>7.000</td>
<td>1.527</td>
<td>5.666</td>
<td>173.6</td>
</tr>
<tr>
<td></td>
<td>GF+1%FA</td>
<td>82.76</td>
<td>47.73</td>
<td>32.53</td>
<td>18.53</td>
<td>18.53</td>
<td>12.46</td>
<td>2.300</td>
<td>8.000</td>
<td>1.527</td>
<td>4.666</td>
<td>203.6</td>
</tr>
<tr>
<td></td>
<td>GF+3%FA</td>
<td>92.60</td>
<td>54.63</td>
<td>37.43</td>
<td>20.73</td>
<td>20.73</td>
<td>14.83</td>
<td>2.766</td>
<td>9.333</td>
<td>1.527</td>
<td>8.000</td>
<td>234.3</td>
</tr>
<tr>
<td></td>
<td>GF+5% FA</td>
<td>78.66</td>
<td>44.60</td>
<td>28.96</td>
<td>20.19</td>
<td>16.36</td>
<td>11.23</td>
<td>2.266</td>
<td>8.000</td>
<td>1.527</td>
<td>6.666</td>
<td>188.0</td>
</tr>
</tbody>
</table>

Note: SL: Shoot length, FWS: Fresh weight of Shoot, DWS: Dry weight of Shoot, RL: Root Length, FWR: Fresh weight of Root, DWR: Dry weight of Root, STD: Stem Diameter, PC: per cent of mycorrhizal colonization, NFL: Number of Flowers, NFR: Number of fruits, SP: Spore Number, P: Phosphorous. Values represent the mean ± SD. Means followed by the same letter within a column are not significantly P= 0.05 according to DMRT.
Table 4.4: Effect of *Glomus fasciculatum* and fly ash different levels treatments on the growth of *Hibiscus cannabinus* L., plants at different interval (60, 90 and 120).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>60 DAYS</th>
<th>90 DAYS</th>
<th>120 DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SL ±0.218e</td>
<td>FWS ±0.115e</td>
<td>DWS ±0.033e</td>
</tr>
<tr>
<td>CN</td>
<td>26.06 ±0.60 ±0.120d ±0.088a ±15.60 ±0.152a ±0.057c</td>
<td>10.60 ±0.352e</td>
<td>8.500 ±0.318b</td>
</tr>
<tr>
<td>GF</td>
<td>40.60 ±0.088a</td>
<td>8.366 ±0.152d</td>
<td>14.86 ±0.120d</td>
</tr>
<tr>
<td>GF+1%FA</td>
<td>53.90 ±0.057c</td>
<td>12.26 ±0.033d</td>
<td>24.80 ±0.088b</td>
</tr>
<tr>
<td>GF+3%FA</td>
<td>67.76 ±0.120d</td>
<td>15.60 ±0.115a</td>
<td>22.43 ±0.088a</td>
</tr>
<tr>
<td>GF+5%FA</td>
<td>53.90 ±0.057c</td>
<td>9.166 ±0.120c</td>
<td>15.96 ±0.033c</td>
</tr>
<tr>
<td></td>
<td>44.76 ±0.120c</td>
<td>16.80 ±0.057c</td>
<td>9.166 ±0.033c</td>
</tr>
<tr>
<td></td>
<td>43.16 ±0.120c</td>
<td>15.13 ±0.176e</td>
<td>4.900 ±0.176e</td>
</tr>
<tr>
<td></td>
<td>34.16 ±0.352e</td>
<td>15.13 ±0.176e</td>
<td>4.900 ±0.176e</td>
</tr>
<tr>
<td></td>
<td>34.16 ±0.120c</td>
<td>15.13 ±0.176e</td>
<td>4.900 ±0.176e</td>
</tr>
<tr>
<td></td>
<td>34.16 ±0.120c</td>
<td>15.13 ±0.176e</td>
<td>4.900 ±0.176e</td>
</tr>
<tr>
<td></td>
<td>34.16 ±0.120c</td>
<td>15.13 ±0.176e</td>
<td>4.900 ±0.176e</td>
</tr>
<tr>
<td></td>
<td>34.16 ±0.120c</td>
<td>15.13 ±0.176e</td>
<td>4.900 ±0.176e</td>
</tr>
<tr>
<td></td>
<td>34.16 ±0.120c</td>
<td>15.13 ±0.176e</td>
<td>4.900 ±0.176e</td>
</tr>
</tbody>
</table>

Note: SL: Shoot length, FWS: Fresh weight of Shoot, DWS: Dry weight of Shoot, RL: Root Length, FWR: Fresh weight of Root, DWR: Dry weight of Root, STD: Stem Diameter, PC: per cent of mycorrhizal colonization, NFL: Number of Flowers, NFR: Number of fruits, SP: Spore Number, P: Phosphorous. Values represent the mean ± SD. Means followed by the same letter within a column are not significantly P= 0.05 according to DMRT.
Table: 4.5: Effect of *Glomus fasciculatum* and fly ash different levels treatments on the Fiber yield of *Corchorus capsularis* L., *Crotalaria juncea* L., *Gossypium hirsutum* L. and *Hibiscus cannabinus* L., at different interval plants at different interval (60, 90 and 120).

<table>
<thead>
<tr>
<th>Treatments</th>
<th><em>Corchorus capsularis</em> L.</th>
<th><em>Crotalaria juncea</em> L.</th>
<th><em>Gossypium hirsutum</em> L.</th>
<th><em>Hibiscus cannabinus</em> L.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN</td>
<td>2.100±0.100e</td>
<td>3.200±0.057e</td>
<td>1.533±0.185e</td>
<td>2.000±0.057e</td>
</tr>
<tr>
<td>GF</td>
<td>4.633±0.251d</td>
<td>7.366±0.088d</td>
<td>2.600±0.115d</td>
<td>6.900±0.057d</td>
</tr>
<tr>
<td>GF+1% Fly ash</td>
<td>5.866±0.057b</td>
<td>8.566±0.202b</td>
<td>3.866±0.033b</td>
<td>8.400±0.115b</td>
</tr>
<tr>
<td>GF+3% Fly ash</td>
<td>8.800±0.173a</td>
<td>10.93±0.202a</td>
<td>4.133±0.120a</td>
<td>11.300±0.057a</td>
</tr>
<tr>
<td>GF+5% Fly ash</td>
<td>5.166±0.152c</td>
<td>8.066±0.088c</td>
<td>2.766±0.088c</td>
<td>7.466±0.666c</td>
</tr>
</tbody>
</table>

Values represent the mean ± SD. Means followed by the same letter within a column are not significantly P= 0.05 according to DMRT.
Fig 4.1: The effect of AM fungi and different levels of fly ash treatments on dry weight shoot of plants *Corchorus capsularis* L., and *Crotalaria juncea* L., at different interval.
Fig 4.2: The effect of AM fungi and different levels of fly ash treatments on dry weight shoot of plants *Gossypium hirsutum* L., and *Hibiscus cannabinus* L., at different interval.
Fig. 4.3: The effect of AM fungi and different levels of fly ash treatments on dry weight root of plants *Corchorus capsularis* L., and *Crotalaria juncea* L., at different interval.
Fig. 4.4: The effect of AM fungi and different levels of fly ash treatments on dry weight root of plants *Gossypium hirsutum* L., and *Hibiscus cannabinus* L., at different interval.
**Fig. 4.5:** The effect of AM fungi and different levels of fly ash treatments on Per cent of root colonization of plants *Corchorus capsularis* L., and *Crotalaria juncea* L., at different intervals.
Fig. 4.6: The effect of AM fungi and different levels of fly ash treatments on Per cent root colonization of plants *Gossypium hirsutum* L., and *Hibiscus cannabinus* L., at different interval.
Fig. 4.7: The effect of AM fungi and different levels of fly ash treatments on Spore number/50 g soil of plants *Corchorus capsularis* L., and *Crotalaria juncea* L., at different interval.
Fig. 4.8: The effect of AM fungi and different levels of fly ash treatments on Spore number/50 g soil of plants *Gossypium hirsutum* L., and *Hibiscus cannabinus* L., at different interval.
**Fig: 4.9:** The effect of AM fungi and different levels of fly ash treatments on P-uptake of plants *Corchorus capsularis* L., and *Crotalaria juncea* L., at different interval
Fig. 4.10: The effect of AM fungi and different levels of fly ash treatments on P-uptake of plants *Gossypium hirsutum* L., and *Hibiscus cannabinus* L., at different interval.
Fig 4.11: The effect of AM fungi and different levels of fly ash treatments on Fiber yield of plants *Corchorus capsularis* L., *Crotalaria juncea* L., *Gossypium hirsutum* L., and *Hibiscus cannabinus* L., at different interval.
DISCUSSION

In the present study the best effects on biomass production were noticed in AMF inoculated plants grown with 3% fly ash. The experimental results revealed that, AM inoculation with fly ash was successful in enhancing the plant growth parameters due to improved supply of nutrients, especially phosphorus and minerals such as Zn, Cu, K and Ca (Copper and Tinker, 1978). In the present study increased growth and higher values for mycorrhizal colonization and spore number have been reported with AMF and 3% fly ash. The AMF helps in binding the fine particles of fly ash and arrest the movement heavy metals and also helps in uptake of micronutrients and phosphorus solubilization (Adholeya, 2000).

Similarly Garampalli et al., (2005) revealed on the basis of pot-culture experiment that, using sterile, phosphorus-deficient soil to study the effect of fly ash at three different concentrations (10 g, 20 g and 30 g fly ash kg\(^{-1}\) soil) on the infectivity and effectiveness of arbuscular mycorrhizal fungus (Glomus aggregatum) on pigeon pea (Cajanus cajan L.) cv. Maruti. All the concentrations of fly ash amendment in soil were found to significantly affect the intensity of AM colonization inside the plant roots. They also reported that higher concentration of fly ash (30 g fly ash kg\(^{-1}\) soil) suppresses the formation of AM fungal structure. The low rate of AM fungal colonization and the presence of very few spores in rhizosphere of plants grown on fly ash were attributed to adverse conditions. The soil structure and composition not only affect the spore population but also the biological activity of AM fungi (Mosse, 1975). In the present study reduction in mycorrhizal colonization was observed at higher fly ash concentration. The dry weight of the experimental plants under the influence of 5% fly ash amendment in AM fungus-inoculated soils was found to be considerably less when compared to the plants grown with 3% fly ash. However, fly ash amendment with AM inoculation was also found to enhance the growth of plants as compared to control plants. These findings were in accordance with report of Sheela and
Sundaram (2003) on Black gram in abandoned ash ponds of thermal power plants. The present experimental results were strongly supports these findings.

Increased concentration of fly ash decreases the plant growth as well as mycorrhizal status in root and rhizosphere of all the experimental plants. Increased tolerance of mycorrhizal plants to toxic heavy metal concentration in the soil makes mycorrhizae significant. Therefore fly ash is used as a nutrient in agriculture or horticulture and also as a limiting agent in acidic agricultural soil. Similar observations were made by Plank, Martens and Hallock, (1975); Sheela and Sundaram, (2003). Present investigations were strongly supported by these workers.

Fly ash contains many essential plant nutrients and their availability to the plant may be problematic as reported by Pandey et al., (1994) and Singh et al., (1997). In the present study, inoculation of AM fungus along with 3% fly ash significantly increased biomass of all the experimental plants. The uptake of nutrients such as P significantly increased in the shoot tissues compared to other treatments. The AM fungi may enhance plant P nutrition and increase the plant growth by diluting metal effect in host plant or by binding of the metal to the fungal mycelium through chitin or glomalin and immobilize them in rhizosphere or roots (Chen et al., 2001 and González-Chávez et al., 2004). It has also been found that AM fungi alleviate metal toxicity of fly ash and enhance plant growth (Ning, 2000).