Effect of low concentration of fly ash on the plant growth performance: A review

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Fly ash constitutes the major portion of the total quantity of residues produced in power plants. The large amount of fly ash that is generated each year calls for a great deal of research to determine its feasibility for various potential uses. Of all the possible uses of fly ash in a productive manner, the best use is as a fertilizer either through soil amendment or reclamation of fly ash dumps by cultivating plants of value. Fly ash is not only a good growing medium, but also better soils ameliorate. Efforts have been made to modify the properties of agriculture soil by addition of fly ash, thus improving the soil fertility and crop yield. The effects on plants are primarily due to shifted chemical equilibrium induced by fly ash added to the soil. Phytoextraction is a remediation technology that uses plants to remove heavy metals from soil. Studies show that various heavy metals and metalloids are available into the fly ash. Plant based approaches, such as phytoremediation, are relatively inexpensive since they are performed in situ and are solar- driven. The specific advances in plant- based approaches for the remediation of wastes such as fly ash because fly ash contains lots of micro and macro elements, those can give positive or negative impact on plants as increase in crop yield, photosynthetic rate, biomass etc. Researches also suggest that abiotic factors may alter the production of bioactive compounds by changing aspects of secondary metabolism with the help of heavy metals uptake. This review represents that low concentration of fly ash is helpful to increase plant growth performance due to the presence of several beneficial elements or metals.

Key words- fly ash, heavy metals, plant growth and remediation.

I. INTRODUCTION

The general composition of Fly ash is listed in Table 1. Fly Ash is collected by electrostatic precipitator or filter bags in thermal power plants. The particles of fly ash are spherical in shape (0.5 µm to 100µm). Depending upon the source of coal being burned, the component of the fly ash vary considerably, but all the fly ash contains substantial amount of silicon dioxide and calcium oxide, both are ingredients in many coal bearing rock strata. Due to heterogeneous characteristics, fly ash contains glassy particles as quartz, mullite and various iron oxides also. Fly ash also contains many elements like: arsenic, barium, beryllium, boron, cadmium, chromium, chromium VI, cobalt, copper, fluorine, lead, manganese, nickel, selenium, strontium, thallium, vanadium and zinc. All other physiochemical properties were reported as Table 2 and Table 3 [1], [2].

According to ASTM C618 fly ash is classified in two classes: Class F fly ash and Class C fly ash. The concentration of calcium, silica, iron and alumina gives differentiation in between these two classes:

Class F fly ash-Anthracite and bituminous coal gives class F type fly ash. This fly ash contains 10% lime (CaO) and pozzolanic property. This fly ash requires cementing agents and water to prepare cementing products.

Class C fly ash-Lignite and sub-bituminous coal gives class C type fly ash. In addition to pozzolanic property, fly ash has self cementing property also. Class C fly ash contains 20% lime (CaO).

Table 1 The General Composition of Fly Ash

S. No.	Substituent (%)	Bituminous	Sub-bituminous	Lignite
1	Fe_2O_3	10-40	4-10	4-15
2	SiO_2	20-60	40-60	15-45
3	Al_2O_3	5-35	20-30	20-25
4	CaO	1-12	5-30	15-40
5	LOI	0-15	0-3	0-5

Table 2 Physical Properties of Fly Ash

Particle size	0.5 µm to 100µm
pH	8.2 -12.8
Electrical conductivity	8.60- 8.70
Bulk Density	1.01- 1.43 gm/ cm^3
Water retention (%)	6.1- 13.4
Organic carbon (%)	0.53- 0.85
Total Nitrogen (%)	0.0- 0.024
Total Phosphorus (%)	0.018- 0.02

Table 3 Trace And Major Elemental Composition of Fly Ash

Trace Elements	(µg/g)
Zn	20- 153.5
Fe	53- 4150
Ni	13- 296.2
Mn	12.1- 353.1
Cu	24.0- 170
Cd	42.3- 52.4
Pb	40.1- 115.2
Mo	33.4- 47.7
Cr	23.4- 152
Na	15- 98

Major Elements	(μg/g)
Ca	338- 177,100
Mg	116- 60,800
K	7,360- 22,400
B	143- 290
Al	4,615- 24,200

II. IMPACT OF LOW CONCENTRATION OF FLY ASH ON PLANT GROWTH PERFORMANCE

As we all know there is always an impact of different elements in plant growth or other from the substrates. The influence of these elements or heavy metals has been studied in various aspects. The influence of Cd, Cu, Zn, and Fluoranthene (FLA), separately applied, and combinations of one of these heavy metals with FLA on the growth of soil bacteria were examined through a 90 day incubation period and compared with the behaviour of no treatment (control). In the soils amended with all doses of Cd, Cu and Zn alone and combination with FLA, total bacterial population was always significantly lower than those of the control soil. Significant reductions of bacterial counts were observed for both doses of heavy metals combined with FLA. Low concentration of heavy metals (50 mg kg^{-1}) which was not affective when added separately was found to reduce bacterial growth when applied in combination with FLA. At higher levels of heavy metals (150 mg kg^{-1}) addition of FLA also increased the toxicity of the metals.

Comparisons of whole treatments revealed that total bacterial growth was more inhibited by 150 mg kg^{-1} Cd alone (85%), and 50 mg kg^{-1} Cd + 150 mg kg^{-1} FLA and 150 mg kg^{-1} Zn + 150 mg kg^{-1} FLA treatments (82.5%). Based on these results, it could be concluded that FLA may enhance the toxicity of low concentrations of heavy metals (50 mg kg^{-1}) to bacteria in soils [3]. Studies of growth character and its accumulation in different parts of Tulsi under various concentration of some heavy metals (Lead and Cadmium), done at Department of Dravyagunna, Faculty of Ayurveda, Institute of Medical science during the year of 2007.The graded levels of these two metals Cd (0, 20, 50, 100 and 200 ppm) and Pb (0, 50, 100, 250, and 500 ppm) applied after the germination of Tulsi. The plant exhibited a decline in growth, chlorophyll content and carotenoids with increasing levels of Pb and Cd, more accumulation of Pb and Cd was observed in roots than shoots in O. tenuifolium L [4]. Pennell, cultivated in Hoagland medium artificially contaminated with micro quantities of $HgCl_2$ and $CdCl_2$ is investigated. Bioaccumulation of Hg and Cd in Bacopa Monnieri reveals the phytoremediation potential while the bioaccumulation is hazards to health since the plant is highly medicinal and one important ingredient of many Ayurvedic preparations [5]. The heavy metals contained in the ashes remain in the bottom ash of the incinerator or leave the incinerator with the off-gas and are collected in the off-gas filter. The amount of the metals in the collected fly ash depends on the composition of the input material. The aim of this study was to examine this influence and compare the results with literature data. For measurement, the fly ash samples were at first dissolved in a microwave digestion unit using nitric acid and hydrochloric acid. Afterwards, 20 metals were analyzed by inductively coupled plasma optical emission spectrometry. Al, Fe, Mg, Mn, and Zn were found in higher concentrations in the fly ash samples. The enrichment factor between the concentrations in the fly ash and the concentrations in the input material was on average in the range of 18 [6. Phytoremediation of heavy metals is a important area of research which executes the phytoextraction, bioaccumulation and phytoremediation [7] processes to reduce toxic contaminations from various sources. Some investigation reveals the accumulation of heavy metals in fields contaminated with fly ash from a thermal power plant and subsequent uptake in different parts of naturally grown plants. Results revealed that in the contaminated site, the mean level of all the metals (Cd, Zn, Cr, Pb, Cu, Ni, Mn and Fe) in soil and different parts (root and shoots) of plant species were found to be significantly ($p<0.01$) higher than the uncontaminated site. The enrichment factor (EF) of these metals in contaminated soil was found to be in the sequence of Cd (2.33) > Fe (1.88) > Ni (1.58) > Pb (1.42) > Zn (1.31) > Mn (1.27) > Cr (1.11) > Cu (1.10). Whereas, enrichment factor of metals in root and shoot parts, were found to be in the order of Cd (7.56) > Fe (4.75) > Zn (2.79) > Ni (2.22) > Cu (1.69) > Mn (1.53) > Pb (1.31) > Cr (1.02) and Cd (6.06) ~ Fe (6.06) > Zn (2.65) > Ni (2.57) > Mn (2.19) > Cu (1.58) > Pb (1.37) > Cr (1.01) respectively. In contaminated site, translocation factor (TF) of metals from root to shoot was found to be in the order of Mn (1.38) > Fe (1.27) > Pb (1.03) > Ni (0.94) > Zn (0.85) > Cd (0.82) > Cr (0.73) and that of the metals Cd with Cr, Cu, Mn, Fe; Cr with Pb, Mn, Fe and Pb with Fe were found to be significantly correlated. The present findings provide us a clue for the selection of plant species, which show natural resistance against toxic metals and are efficient metal accumulators [8]. A pot experiment was conducted to test the heavy metal phytoremediation capacity of Jatropha curcas from fly ash. Both natural accumulation by J. curcas and chemically enhanced phytoextraction was investigated. Plants were grown on FA (Fly ash) and FA amended with fertile garden soil, in presence and absence of chemical chelating agent EDTA at 0.1 g $kg^{-1}$and 0.3 g kg^{-1} of soil. EDTA enhanced the uptake of all five elements (Fe, Al, Cr, Cu and Mn) tested. Fe and Mn were retained more in roots while Cu, Al and Cr were translocated more to the shoot. Metal accumulation index indicates that the effect of EDTA at 0.3 g kg^{-1} was more pronounced than EDTA at 0.1 g kg^{-1} in terms of metal accumulation. Biomass was enhanced up to 37% when FA was amended with GS. Heavy metal uptake was enhanced by 117% in root, 62% in stem, 86% in leaves when EDTA was applied at 0.3 g kg^{-1} to FA amended with GS. Study suggest that J. curcas has potential of establishing itself on FA when provided with basic plant nutrients and can also accumulate heavy metals many folds from FA without attenuating plant growth [9]. In another research fly ash was amended to field soil at six rates (0, 5, 10, 20, 40, and 70 % w/w) on which was grown. After 8 months of growth, the height of J. curcas plants was significantly increased at 5 and 10 % FA-amended soil, whereas, biomass significantly increased at 5, 10, and 20 % FA-amended soil compared to control soil (0 % FA). Leaf nutrients uptake, followed by stems and roots uptake were highly affected by fly ash amendment to soil. Most of nutrients accumulation were increased up to 20 % fly ash and decreased thereafter. The results of available nutrient analysis of soil revealed that availability of nitrogen, potassium, sulfur, copper, iron, mangnese, and zinc declined significantly at higher levels of fly ash amendments, whereas, availability of phosphorus increased at these levels. However, pH, organic carbon, and available boron were not influenced significantly by fly ash amendment to soil. Microbial biomass C, N, and ratio of microbial-C to organic C were significantly reduced at 20 % fly ash and higher amounts. This study revealed that J. curcas plants could gainfully utilize the nutrients available in fly ash by subsequently amending soil [10].

Because of high concentration of many elements in fly ash, numerous studies have evaluated the usefulness of fly ash in nutrient deficient soil. It can be used as a source of B, Ca, Cu, K, Mg, Mo, S and Zn [11], [12], [13], [14], [15], [16], [17], [18]. The trace elements present in fly ash are potentially toxic due to their chemical limitations. These elements including As, B, Mo, Se and V are generally readily available to plant and tend to accumulate in plant tissue [19], [20].

If alkaline fly ash is used to treat acidic soil and it is also studied that the liming effect and the uptake of micro nutrients copper, zinc and manganese from fly ash can enhance plant growth [21]. In sun flower plant the heavy metals (Cd, Cu and Zn) from fly ash have no significant effect on dry mass but gives good growth in plant parts, stem, leaves and roots [22].

Fly ash can be used an amendment to increase Se uptake by crops serving as an essential micronutrient for many deficient soils and crops [23. Onions grown on coal fly ash contained a significantly high concentration of Se resulting in agricultural problems [24].

It is also studied that by using alkaline fly ash based product with soil for Zea mays plant the absorption of Cd, Ni or Mn was reduced as these are toxic and increased in other elements occurred in 5% w/w fly ash with soil [25]. The phytoextraction of Mn, Cu, Ni, Pb and Zn has been studied by Scirpus littoralis (a wetland plant). It growth showed good performance after 3 months in 25% fly ash with soil [26]. Sudan grass and oats showed low absorption of Fe, Cu, Mn and Zn from fly ash in Dadri, Gaziabad, Uttar Pradesh (India) [27]. The effect of organic wastes (biosludge and dairy sludge) and biofertilizer (Azotobacter chroococcum) on the growth conditions of Jatropha curcas in metal contaminated soils. All results showed that the plants survival rate in heavy metal contaminated soil increased with addition of amendments. Treatment T6 (heavy metal contaminated soils + dairy sludge + biofertilizer) observed to be the best treatment for growth (height and biomass) as compared to the treatment T5 (heavy metal contaminated soils + biosludge + biofertilizer) [28]. In Hyderabad the different source of nutrients applied to pruned and unpruned Jatropha plants from 2005-2007. The result showed that the plant height and stem girth of unpruned Jatropha increased significantly in the years by the application of 5 kg FYM per plant compared to control. The plant height of pruned Jatropha was not influenced by this organic source of nutrients, while stem girth improved significantly only in the third year. The application of 46:50:25 kg ha^{-1}NPK significantly increased the plant height and number of branches per plant of the pruned Jatropha compared to the organic source of nutrient supply in the third year. The response of unpruned crop to fertilizer application was of a higher magnitude. The integrated supply of nutrients by the application of 46:50:25 kg ha-1 NPK and 5 kg FYM per plant to the unpruned crop was the best. It maximized the plant height, number of branches per plant and the stem girth in the three years consistently [29].

The plants of Sesbania cannabina Ritz grown on different amendments of fly ash (FA), which have high accumulation of metals (Fe, Mn, Zn, Cu, Pb and Ni). The highest accumulation of Fe and lowest level of Ni were recorded in these plants. The different amendments of fly ash with garden soil (GS) were extracted with DTPA and the levels of metals were found to be decreased with an increase in fly ash application ratio from 10% to 50% FA. The analysis of the results showed an increase in the level of malondialdehyde (MDA) content of the roots for all the exposure periods. The maximum increases of 136% (roots) and 120% (leaves) were observed in MDA content at 100% FA after 30 d of growth of the plant, compared to GS. The level of antioxidants was found to increase for all the exposure periods in the roots of the plants to combat metal stress. At 30 d, the maximum increase of 57% (ascorbic acid) and 78% (free proline) was observed in the roots of the plants grown on 100% and 10% FA, respectively, as compared to their respective GS. At 90 d, a maximum increase of 42% (cysteine) and 117% (NPSH) was recorded in the roots of the plants grown on 25% and 100% FA, respectively, as compared to their respective GS. In leaves, a significant increase in antioxidants i.e. cysteine, NPSH and free proline content was recorded after 30 d, whereas no such trend was observed for the rest of the exposure periods. Not only have heavy metals, in drought stress conditioned the proline content also increases [30]. The chlorophyll and carotenoid contents increased with an increase in the FA amendment ratio from 10% to 50% FA for all the exposure periods as compared to GS. In both roots and leaves, the level of protein content increased in all the amendments and 100% FA at 30 d as compared to GS. Thus, there is a balance in the level of MDA content and level of antioxidants in the plants at 90 d. In view of its tolerance, the plants may be used for phytoremediation of metals from fly ash contaminated sites and suitable species for plantation on fly ash landfills [31]. Cotton and wheat grain yield with 20% fly ash which increased N, P and K nutrients and increased the growth and yield [32]. Sunflower plant (Helianthus annus L.) plants treated with fly ash exhibited improved growth. Relative growth rate (RGR) and net assimilation rate increased by over 20% at low fly ash application rate [33].

The increase in chlorophyll content and photosynthetic rate of Jatropha curcus has been observed with low dose of fly ash (20%) with soil [34]. Response of egg plant (Solanum melongena L.) with respect to fly ash was observed that its growth and yield were significantly increased in 5 to 30% fly ash with soil and same observations are also studied with Pisum sativum L. plant with 10% fly ash content [35].

It is also observed that tomato plant grown in fly ash mixture showed luxuriant growth with bigger and greener leaves. Plant growth, yield, carotenoids and chlorophylls were enhanced in 40 - 80 % fly ash amended soils. At 100% fly ash, yield was considerably reduced.

[36]. In drought conditions the plant growth of mustard also increased in 20% fly ash with soil as compared to 0%, 40%, 60% and 80% fly ash with soil [37]. This was also reported that in low concentration of fly ash the plant growth of J. Curcas increased and its antibacterial activity also increased [38].

III. CONCLUSION

We can conclude that due to the presence of heavy metals in fly ash, it acts as fertilizer for the soil which increases the plant growth performance. But high concentration of fly ash inhibits the plant growth due to the toxicity of heavy metals. We can utilize several non edible plants for phytoremediation of fly ash dykes, which can be a sustainable approach for absorption of these metals to avoid toxicity in soil. Also plants can helpful for carbon dioxide sequestration and oxygen production.

IV. REFERENCES

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