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An Eco-friendly Method for Reducing the Risk of Fly Ash using *Sesbania cannabina* (Dhaincha)

Nitisha Srivastava* and Girjesh Kumar
Department of Botany, University of Allahabad, Allahabad-211002, U. P., INDIA

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Abstract

Fly-ash disposal has a significant impact on terrestrial and aquatic ecosystems. Present investigation has been carried out to study the effect of different fly ash amendment levels on growth of green manure crop Sesbania cannabina. Fly ash obtained from IFFCO (Indian Farmers Fertilizers Cooperative Limited), Phulpur, Allahabad, India was mixed with garden soil in four different concentrations i.e. 0% (control/garden soil), 25%, 50%, 75% and 100%. A portion of the soil-fly ash mixtures was separated for physio-chemical properties. Dry and healthy seeds of Sesbania cannabina were soaked in water for 14 hrs and were sown in different amendment levels of fly ash in triplicates. Data for germination and survival percentages were taken after 15 and 30 days of sowing, respectively. Data for all morphological parameters were taken after 45 days of sowing. The result of present study concludes that the fly ash amendment in soil upto 75% has no adverse effect on the growth of Sesbania cannabina and it offers an eco-friendly method for removal of fly ash wastes from environment.

Keywords: Fly-ash, *Sesbaniacannabina*, morphological parameters, plant growth.

Introduction

In India, coal fired power plants produce 1.3×10^7 tonnes of fly-ash every year[1]. The fly-ash is generally not suitable for agriculture or for vegetation establishment due to its deficiency of nitrogen and phosphorus, its low soil microbial activity, and its high pH[2]. Although a small fraction of fly-ash is now used in the manufacture of cement, bricks, land filling, fertilizer fill etc., these activities have not yet gained much attention. Most fly ashes are disposed of in landfills and surface impoundments like fly ash ponds and dykes, and only about 30% is used in construction, engineering, manufacturing, and agricultural activities[3] and disposal of which may be harmful to residing organisms. Therefore it is important to know its effect on living beings and also the researches should be carried out for their proper disposal using eco-friendly methods.

Fly ash is an amorphous mixture of ferroaluminosilicate minerals generated from the combustion of ground or powdered coal at 400-1500^{0}C[4]. Fly ash also contains metals in significant amounts, including arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, fluorine, lead, manganese, nickel, selenium, strontium, thallium, vanadium, and zinc[5]. In addition, it has the primary nutrients like phosphate and potash and secondary nutrients like calcium, magnesium and sulfur as well as micronutrients like zinc, copper and manganese etc. Thus, fly ash may be regarded as a source of essential nutrients to the plants.

Fly ash may act as a good conditioning material for agricultural uses. To study the efficacy of fly ash for reclamation of alkaline soil and to enhance bulk utilization of fly ash in the field of agriculture, IFFCO Phulpur has undertaken a RandD project with Fly Ash Mission, TIFAC, Dept. of Science and Technology, Government of India, New Delhi. Fly ash, on application in waste land / usar (alkali soil) improves soil fertility, lowers soil pH, changes soil texture, improves soil porosity and soil density and increases water holding capacity. It is by virtue of this and the ability of fly ash to modify the physical properties of soils, it works as a soil conditioner/ modifier enhancing the yield of the cereals, pulses, oil seeds, sugarcane, vegetables etc.

A number of studies have shown that addition of alkaline ash can increase the pH of acidic soils[6-9]. In some cases, soils have been amended with fly ash in order to correct micronutrient deficiencies. Although the presence of toxic elements (Al, Pb, Cd, Cr, etc.) in the fly-ash limits its application in the agricultural field[10].

The phytoremediation technology is using plants to clean and rehabilitate such waste lands generated by fly-ash (fly-ash dykes) by suitable plantation. *Sesbaniacannabina* is a multipurpose leguminous crop generally used as green manure crop to increase soil fertility. It is cultivated almost in monsoon season and grows well in loamy, clayey, black and sandy soil. It grows well under waterlogged or un irrigated conditions, tolerant to high temperatures (36-44^{0}C), high soil alkalinity (pH 10) and establishes during rainy season in a wide variety of soils such as loamy, clayey, black and sandy soils[11]. It is a valuable green manure crop due to its fast growth, nitrogen fixation (by root and stem nodulation) and fast decomposition rates[11]. Therefore present study was undertaken to study the effect of different percentages of fly ash on morphological aspects of Sesbania pea and to study its tolerance and growth in fly ash amended soil, so it can be used to clean and rehabilitation programs to clean fly-ash dykes by planting it.

Material and Methods

Fly ash used in present was obtained from IFFCO (Indian Farmers fertilizers Cooperative Limited), Phulpur. Fly ash was mixed with garden soil of Botany Department of University of Allahabad, in four different concentrations of fly ash i.e. 0% (control/garden soil), 25%, 50%, 75% and 100%. A portion of the soil-fly ash mixtures was separated for physio-chemical properties. Presoaked seeds of *Sesbaniacannabina* were sown in their respective pots. Data for germination and survival percentages were taken after 15 and 30 days of sowing, respectively. Data for morphological parameters were taken after 45 days of sowing. Some morphological data were taken after maturity of plants.

Results and Discussion

Table 1 and 2 shows the physiochemical properties of fly ash used in present study and effect of different levels of fly ash amendment on PH and Electrical Conductivity (EC) of soil.

Table-1
Physiochemical properties of fly ash used in present study

Properties	Fly Ash
EC (µS/cm)	382.00
PH	7.9
Bulk density (gcm-1)	<1.0
W.H.C. (%)	35-40
Porosity (%)	50-60
P (%)	0.03
K (%)	0.19-3.0
SiO_2 (%)	42.00
Al_2O_3 (%)	19.60
Fe_2O_3 (%)	2.90
CaO (%)	1.52
MgO (%)	0.30
S (%)	0.02
Zn (ppm)	14-1000
Cu (ppm)	1-26
Mn (ppm)	100-3000
B (ppm)	46-618
Loss of ignition	0.5-3.0

Table-2
PH and EC (electrical conductivity) of different concentrations of soil and fly ash used in study

Garden Soil + Fly Ash	PH	EC (µS/cm)
Control (Garden soil)	8.55	175.20
25% Fly Ash+75% Garden soil	8.25	422.00
50% Fly Ash+ 50% Garden soil	8.15	469.00
75% Fly Ash+ 25% Garden soil	8.11	373.00
100% Fly Ash	7.9	382.00

Germination and Survival: The control set of garden soil and 25% fly ash exhibited 100% germination and 100% survival (table-3). In case of 50% fly ash amended soil germination was 100% while survival was 93.33%. The overall estimation of germination percentages illustrated that it was not much affected by fly ash amendment while survival was greatly affected in case of 100% fly ash. The plants sown in 100% fly ash survived only about 2 months and were with very significantly reduced biomass. This shows that sesbania pea can be easily grown in fly ash amended soil with 75% fly ash amendment as germination and survival were 93.33% and 80%, respectively.

Table-3
Effect of different levels of Fly ash amendment on germination and survival percentages of Sesbania pea

Fly Ash amenments	Germination % (mean)	Survival % (mean)
Control	100	100
25% Fly Ash	100	100
50% Fly Ash	100	93.33
75% Fly Ash	93.33	80
100% Fly Ash	86.66	36.66

Morphological Parameters: Morphological traits such as plant height, stem girth, internode length, number of leaves/plant, leaf length, stem length after maturity, root length after maturity and pod length were taken into consideration. The ranges of mean, min. and max. have been calculated for each set and presented in table-4 and 5.

Table-4
Effect of Fly ash amendment on morphological characters of *Sesbaniacannabina*

Fly ash Amendment		Mean	Min	Max
Plant height (cm)	Control	84.80	70.00	95.00
	25% Fly Ash	88.20	72.00	94.00
	50% Fly Ash	91.80	83.00	102.00
	75% Fly Ash	80.80	75.00	87.00
	100% Fly Ash	30.00	25.00	35.00
Stem girth (cm)	Control	3.26	2.90	3.50
	25% Fly Ash	3.06	2.50	4.00
	50% Fly Ash	2.44	1.70	3.30
	75% Fly Ash	2.42	1.60	2.90
	100% Fly Ash	0.76	0.65	0.90
Internode length (cm)	Control	4.54	4.02	5.20
	25% Fly Ash	5.83	4.42	6.72
	50% Fly Ash	5.87	4.76	6.60
	75% Fly Ash	6.75	6.20	7.20
	100% Fly Ash	1.64	1.02	2.16
Number of leaves/plant	Control	18.20	17.00	20.00
	25% Fly Ash	17.80	14.00	20.00
	50% Fly Ash	15.80	14.00	19.00
	75% Fly Ash	15.00	13.00	19.00
	100% Fly Ash	6.60	5.00	8.00

Table-5

Effect of Fly ash amendment on morphological characters of *Sesbaniacannabina*

Fly ash Amendment		Mean	Min	Max
Leaf length (cm)	Control	13.20	8.62	16.60
	25% Fly Ash	12.50	8.87	15.75
	50% Fly Ash	12.33	10.11	15.88
	75% Fly Ash	12.14	10.00	15.72
	100% Fly Ash	5.79	4.88	6.50
Pod length (cm)	Control	19.80	18.00	22.00
	25% Fly Ash	19.90	18.50	21.00
	50% Fly Ash	18.90	18.00	20.00
	75% Fly Ash	17.90	16.50	19.00
	100% Fly Ash	-	-	-
Stem length after maturity (m)	Control	2.50	1.70	3.20
	25% Fly Ash	2.44	2.10	3.20
	50% Fly Ash	2.21	1.45	3.25
	75% Fly Ash	2.21	1.70	3.30
	100% Fly Ash	-	-	-
Root length after maturity (cm)	Control	17.60	12.00	23.00
	25% Fly Ash	15.40	8.00	22.00
	50% Fly Ash	11.20	8.00	18.00
	75% Fly Ash	12.20	10.00	14.00
	100% Fly Ash	-	-	-

Figure-1
Legends: 1. Effect of different levels of fly ash amendments on *Sesbaniacannabina*

Plant height (cm): The mean height of the control plants has been recorded as 84.80cm. The mean plant height showed an increasing trend with increasing fly ash amendment upto 50% set as mean plant heights were observed to be 88.20cm and 91.80cm at 25% and 50% fly ash amendment sets, respectively, which were comparatively much higher than the control. While 75% fly ash amended set exhibited a slight lower value as compared to control. The plant height was significantly reduced in case of 100% fly ash set (figure-1) as it was observed to be only 30cm as compared to 84.80cm of control.

Stem Girth (cm): The mean stem girth of the control plants has been recorded as 3.26cm. In fly ash amended soil plants exhibited lower values than the control and showed a decreasing trend with increasing fly ash amendment. Plants in case of 25% fly ash amendment set exhibited a value for stem girth which was nearly comparable to control while it was greatly reduced to 0.76cm in case of 100% fly ash set.

Internode length (cm): The mean value for internode length in case of control plant was observed to be 4.54cm and it showed an increasing trend with increase in fly ash amendment. The internode lengths were observed to be 5.83cm, 5.87cm and 6.75cm at 25%, 50% and 75% fly ash amendment sets, respectively. In case of 100% fly ash amendment set internode length was significantly reduced to 1.64cm, which was very less as compared to control.

Number of leaves/plant: The mean value for number of leaves/plant in case of control plants has been recorded as 18.20cm and it showed a decreasing trend with increasing fly ash amendments. The minimum value for number of leaves/plant was observed to be 6.60 at 100% fly ash amendment set.

Leaf length (cm): The mean value for leaf length of the control plants has been recorded as 13.20cm and it showed a decreasing trend with increasing fly ash amendments. The leaf length in case of 25% fly ash amendment set was observed to be 12.50cm while it was reduced significantly in case of 100% fly ash amendment set and was observed to be 5.79. Thus in case of lower 3 amendments, leaf length was not much affected.

Pod length (cm): The mean value for pod length of the control plants has been recorded as 19.80cm. The fly ash amendment sets exhibited a lower mean value for pod length as compared to control except plants at 25% fly amendment set. In case of 25% fly ash amendment set, pod length was observed to be 19.90cm which was comparatively higher than the control.

Stem length after maturity (m): The mean value for stem length after maturity in control plant was observed to be 2.5m and the plant in case of 25% fly ash amended set exhibited a slight decrease in stem length after maturity and was observed to be 2.44m. The mean values for stem height after maturity in case of 50% and 75% fly ash amended set were observed to be 2.21m in both the cases.

Root length after maturity (cm): The mean value of root length after maturity in case of control plants has been recorded as 17.60cm. The maximum value for root length after maturity in fly ash amended set was observed in case of 25% fly ash and was observed to be 15.40cm. Root lengths after maturity in 50% and 75 % fly ash amended sets were observed to be 11.20cm and 12.20cm, respectively. Thus root length was found to be decreased along with fly ash amendment in soil.

Discussion: The role of fly ash in agriculture and related applications is now a well-established fact and more and more researchers and `users' are getting convinced with its utility potential in agricultural fields. It contains almost all the essential plant nutrients except organic carbon and nitrogen which makes fly ash suitable for agriculture. Although fly ash cannot be used as a substitute of chemical fertilizers or organic manure, while, it can be used in combination with these (or in some cases may partly substitute their requirement) to get additional benefits in terms of improvement in soil physical characteristics, increased yields etc. Fly ash amendment in soil significantly increased the electrical conductivity of the amended soil by increasing the levels of soluble major and minor inorganic constituents[12].

Present investigation has been carried out to study the effect of different amendment levels of fly ash in normal garden soil on morphology and growth of *Sesbaniacannabina*. Reduction in germination and survival in 75% fly ash amendment and 100% fly ash amendment set may be attributed to high level of non-essential elements e.g., Cu, Al, Ni, Se, Cr, Pb, Cd, which might impair with various metabolic processes[13-15]. While in case of 25% and 50% fly ash amendment sets germination was 100%. Plants in 100% fly ash could not survive after the period of 2 months, may be due to ambient heat (induced drought) stress coupled with 100% fly ash substrate conditions posing risk of metal toxicity[16,17].

Plant heights in case of 25% and 50% fly ash amendment sets were significantly increased as compared to control and were very beneficial aspect of present study. While, stem girth was slightly decreased with increase in fly ash amendments upto 75% fly ash and plant height and stem girth both were significantly affected in case of 100% fly ash amendment. Internode length was also found to be increased with increasing fly ash amendments upto 75% amendment level. Similar increase in growth was also reported by many authors and fly ash has been found to increase yield of alfalfa (*Medicago sativa*), barley (*Hordeumvulgare*), Bermuda grass (*Cynodondactylon*) and white clover (*Trifoliumrepens*) and improve physical and chemical characteristics of the soil[18-22].

Number of leaves/plant and leaf lengths showed a decreasing trend with increasing fly ash amendments but were not significantly affected upto 75% fly ash amendment level. Pod length in case of 25% fly ash amendment was found to be increased as compared to control while it showed a slight reduction in higher levels of amendments. The plants grown in 100% fly-ash, when compared to the plants growing in normal soil and amended ash, showed a significant reduction in plant height, stem girth, number of leaves/plant, internode length etc. Fly-ash contains many essential metals such as K, Mg, Fe, Zn, B, Mo, Se, etc. It might stimulate plant growth if applied at low concentrations. However, in 100% fly-ash other non-essential elements e.g., Cu, Al, Ni, Se, Cr, Pb, Cd, might impair with various metabolic processes and so either delay or inhibit the process[13,14,23]. This decrease may have been due to the decreased level of chlorophyll and the toxicity of metals which gives undesirable changes in the chemical properties of the soil[24,25].

Most of the options of fly ash utilization systematically and explored yet at field level allow restricted level of application, whereas the present study offers a better bulk utilization of thermal power plant waste and also to help in managing the problems of land-uses as well as food security. The result of present study indicates that the four different amendments tested the amendment level upto 75%, showed no adverse effect on Sesbania pea plant growth and this plant could be used in reclamation of fly ash deposited sites.

Conclusion

As the *Sesbaniacannabina* is a very resistance plant to different adverse climatic conditions and there is possibility of its use in fly ash reclamation programmes. Therefore present study was undertaken to study the growing capacity of *Sesbaniacannabina* in different amendment levels of fly ash in soil. Present study clearly shows that it is able to survive in such condition due to which it offers an ecofriendly method for removal of fly ash content from their deposited sites.

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