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Utilization of Paper Mill Fly Ash for Sustainable Crop Production: Effect on the growth of Corn (*Zea mays* L.) and Soil Properties

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ABSTRACT

The analysis of soil quality before cultivation and after cultivation in control plot and treated plot were presented in the report. The experimental plots also showed the growth rate of production.

Key Words: Chemical fertilizer, Fly ash, Soil quality, Zea mays L., Soil fertility

Abbreviations: N – Nitrogen; P – Phosphorous; K – Potash; Fe – Iron; Mn – Manganese; Zn – Zinc; Cu – Copper; Cd- Cadmium; Cr – Chromium; Ni – Nickel; Pb – Lead; Mg – Magnesium; Al – Aluminum; Si – Silicon; g – Gram; Sqkm - Square kilometer; EPML - Emami Paper Mill Ltd; cm – Centimeter; ppm - Parts per million; kg – kilogram; ha – Hector; µ - Micro; q - Quintal

1. INTRODUCTION

The fly ash particles are also deposited on the surrounding agricultural lands. Every year thermal power plants in India produces more than 100 million tones of fly ash which is expected to reach 175 millions in the near future (Jamwal Nidhi, 2003). Production of pulp for paper manufacture generates large quantities of solid waste (Norrie and Fierro, 1989). Disposal of this huge quantity of fly ash is posing a great problem due to its limited utilization in the manufacturing of bricks, cements, ceiling and other building construction activities (Kalra et al., 1996; Aggrwal et al., 2009). Fly ash is a finely divide residue originates from the combustion of bituminous coal of thermal power plants. It is an amorphous ferro-allumino-silicate mineral containing the naturally occurring essential elements. It is alkaline in nature and contains certain physical and chemical properties that might be useful as soil amendment and improve crop production (Mitra et al., 2003). Some metals enriched in fly ash such as Cd, Cr, Ni, Pb and Zn with some enriched intermediate metals like Al, Si, Mg, Fe and Mn (Adriano et al., 1980). Presently, in the study area site, the fly ash at industrial site is not usually used and is disposed of at the dumping sites in the vicinity of the plants which cover an area of about 100 hectors of agriculturally productive land. The collected

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residues may adversely affect the environment by mobilizing their hazardous constituents. So, its disposal and utilization is very much essential to prevent its contamination (Putruzzelli, 1989). Its utilization in agricultural field can create a new revolution in sustainable agricultural practice and management of soil fertility as well as reclamation of waste land (Panda et al., 2013). The use of fly ash along with compost is an integrated way can save chemical fertilizer as well as helps in manufacturing the soil fertility (Kishore et al., 2010). The present study deals with the effect of the application of varying levels of fly ash and compost in different composition on the agricultural land for production of *Zea mays* and also the study of early plant growth and the yield of corn crops along with the properties of the cultivated soil on farmer's field.

2. STUDY AREA

Balasore is one of the coastal districts of Odisha. It lies on the northern most part of the state having 21 degree 03' to 21 degree 59' North Latitude & 86 degree 20' to 87 degree 29' East Longitude. Geographical area of the district is 3634 sqkm. The soil type of the study area is alluvial in nature. The major industries located in this area are Birla Tyres Ltd, Balasore Alloys Ltd, Emami Papers Ltd and Oriplast Ltd. Since early eighties of the twentieth century many industries have been set up within a radius 12km from Balasore town.

The present study was conducted around the ash disposal sites of Balgopalpur industrial area where two types of fly ash generated industries are present one is Emami Paper Mill Ltd. (EPML) and other is Balasore alloys. F.M. University, Balasore has been selected for carrying out the research work. F.M. University situated 15km away from Balasore town and 2km away from Balgopalpur industrial estate. The aim of the present study is to utilization of fly ash for sustainable agriculture as well as to maintain the soil fertility by addition of micro and macro nutrient to the soil.

3. MATERIALS AND METHODS

3.1. Collection of Fly Ash Sample

Fly ash samples were collected from Emami Paper Mill, Balgopalpur, Balasore, Odisha, India. Then physical and chemical Characterization was done by standard method (Chopra et al., 2005). The fly ash samples were air dried then the parameters like bulk density, moisture content, specific gravity, pH, electrical conductivity, water holding capacity, organic carbon, nitrogen, potash, phosphorous, and heavy metals like Pb, Cr, Cd, Mn were analyzed.

3.2. Field Experiment

Field experiment were conducted during 2009-10 with *Zea mays* L. grown with different composition of fly ash in farmer's field as well as experimental field (Table 1) at F.M. University vicinity and also in Nuapadhi Village, Balasore, Odisha, India. Soils from all experimental sites and fly ash used in the present study were analyzed for their Physical and Chemical characteristics as suggested by Jackson, 1973. Surface soil samples (0-30cm) of each location were collected and analyzed and averaged for site characterization. Fly ash was applied uniformly in the entire experimental field and ploughed to mix it properly in the soil in the year 2009-2010. Irrigation scheduling, fertilizer application and intercultural operations were followed as per normal agronomic recommendations. The ground biomass and grain yield were recorded at harvested time for all treatments. Harvesting of crops done separately and yields were recorded. After the harvesting, post harvesting soil and grain of corn samples were collected from the control and treated field separately. The soil samples were analyzed for its physical and chemical properties and grain samples were analyzed for its nutrients content. Standard analytical procedures were followed for the soil, ash and crop analysis.

4. RESULT AND DISCUSSIONS

After preparing the above mentioned soil mixtures in the experimental plot, Zea mays plants were cultivated with periodic watering (Figure 1). The growth and yield of plant observed in the early stage up to harvest of crops along with different parameters of vegetables were calculates by following standard procedures. Soil before cultivation, soil after cultivation, the percentage of seeds germinated, number of leafs of the plant, length of the plant, height of the plant, number of cobs per corn plans etc. were recorded with compare to control plot and the vegetable analysis report as compares to fertilizer applied, report were presented in the result part (Table 2 to Table 6). Different physico-chemical parameters of soil were improved when soils are supplemented with different concentration of fly ash and cow dung. Combined application of fly ash, compost and soil favorably improved dry matter production yield and nutrient uptake than control plot. The yield of fertilizer applied plot and the amount of crop harvested are high and the heavy metal uptakes by the corn seed are also high in compare to the fly ash treated plant. Fly ash also increases the crop yield of *Zea mays*.

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Figure 1
Zea mays cultivation in different plot

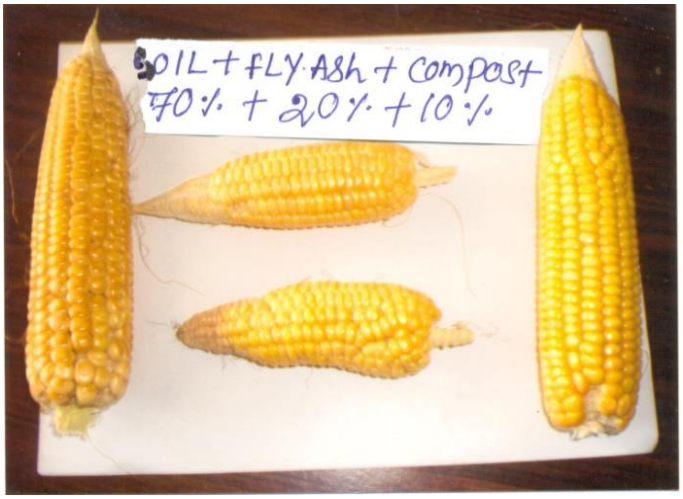

Figure 2
Zea mays production in plot no.4

Figure 3
Zea mays production in plot no.1

Figure 4
Zea mays production in plot no.2

Figure 5
Zea mays production in plot no.3

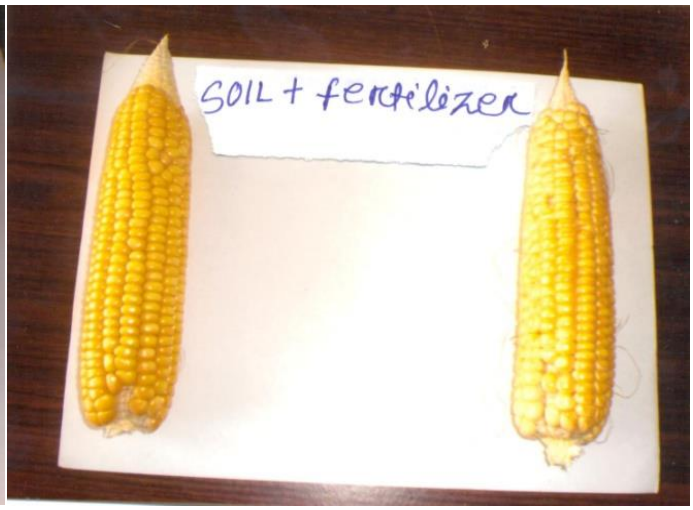

Figure 6
Zea mays production in plot no.5

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Table 1

Experimental field preparation

Sl. No.	Plot No.	Composition
01	Plot No-1	Control 100% soil
02	Plot no-2	50% soil + 50% fly ash
03	Plot no-3	70% soil + 30% fly ash
04	Plot no-4	70% soil + 20% fly ash + 10% cow dung
05	Plot no-5	Soil + Chemical Fertilizer

Table 2

Pre-harvested soil analysis report

Parameters	Plot no.1	Plot no.2	Plot no.3	Plot no.4	Plot no.5
pH	6.7	6.8	6.7	6.2	6.4
Water Holding Capacity/100 g of soil	50	62	58	61	51
Soil texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Electrical Conductivity (μmho/cm)	944	1250	1079	999	1213
Av. Nitrogen (kg/ha)	280	422	310	390	465
Av. Phosphorous (kg/ha)	17.92	41.81	20.90	50.77	23.89
Av. Potash (kg/ha)	20.10	40.20	35.15	37.05	38.15
Zn (ppm)	1.25	2.52	2.26	2.15	5.26
Cu (ppm)	1.9	3.6	2.5	2.7	3.5
Fe (ppm)	4.6	5.1	4.8	5.0	5.6
Mn (ppm)	6.5	8.5	7.5	7.1	8.6

Table 3

Crop growth of the plant

Plot no.	Plot No.1	Plot No.2	Plot No.3	Plot no.4	Plot no.5
% Germination	73	87	100	100	100
No. of Leafs	9	11	15	15	15
Plant height in 1 month (cm)	100	105	150	164	165
No. of Cobs/ Plant	1	2	2-3	2-3	2-3

Table 4

Growth and yield attributes of Maize recorded during cultivation

Sl. no	Growth/Yield parameters	Plot No.1	Plot No.2	Plot No.3	Plot no.4	Plot no.5
01	Plant height (cm)	182	201	221	245	241
02	Plant girth (inch)	3	4.1	5	5.5	6
03	Seed filling	Incomplete	Complete	Complete	Complete	Complete
04	COBs weight (g)	85-105	250-260	285-290	350-380	355-385
05	Grain wt./ Cob (g)	55-85	185-190	195-200	225-250	225-230
06	No. of seeds/cob	225	325	330	466	440
07	Length of cob (cm)	8-10	13-15	15-17	19-21	18-20
08	Width of the cob (cm)	10-12	11-12	11-12	13-15	13-15

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09	100 seeds weight (g)	15.20	17.25	18.52	20.14	19.21
10	Harvested q/ha	14.65	18.56	21.12	25.25	25.65
11	% Increased over control	-	21	31	42	43

Table 5

Analysis Report of *Zea mays*

Parameters	Plot No.1	Plot No.2	Plot No.3	Plot no.4	Plot no.5
Cr (ppm)	1.345	3.309	2.591	1.856	4.449
Cd (ppm)	0.448	0.748	0.647	0.425	1.849
Pb (ppm)	0.808	1.508	0.934	0.756	2.301
Ni (ppm)	4.117	6.97	5.414	4.125	9.411
As (ppm)	0.062	0.169	0.087	0.071	1.169

Table 6

Post harvested soil analysis report

Parameters	Plot no.1	Plot no.2	Plot no.3	Plot no.4	Plot no.5
pH	6.6	6.6	6.6	6.5	6.6
Water Holding Capacity/100 g of soil	49	55	52	58	49
Soil texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Electrical Conductivity (µmho/cm)	944	1250	1079	999	1213
Av. Nitrogen (kg/ha)	250	380	170	220	301
Av. Phosphorous (kg/ha)	15.82	40.23	18.82	48.77	22.68
Av. Potash (kg/ha)	15.15	32.15	28.17	29.13	27.45
Zn (ppm)	1.04	2.02	2.07	1.9	5.01
Cu (ppm)	1.17	3.01	2.12	2.36	3.44
Fe (ppm)	4.51	4.65	4.61	4.8	4.6
Mn (ppm)	5.55	7.58	6.5	6.1	7.6

The application of fly ash also enhances growth and metabolic rates, as well as increasing the photosynthetic pigments of crops like maize. The post harvested soil samples all parameters are reduce slightly but there are no significant changes in pH. The percentage increases of harvested crop over control plot; the plot no.2 is 21%, the plot no.3 is 31%, the plot no.4 is 41% which is treated with fly ash and compost and the plot no.5 the increase percentage is 42 which are treated with chemical fertilizer. The maize plants grown in different condition are contains different types of heavy metals. The heavy metal content of maize grown in control plot shows under the safe limit but in different concentration of fly ash contains slightly higher amount than the control plot but in case of chemical fertilizer treated plot the concentration of metals is at highest site. In case of plot no 4 the application of fly ash, compost with soil in required proportion, the production is high and the cost of production is reduces. So, from the result we concluded that the plot on 4 shows a very good in production in compare to control and reduces the amount of cost in compare to the fertilizer plot. The growth of production in all plot are shown in the figure (Figure 2 to Figure 6). Saving of chemical fertilizers by use of fly ash along with compost is an integrated way can save chemical fertilizer as well as the fertilizer use efficiency.

5. CONCLUSION

From the above results and discussion of present study it is concluded that there is an ample scope for utilization of paper mill fly ash and organic manure for improving soil fertility and plant productivity. It improves the soil texture, improves the water holding

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capacity, and increases the soil buffering capacity, increase the aeration, percolation and water retention in the treated area due to silt size particle in fly ash. Such utilization of fly ash in an integrated manner can save chemical fertilizer to greater extent with the added advantage of minimizing environment pollution.

SUMMARY OF RESEARCH

- *Zea mays* crops were been cultivated in five different plots.
- In the present study, soil before cultivation, after cultivation, the percentage of seed germinated, length of the plants, numbers of cob/plants etc. were recorded.
- Combined application of fly ash, compost and soil favorably improved dry matter production yield and nutrient uptake than control plot.
- The yield of control plot is less compared to the other plot because the nutrient uptake is reduced in plants due to unavailability of micronutrients as well as essential elements.
- The application of fly ash also enhances growth and metabolic rates, as well as increasing the photosynthetic pigments of crops like maize.
- Saving of chemical fertilizers by use of fly ash along with compost is an integrated way can save chemical fertilizer.
- It increases water holding capacity.

FUTURE ISSUES

Fly ash can be used as a potential nutrient supplement for degraded soils for which the solid waste disposal problem reduced to some extent. Such utilization of fly ash in an integrated manner can save chemical fertilizer to greater extent with the added advantage of minimizing environment pollution.

Disclosure statement

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Conflict of interest

The authors declare that they have no conflict of interest.

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Data and materials availability

All data associated with this study are present in the paper.

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