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Study of *Jatropha Curcas* Growth in Fly Ash Amended Soil

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Abstract:

***Jatropha curcas* is gaining importance commercially as a biodiesel plant. It can be grown in wastelands. The present study has been performed in an attempt to examine its growth and survival in fly ash amended wasteland.Studies have proved that organic carbon is enhanced in 30% fly ash amended soil from 0.46% to 1.2%.Considering a 2m x 3m planting, having 1666 plants per hectare, the total fresh biomasses produced in 'only soil' and 30% fly ash amended soil are 24.8 t/ha and 36.9 t/ha respectively. Similarly total dry biomasses in 'only soil' and 30% fly ash amended soil are 8t/ha are 14 t/ha respectively. Heavy metal uptake is enhanced in roots when fly ash amended soil is used. The study suggests that the plant has the potential of establishing itself on fly ash amended soil. It can accumulate heavy metals many folds from soil without attenuating the plant growth and can be considered as a hyper-accumulator of zinc and iron .**

Keywords:Biomass; fly ash; hyperaccumulation; *Jatrophacurcas*; soil pH

1.0 Introduction:

*Jatropha curcas*is a deciduous shrub that grows up to a height of 3–5 m and has a productive life of 50 years. It is a multipurpose shrub and is considered to have originated in Latin America, but presently it grows throughout the arid, semi-arid, tropical and subtropical regions of the world (Hikwa, 1995 ; Makkar,1997). In India, the growth and management of *Jatrophacurcas*be it on private, public or community lands, have been poorly documented, with little field experience being shared amongst researchers and farmers. *Jatrophacurcas*has been promoted under the National Biodiesel Mission in India to reduce dependence on crude oil . The seed oil can be easily processed to petroleum-based diesel fuel (Forson 2004). Thus, the use of this plant for large-scale biodiesel production is of great interest with regard to solving the energy shortage, reducing carbon emission and increasing the income of farmers (Banerji*et al.,*1985; Martin and Mayeux, 1985;Gubitz *et al*.; Keith 2000; Zhou et al., 2006). Recently, the high yield of seeds from the tree (~5 t/ha/yr) and the high oil content of the seeds (~66.4%) attracted global attention for the development of *Jatrophacurcas*as a source of bio-fuel. The plant can be propagated on a massive scale by direct seedling, planting stem cuttings, stumps and perennial plants adapted to various kinds of soil conditions (Srivastava, 1999). The plant is widely distributed and fits easily into agricultural systems in the form of hedges, windbreak, anti erosion barrier or source of firewood (Srivastava, 1999). So far no study is reported to establish its growth in fly ash amended soil. Therefore the present investigation has been carried out to examine its survival, growth and biomass production capacity of the plant species in fly ash amended soil.

2.0 Materials and Methods:

Fly ash from Unit 7 of Koradi thermal power station (KTPS) was mixed with the soil of Koradi taken from topmost soil profile 0-15 cm, v/v basis so as to have concentrations of 0 %, 10 %, 20 % and 30 % of fly ash.

A) Layout (Experimental Design) :

Spacing between consecutive: 2 m

Size of the pit : 30 x 30 x 30 cm^3

Total number of pits: 40

No. of plants in column: 10 plants in each column for 0 % ash, 10 % ash, 20 % ash and 30 % ash

Spacing between each row :4 meter

B) Weight of a hectare soil (Rai, 2002):

Area of one acre = 43,560 sq.ft

Volume of soil up to 6 inches depth = 21,780 cu ft

Since 1 cu ft. water weighs 62.43 lb ; the weight of 21,780 cu ft soil will be = 62.43 x 21,780 x 1.5 (specific gravity of soil) = 2,040,000 lb.1lb/acre = 1.12 kg/ha. For calculation purposes, it is taken as 2,000,000 lb. Therefore, weight of one acre of soil up to 6 inches or 15 cm depth is taken as 2,000,000 lb or 22, 40,000 kg/hectare.

C) Calculation of ash addition:

10 % of ash is equivalent to 200 t (approx.) of ash/hectare (Tripathi and Das, 1999) .Hence 20,40,60 kg of ash/m^2 of land are equivalent to 10 %,20% and 30% ash.A portion of the soil-fly ash mixture was separated for physical and chemical analysis prior to beginning of trial. The different fly ash-soil mixtures were placed in half-kg polythene bags perforated at the bottom to allow air passage. The soil-fly ash mixtures before and after the trial were processed by sieving and separating into different fractions for analysis.1 kg cattle dung manure and 50 g trisodium phosphate were added in each pit. The above mentioned quantity of fly ash was used only once before plantation.

D) Processing of fly ash and soil

Fly ash from the electrostatic precipitator (ESP fly ash) was collected from KTPS and analyzed for physicochemical properties after air-drying. Soil was collected up to the depth of 15 cm and processed and analyzed for physical and chemical properties as described in the Indian Standard (IS 1727). The soil after collection is gently broken up for clods and macro aggregates using pestle and mortar followed by removal of plant residues, gravel and other debris. The soil is spread on polythene sheets then air-dried at 27 ^{0}C and sieved through a 2 mm mesh sieve and used for physical analysis. The 2 mm-sieved soil had been crushed to pass through a 0.2 mm sieve for pH, electrical conductivity (EC) and heavy metals (Fe, Mn, Zn, Cu, Pb and Cr). The pH is analyzed in the ratio of 1:2.5 ratio and 1:1 (w/v, fly ash: water) by Mettler Toledo 220 pH meter and the same mixture is used for the measurements of EC by an electrical conductivity meter (EI -103 EI India). Total organic carbon is estimated by potassium dichromate method (Walkley and Black, 1934). Total metals are estimated after digestion with concentrated HNO_3 and $HClO_4$ mixture (3:1) (Page et al, 1982). Mobile or exchangeable forms of metals are extracted using diethylenetriaminepentaacetic acid (DTPA)-calcium chloride ($CaCl_2$) extractant (Lindsay and Norvell, 1978). The collected roots of the plants are rinsed with tap water followed by distilled water, oven-dried at 80° C for 8 h and ground with mortar and pestle. Approximately 2.5–3.0 g sample was ashed by heating at 250° C and the temperature was gradually increased to 500° C in 2h. The ashed samples were treated with conc. HNO_3 and $HClO_4$ mixture (3:1) in a hot plate and washed with dilute HCl. It was then filtered through Whatman 42 filter paper and the solution was analysed for metal content by Atomic Absorption Spectrometer. For dry biomass calculation, the plants were rinsed with tap water, followed by distilled water and then oven-dried at 80° C for 8 hrs.

3.0 Results and Discussion:

(i) Physical properties of fly ash amended soils :

Based on the percentage of silt, sand and clay, (Table no 1) shows the texture, density, porosity and water holding capacity of soil amended with varying percentage of fly ash ranging from 0 to 30% with an interval of 10%. Bulk density of soil without fly ash was1.23 g /cc which decreased to 1.19, 1.13 and 1.10 g/cc for soils amended with 10, 20 and 30% flyash respectively. Porosity of the soil (39.2%) decreased to 37.5, 33.6and 32.5% respectively. Soil under investigation was found to be sandy loam in texture with low water holding capacity(17.95%).Water holding capacity for soil with10, 20 and 30 % fly ash mixtures increased from 21.91%, 26.51%and 31.25% respectively. This may be due to the fact that fly ash particles are mostly hollow and crumb in structure with a capacity to absorb more water and therefore retains it for a longer time without losing its shape.

This results in saving of much of the irrigation water creating a desirable soil condition to release the nutrients (Mandal and Saxena,1998).

Texture of the soil has been analyzed in terms of sand, silt and clay percentages. Sand percentage of the soil without fly ash (73.45 %) increased to 74.30, 79.30 and 82.20% for soils amended with 10, 20 and 30% fly ash. Consequently. Texture of soil appears as sandy loam in all cases.

Table 1: Bulk density ,water holding capacity,texture of soil with and without fly ash used in nursery trials of *Jatrophacurcas*.

Parameters	0% Fly ash	10% Fly ash	20% Fly ash	30%Fly ash
Bulk density gm/cc	1.23	1.19	1.13	1.10
Water holding capacity %	17.95	21.91	26.51	31.25
Porosity %	39.2	37.5	33.6	32.5
Sand %	73.45	74.20	79.30	82.20
Silt %	7.35	4.50	4.50	4.50
Clay %	19.20	21.30	16.20	12.80
Texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam

(ii) ***Chemical characterization of fly ash amended soils:***

(a) ***pH, Electrical Conductivity and organic carbon*** **:**The analytical results are shown in (Table 2)**.** Fly ash used for amending Koradi soil is found to be alkaline (pH 7.3). As a result the soil pH varied slightly from 7.20 to 7.50. Overall no distinct variation was observed in pH with increasing fly ash percentage in the soil. Electrical conductivities(EC) in soil amended with 10%, 20%and 30% fly ash are 180 µS/cm, 200µS/cm and 220µS/cm compared to130µS/cm in soil without fly ash, thus showing a marked increase of EC with a rise in fly ash percentage in the soil. This can be attributed to the high soluble salt concentration in the fly ash.

Organic carbon contents of the soil amended with 10%, 20% and 30% fly ash are 0.57±0.06, 0.68±0.13 and1.02±0.34 as compared to 0.48±0.1in soil without fly ash. The soil is moderate with respect to organic carbon, classification of soil was conducted by MPK Vidyapeeth,Rahuri,India(Table 7) .Organic carbon in soil without fly ash(0.48±0.1) increased in second year to 0.58 % and then decreased to 0.40% in the third year .Organic carbon increased steadily every year in soil amended with 10%, 20% and 30% fly ash. Organic carbon in fly ash amended soil increased with addition of fly ash upto 10**%** (Fang et al,1998). Fly ash amendments catalyzes soil carbon sequestration (Amonette et al 2003). The mechanism of humification process by which soil carbon being stabilized is believed to involve several parallel pathways. Of these, the polyphenol formation pathway generally Dominates (Stevenson,1994). Polyphenols and hydroxybenzoic acids react in the presence of polyphenol oxidase enzyme (tyrosinase) to form polyquinones, which then polymerize with amino acids to form humic polymer(Amonette et al ,2003).

(b) ***Major nutrients*** **:**Table-2 shows that the total nitrogen content was 338±66.9kg/ha for the soil without fly ash. An increase in nitrogen content was observed in soils amended with 10%, 20% and 30% fly ash. These are 403±57 kg/ha, 502±87 kg/ha and 714±161 kg/ha respectively. The increased soil nitrogen can be attributed to decomposition of leaf litter, etc resulting in enzyme-aided nutrient mineralization carried out by the native microbial population (Stevenson, 1994). Phosphorous content also increased in soil with the increase in percentage of fly ash amendment. 19.50 ±1.8kg/ha phosphorus in the soil increased to to 23.38±0.69 kg/ha in soils amended with 10%, 20% and 30% fly ash respectively. This can be attributed to fly ash itself and partly because of some native phosphate-solubilizers (Klose et al, 2004). Positive effect of fly ash application on crop productivity and increased phosphorous uptake may be attributed to reduced soil crust strength, improved texture of soil and water holding capacity besides presence of organic matter (Gaind and Gour 1991; Elseewi et al, 1978). The compounds present in organic matter react with interfering compounds thereby leaving the phosphates free and also help in the adsorption of phosphorus on humic compounds and silicate clays thus protecting the phosphates from microbial attack (Sims et al, 1995).

Table 2: Characterisationof soil with and without fly ash used in nursery trial of *Jatrophacurcas* at yearly interval

Parameter	Values			
	12 months	**24 months**	**36 months**	**Mean ±SD**
(1) 0% Fly ash				
pH (1:2.5)	7.35	7.45	7.4	7.40±0.05
EC (µS/cm)	120	140	130	130±10
Organic C (%)	0.46	0.58	0.40	0.48±0.1
Nitrogen (kg/ha)	322	411	280	338±66.9
Phosphorus (kg/ha)	20.15	20.86	17.5	19.50±1.8
Potassium (kg/ha)	360.2	360.3	359.2	359.9±0.60
(2) 10% Fly ash				
pH (1:2.5)	7.4	7.5	7.5	7.46±0.06
EC (µS/cm)	190	180	180	180±7.07
Organic C (%)	0.49	0.59	0.65	0.57±0.06
Nitrogen (kg/ha)	342	413	455	403±57.11
Phosphorus (kg/ha)	22.15	21.6	20.3	21.35±0.95
Potassium (kg/ha)	370.5	374.6	373.6	372.9±2.13
(3) 20% Fly ash				
pH (1:2.5)	7.5	7.35	7.4	7.41±0.07
EC (µS/cm)	210	200	200	200±7.07
Organic C (%)	0.58	0.75	0.82	0.68±0.13
Nitrogen (kg/ha)	406	525	575	502±86.81
Phosphorus (kg/ha)	22.18	22.09	22.52	22.26±0.22
Potassium (kg/ha)	371.2	372.6	371.2	371.6±0.81
(4) 30% Fly ash				
pH (1:2.5)	7.4	7.2	7.3	7.30±0.01
EC (µS/cm)	240	220	220	220±14.11
Organic C (%)	0.76	1.1	1.2	1.02±0.34
Nitrogen (kg/ha)	532	770	840	714±161.4
Phosphorus (kg/ha)	22.59	23.89	23.68	23.38±0.69
Potassium (kg/ha)	371.6	372.3	373.5	372.4±0.96

Potassium content varied from 359.9±0.60 kg/ha in original soil to the maximum of 372.4±0.96 kg/ha in 30% fly ash amended soil. Potassium shows the highest concentration compared to other elements as happens in soil generally (Brady, 1995). The increased availability of potassium could be due to breakdown of minerals by several organic and inorganic acids.

The highest organic carbon content was observed in soil amended with 30% fly ash along with an increase in nitrogen, phosphorus and potassium contents. For biomass production 30% fly ash amended soil offers as the most favourable source of nutrient.

Micronutrients such as Zn and Fe from fly ash, may not be consistently available to plants. Depending on the chemical composition fly ash can alter soil pH levels, base saturation, carbon content, soluble salts and concentrations of major and heavy elements (Bellman and Grote,1998). Iron, manganese, zinc and copper ranged from 11083.3±437 mg/kg to 22253.3±2722 mg/kg, 199.7±1.34mg/kg to 2296.18±1.68mg/kg , 21.82±7.72 mg/kg to 43.98±19.22, 15.43±1.15 to 21.43±4.0mg/kg respectively(Table-3). Variation in concentration is distinct for all elements. Iron availability depends to a large extent on soil pH and redox potential and is affected by several environmental conditions, including concentration of macronutrients and the ratios between heavy metals (Chaney et al 1972; Braggermann et al 1990). In soil, iron and manganese have an oxidative or catalytic effect and maintain an optional nutritional balance for normal growth**.** The result reveals that as the concentration of fly ash increased the availability of Fe and Mn increased. But iron does not impart any toxicity to the plants. Copper acts as an 'electron carrier' in an enzyme and brings about redox reaction to regulate respiratory activity in plants(Vaidya and Sahastrabuddhe, 1973). Copper increased with the increase in the percentage of fly ash but did not impart any toxicity as excess availability was hindered due to alkaline pH, organic matter and clay content(Rodhe 1962;Milovsky and Konovnov, 1992). Improvement in the available micronutrient status due to application of fly ash has also been reported (Sikka and Kansal 1993and Matte and Kene, 1995).The regression analysis indicates that the increase in fly ash dose by 1% enhanced the availability of Fe, Zn, Mn and Cu by 17.58, 3.72, 19.48and 4.54% respectively(Bhoyar and Matte,2005).

(iii) ***Biometric parameters :***

*Jatrophacurcas*has been evaluated for growth and survival at ages of 12, 24 and 36 months in nursery trials for soil with and without amendment with fly ash.

Table 3: Micronutrients and Trace/Heavy metals status in soil with and without fly ash

Parameter	**Values**			
	12months	**24 months**	**36months**	**Mean ±SD**
(1) 0% Fly ash				
Copper (Cu)mg/kg	16.5	15.2	14.6	15.43±1.15
Zinc (Zn)mg/kg	29.64	21.64	14.20	21.82±7.72
Manganese (Mn)mg/kg	201.2	199.3	198.6	199.7±1.34
Iron (Fe)mg/kg	11450	11200	10600	11083.3±437
Chromium (Cr)mg/kg	0.11	0.11	0.10	0.106±0.005
Lead (Pb)mg/kg	12.5	9.6	10.5	10.86±1.48
(2) 10% Fly ash				
Copper (Cu)mg/kg	21.2	16.12	16.5	17.94±2.92
Zinc (Zn)mg/kg	35.96	31.56	20.5	29.34±7.96
Manganese (Mn)mg/kg	234.36	202.2	235.31	223.95±18.82
Iron (Fe)mg/kg	18420	18120	17950	18163.3±238
Chromium (Cr) mg/kg	4.2	4.2	4.0	4.13±0.11
Lead (Pb)mg/kg	17.6	16.6	15.4	16.53±1.10
(3) 20% Fly ash				
Copper (Cu)mg/kg	23.3	21.6	19.5	21.46±1.90
Zinc (Zn)mg/kg	58.52	35.23	29.95	41.23±15.20
Manganese (Mn)mg/kg	275.36	285.32	275..14	278.60±5.81
Iron (Fe)mg/kg	21230	20150	20050	20476.6±654.31
Chromium (Cr)mg/kg	7.8	7.9	7.8	7.83±0.06
Lead (Pb)mg/kg	21.6	20.1	19.2	20.3±1.21
(4) 30% Fly ash				
Copper (Cu)mg/kg	25.5	21.30	17.5	21.43±4.0
Zinc (Zn)mg/kg	65.12	39.26	27.56	43.98±19.22
Manganese (Mn)mg/kg	295.12	295.3	298.13	296.18±1.68
Iron (Fe)mg/kg	25320	21320	20120	22253.3±2722
Chromium (Cr)mg/kg	10.2	10.0	10.0	10.06±0.11
Lead (Pb)mg/kg	24.6	20.2	19.6	21.46±2.73

Table 4: Growth performance in nursery trials of *Jatrophacurcas*in soilwith and without fly ash .Plant height at the time of plantation: 32-35 cm.

Age of plant (month)	Fly ash %	Height (cm)	Stem girth (cm)	Field survival (%)	No.of leaves per plant	Weight of 100 seeds (g)
12	0	114.50	4.50	80	25	---
	10	129.00	5.10	90	29	---
	20	110	7.95	90	32	---
	30	95.37	9.98	90	35	---
24	0	205.5	11.50	100	39	70.60
	10	180.5	13.00	100	45	77.20
	20	176.5	18.5	100	44	79.50
	30	190.98	22.6	100	43	82.10
36	0	197.6	11.85	100	42	65.3
	10	175.6	13.21	100	44	69.5
	20	171.2	18.60	100	47	70.3
	30	181.2	22.70	100	45	72.1
	--- Negligible fruiting , hence not calculated					

The mean biometric parameters are given

***(a) Age of 12 months*:**

Height of the plants at the time of transplantation from polythene bags was 32-35cms. Mean maximum height attained after the twelfth month in soil without fly ash was 114.50cm with stem girth of 4.5cm and survival was found to be 80% with no fruiting. Mean maximum height gained after twelfth month in soil with 10%, 20% and 30% fly ash are 129, 110 and 95.37cm respectively with respective stem girths of 5.10, 7.95 and 9.98 cm. Survival was found to be 90%. Fruiting was observed only in plants grown on soil amended with 20% and 30% fly ash and one plant bore an average of 6 fruits. Fruiting was observed twice a year: July – August and December- January. The variation in period of fruiting was observed from plant to plant. The height attained its highest in 10% fly ash amended soil and the lowest in 30% fly ash amended soil. But the stem girth measured at 50 cm above the soil level was found to be highest in 30% fly ash amended soil and lowest in the soil without fly ash.

(b) Age 24 months

Mean maximum height attained after 24 months in soil without fly ash was 205.5cm with stem girth of 11.50 cm and survival was found to be 100%. Fruiting as well as the growth of 39 leaves per plant was found. The weight of 0.706 g/seed was observed in plants grown in soil without fly ash. Mean maximum height reached after 24th month in soil amended with 10%, 20% and 30% fly ash were 180.5, 176.5 and 190.98 cm respectively with stem girth of 13.00, 18.5 and 22.6 cm. Survival rate of all the plants in fly ash amended soil was found to be 100%. Fruiting was observed in all the plants in soil with and without fly ash. Number of leaves per plant grown on 10%, 20% and 30% fly ash amended soil was found to be 45, 44 and 43 respectively. The weight of hundred seeds in 10%, 20% and 30% fly ash amended soil was found to be 77.20, 79.50 and 82.10 g respectively. There is a direct relationship between the stem girth and seed weight. The stem girth and seed weight were maximum for plants grown on 30% fly ash amended soil. Consequently *Jatrophacurcas* can tolerate a high percentage of ash and vegetative growth is highest in 30% ash. 10%, 20% and 30% fly ash at field level is equivalent to 200, 400 and 600 t/ha (Markert, 1997). 25% ash at field level is equivalent to 654 t/ha on a dry weight basis(Singh et al, 2005).

***(c)Age 36 months*:**

Pruning in this study has been done after two and a half year (in the month of February). Pruning was done to all plants at 100 cm above the ground. Analysis of total fresh and dried biomass has been done after uprooting all 35 *Jatrophacurcas* from the nursery site after fruiting.

Mean maximum height attained after 36th month in soil without fly ash was 197.6 cm with stem girth of 11.85 cm and the survival was found to be

100%. Fruiting was observed and the number of leaves per plant was 42 and the weight of 100 seeds was found to be 65.3 g in soil without fly ash. Mean maximum height gained after 36th month in soil amended with 10%, 20% and 30% fly ash were 175.6, 171.2 and 181.2cm respectively with respective stem girths of 13.21,18.60 and 22.70 cm and the survival was found to be 100% in all form of amended soil used. Fruiting was observed in all the plants in soil without fly ash also. Number of leaves per plant grown on 10%, 20% and 30% fly ash amended soil was found to be 44, 47and 45 respectively. The weights of hundred seeds collected from plants grown on 10%, 20% and 30% fly ash amended soil were found to be 69.5, 70.3 and 72.1 g respectively. Seed yield reduced after 36 months by 8% in soil without fly ash and 13.95, 13.08 and 13.8% in soil amended with 10%, 20% and 30% fly ash respectively. The data indicates that *Jatrophacurcas* needs high amount of fertilizer and micronutrients every year to increase the seed yield . Roots are found to be extended up to 40 to 90 cm in soil. The results are shown in Table- 5. The mean total weight of fresh biomass and dried biomass are found to be 14.88±2.18kg and 4.79±1.85kg in soil without fly ash. In contrast the mean weights of fresh biomass of the plant grown on 10%, 20% and 30% fly ash were found to be 15.45±1.10, 18.80±0.73 and 22.13±0.51kg respectively and dried biomass weight were found to be 5.39±1.26, 7.21±1.68 and 8.8±2.05 kg respectively as shown in fig a. In addition more than 10-15 kg biomass may be available per plant annually as a result of pruning. Thus 24.8 to 36.9t of fresh biomass can be obtained with normal 2x 3 m planting having 1666 plants per hectare providing 8 to 14 t of dry sticks, to be used as domestic fuel in rural areas or for biomass based power plants.

Table 5: Fresh and dried biomass of 36 months old *Jatropha Curcas plants* in soil with and without fly ash (Average of 09 experimental results are given)

	Fly ash %	Shoot (kg)	Root (kg)	Leaves (kg)	Total Plant (kg) Mean±SD
Fresh Biomass	**0**	10.71	3.11	1.06	14.88±2.18
	10	11.47	2.84	1.13	15.45±1.10
	20	13.53	4.01	1.25	18.80±0.73
	30	15.64	5.14	1.35	22.13±0.51
Dried Biomass	**0**	3.19	1.02	0.58	4.79±1.85
	10	3.78	0.99	0.62	5.39±1.26
	20	5.34	1.16	0.71	7.21±1.68
	30	6.27	1.74	0.79	8.8±2.05

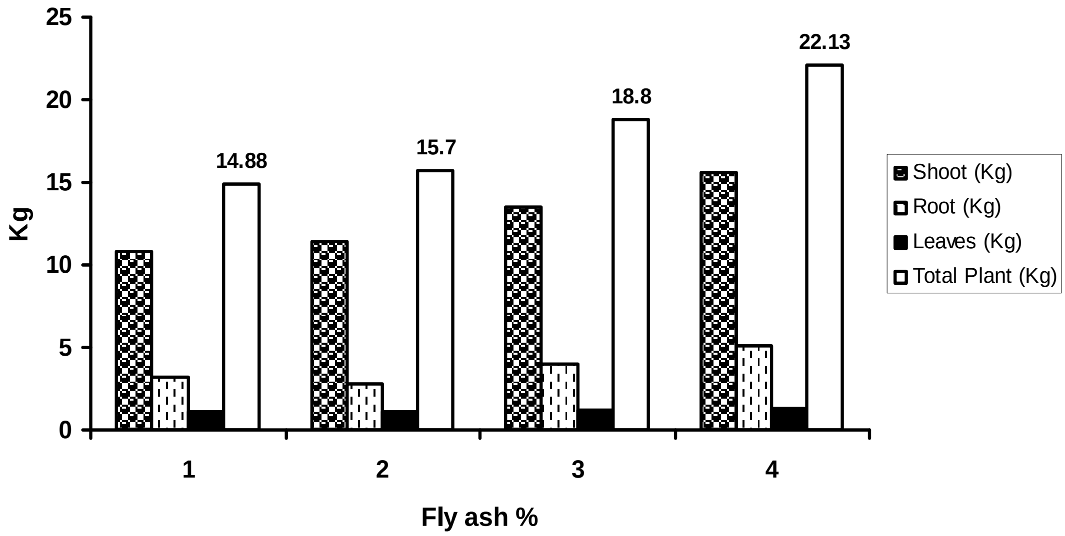

Figure- a Mean value of Fresh biomass of plants of three year old Jatropha Curcas plants in soil with and without fly ash

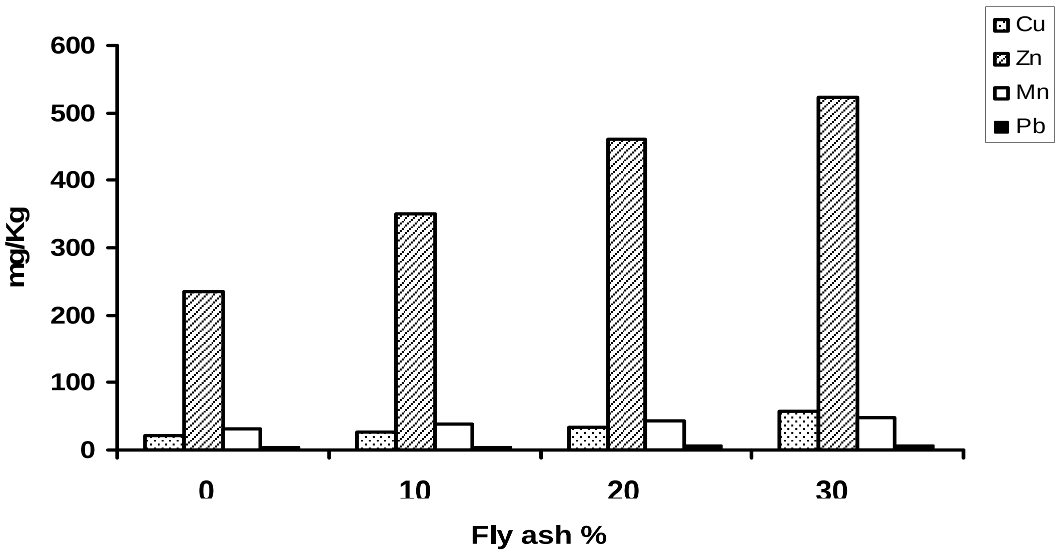

Figure- b Mean Value of trace and heavy metal in the roots of the *Jatropha curcas* in soil with and without fly ash

Table 6: Mean Value of trace and heavy metals in the roots of the *Jatropha Curcas* in soil with and without fly ash (Average of 09 experimental results are given)

Metal	Metal content (mg/kg)of roots in soil containing			
	0% fly ash	10% fly ash	20% fly ash	30% fly ash
Manganese (Mn) mg/kg	30.73 ±1.45	38.62 ±0.88	43.18 ±2.064	48.36±1.28
Iron(Fe) mg/kg	1686.87 ±101.02	1873.33±61.44	3707.66±106.33	4615.44 ±127.19
Copper(Cu) mg/kg	21.25±3.03	31.08±1.44	34.71±3.02	58.76±3.83
Zinc(Zn) mg/kg	265.37±3.81	351.33±16.17	460.33±7.66	523.11±12.47
Lead(Pb) mg/kg	5.76 ±0.84	5.45±1.20	6.18±1.019	6.51±1.25

(iv) Accumulation of trace and heavy metal (Cu,Zn,Mn,Fe,,Pb) *in the roots of Jatrophacurcas* :Elements such as Fe, Cu, Zn and Mn are essential for plant nutrition (required for the activity of various types of enzymes) while Cr and Pb do not have any physiological function in plants. Zn can penetrate into the leaf while Pb is mostly adsorbed to the epicuticular lipids at the surface (Saxena and Asokan, 1988). The root of *Jatrophacurcas* was analyzed for trace and heavy metal contents (Table-6), which varied as Fe>Zn>Mn>Cu>Pb except in case of 30% fly ash whereas these varied as Fe>Zn>Cu>Mn>Pb and corresponding metal concentration in roots of soil without fly ash were found to be Fe 1686.87 ±101.02, Zn 265.37±3.81, Mn 30.73 ±1.45, Cu 21.25±3.03, Pb 5.76 ±0.84mg/kg respectively. Metal concentration in the roots of the soil with 10% amended fly ash was found to be Fe 1873.33±61.44, Zn 351.33±16.17, Mn 38.62 ±0.88, Cu 31.08±1.44, Pb 5.45±1.20mg/kg and metal concentration in the roots of the soil with 20% amended fly ash was found to be Fe 3707.66±106.33, Zn 460.33±7.66, Mn 43.18 ±2.064, Cu 34.71±3.02, Pb 6.18±1.019mg / kg. Metal concentration in the roots of the soil with 30% amended fly ash was found to be 4615, Zn 523.11, Mn 48.32, Cu 58.76, Pb 5.45 mg / kg and chromium was found below detectable limits.

***(v) Metal Hyper-accumulation*:**

The data revealed that Fe and Zn in soil sediments with and without flyash used in nursery trials of *Jatrophacurcas* is in the range of 11083.3±437mg/kg to 22253.3±2722 mg/kg and

21.82±7.7 to 43.98±19.2 mg/kg (table -3). Root analysis of *Jatrophacurcas* reveals that the concentration of Fe ranges between 1686.87 ±101 to 4615.44 ±127 mg /kg and Zn is within 265.37±3.8 to 523.11±12.4 mg/kg respectively (table 6)and presented in Figure b. Higher plants predominantly absorbs Zn as a (Zn^{2+}). Availability of Zn to the plants depends on total content, pH, organic matter, adsorption sites, microbial activity and moisture regime(Sharma et al, 2008) . *Jatrophacurcas* is found to have a very good potential for metal uptake due to high biomass production as well as fast growth, hardiness and the ability to re -sprout when cut as a result of which it can be propagated as cuttings .

Table 7: Classification chart for soil test data in Maharashtra state *

Soil fertility Level	Organic carbon (%)	Available N (kg/ha)	Available P** (kg/ha)	Available K** (kg/ha)
Very low	<0.20	<140	<7	<100
Low	0.21-0.40	141-280	7-14	101-150
Moderate	0.41-0.60	281-420	14-21	151-200
Moderately high	0.61-0.80	421-560	21-28	201-250
High	0.81-1.0	561-700	28-35	251-300
Very high	>1.0	>700	>35	>300
*Mahatma PhuleKrishiVidyapeeth,Rahuri, Maharashtra,India **P x 2.29 = P_2O_5 , *K x 1.20 = K_2O				

4.0 Conclusion:

It is concluded that *Jatrophacurcas* has potential of establishing itself on fly ash amended soil upto30%(600t/ha of ash) and can also grow on marginal soil with low to moderate organic carbon. Jatropha plants have good potential to produce biomass for fuel.*Jatrophacurcas* is found to have a very good potential for metal uptake and other purposes and yield significant leaf litter to improve soil quality. Pruning after seed harvest and leaf fall help promote biomass. Fresh biomass every year can be used as a domestic fuel after drying.

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References:

1) Amonette, J.E., Kim, J., Russell, C.K., Palumbo, A.V. and Daniels, W.L. 2003.Enhancement of soil carbon sequestration by amendment with fly ash. In: Proceedings 2003 International, Ash Utilization Symposium, Lexington, Kentucky, Paper #47.
2) Banerji R., Chowdhury, A. R., Misra G., Sudarsanam G., Verma S. C. and Srivastava, G. S.((1985). *Jatrophacurcas*seed oils for energy, *Biomass*, **8**: 277–282
3) Bellmann K., Grote R., (1998). Introduction to the SANA-project (SANA: regeneration of the atmosphere above the new state of Germany-effects on forest ecosystems). In: Hutti, R.F. and Bellmann, K. (Eds). Changes of atmospheric chemistry and effects on forest ecosystems: a roof experiment without a roof. Nutrients in ecosystems, Vol. 3. Kluwer Academic Publishers Dordrecht B.V., The Netherlands, 1-15.
4) Bhoyar S., Matte D.B. (2005)Effect of fly ash application on some physical properties and available micronutrients status of black soil. Proc.Int. confFly Ash India , TIFAC, DST, New Delhi , 13.1-13.5.
5) Brady N.C., (1995).The nature and properties of soils, 10th edition. Prentice Hall of India Private Limited. New Delhi., 621.
6) Bruggemann W., Moog P.R., Nakagawa H., JanieschP.and Kuiper P. J. C., (1990). Plasma membrane bound NADH: Fe^{3+} reductase and iron deficiency in tomato (Lycopersiconesculentum) *Physiologiaplantarum* ,**79**: 339-346
7) Chaney R.L., Brown J.C. and Tiffin, L.O. (1972) Obligatory reduction of ferric chelates iron uptake by soyabeans. *Plant Physiol*. **50**: 208-213
8) Elseewi A.A., Bingham, F.T. and Page A.L., (1978). Growth and mineral composition of lettuce and Swiss chard grown on fly ash amended soils In :D.C.Adriano and I.L.Brisbin (Eds.) Environmental Chemistry and Cycling processes, Conf -760429, U.S. Department of Commerce, Springfield, VA, 568-581.
9) Fang M., Wong J.W.C., Li G.X., Wong, M.H., (1998). Changes in biological parameters during co-composting of sewage sludge and coal ash residues. *Biores. Technol*.,**64** :55-61.

10) Forson F. K.(2004). Performance of Jatropha oil blends in a diesel engine. *Renewable Energy*,**29**:1135–1145.
11) Gaind S., Gaur A.C., (1991). Thermotolerant phosphate solubilizing bacteria and their interaction with mung bean. *Plant Soil*, **133**: 141-149.
12) Gubitz G. M., Mittelbach M. and Trabi M. (1999). Exploitation of the tropical seed plant *Jatrophacurcas*L. *Bioresour. Technol*., **67**: 73–82.
13) Hikwa D.(1995).*Jatrophacurcas*L. Agronomy Research Institute, Department of Research and Specialist Services, Harare, Zimbabwe, 1-4.
14) Keith O.(2000) A review of *Jatrophacurcas*: an oil plant of unfulfilled promise. *Biomass Bioenergy*. **19**: 1–15.
15) Klose S., Wernecke K.D. and Makeschin F.,(2004). Microbial activities in forest soils exposed to chronic depositions from a lignite power plant. *Soil Biol. Biochem*, **36**: 1913-1923.
16) Lindsay W. L., and Norvell W. A. (1978). Development of DTPA tests for Fe,Mn, Cu and Zn. Soil Science Society of America, **42**: 421–428.
17) Makkar H. P. S., Becker, K. and Schmook, B.(1997). Edible provenances of *Jatrophacurcas*fromQuintnaRoo State of Mexico and effect of roasting on anti-nutrient and toxic factors in seeds. Institute for Animal Production in the Tropics and Subtropics, UniversityofHohenheim, Germany, 1-6.
18) Markert B. (1987). Interelement correlations in plants. Fresenius *J.Anal. Chem*., **329**: 462-465
19) Martin G. and Mayeux A.(1985). Curcas oil (*Jatrophacurcas*L.): a possible fuel. *Agric. Troop*., **9**: 73–75
20) Matte D. B. and Kene D. R. (1995) Response to graded levels of fly ash by different major common crops grown in Vidarbha (Maharashtra). Research report submitted to M.S.E.B Mumbai, 1-131)
21) McBride M.B.and Martinez C.E. (1994). Copper phytotoxicity in a contaminated soil: remediation tests with adsorptive materials. *Sci. Technol*. **34**:4386-4391.
22) Milovsky A.V and Kononov O.V (1992), Mineralogy, Mir Publisher, Moscow, 37-45 .
23) Mondal S. and Saxena M., (1998). Potential Impact Of Fly ash constituents for sustaining crops. In: Proc. International conference onflyash disposal and utilization, session VI-8, New Delhi, India. 56-67.
24) Page, A. L., Miller, R. H. and Keeney, D. R. eds.(1982) Methods of Soil Analysis, part II: Chemical and Microbiological Properties, 2nd ed. (SSSA Book Series No. 5), Madison, Wisc.: Soil Science Society of America and American Society of Agronomy. 181–198.
25) Rodhe (1962). The effects of trace elements on the exhaustion of sewage irrigated land. *Water Pollution Abstracts*,**36**: 421.
26) Ruby M.V., Schoof R., Brattin W., Goldade M., Post G., Harnois M., Mosby D.E., Casteel S.W., Berti W., Carpenter M., Edwards D., Cragin D., Chapell W., (1999). Advances in evaluating the oral bioavailability of inorganics in soil for use in human health risk assessment. *Environ. Sci. Technol*., (**32:**3697-3705).
27) Rai M.M (2002) Principles of soil science (fourth edition,), Macmillan India Ltd, New Delhi 59-60 .
28) Saxena M., Asokan P (1988) Fertility improvement by fly ash application in wasteland. In: Proc. International Conference on fly ash disposal and utilization, 20-22 January1998, New Delhi ,India. VI-10 , 90-104
29) Sharma S.K, Singh G., Rao G.G. and Yaduvanshi N. P. S. (2008) Biomass and biodiesel for energy production from salt – affected lands , Central Soil Salinity Research Institute Karnal (India),Technical bulletin :2/2008 p 1.http//www.cssri.org.
30) Shen Z.G., Li X.D., Wang C.C., Chen H.M., Chua H. (2002). Lead phytoextraction from contaminated soil with high biomass plant species. *J. Environ.Qual*., **31**: 1893- 1900
31) Sikka R and Kansal B.D. (1993) Impact of fly ash on soil and plants. In Abstracts:National Seminar on Developments in Soil Science-1993. Oct. 8- 12, 1993, Dehradun, 133- 134
32) Sims J.T., VasilasB.L.andGhodrati, M., (1995). Development and evaluation of management strategies for the use of coal fly ash as a soil amendment. Proceeding of the 11th Int. Symp. of the American Coal Ash Association , Orlando, Florida, 8.1-8.18.
33) Singh K., Moinuddin and Bansal S.K. (2005). Use of fly ash for efficient management of irrigation water and fertilizers in rice-wheat production system. Proceedings of the National Seminar cum Business Meet on Use of Fly ash in Agriculture, Sept. 2005, New Delhi, 69- 92
34) SrivastavaR .(1999).Study in variation in morpho-physiological parameters with reference to oil yield and quality in *Jatrophacurcas*L.PhD thesis ,FTRI(Deemed University),Dehradun,India.

35) Stevenson F. J. (1994). Humus chemistry: genesis, composition, reactions. 2nd ed. Wiley, New York., 496
36) Tripathi, R.C. and Das, M.C., 1999, Impact of fly ash application on some root crops grown under green house conditions ,National Seminar on Utilization of Fly Ash in Agriculture and for Value Added Products, 15-16 Nov ,1999, Tech Session –V, 41, CFRI, Dhanbad.
37) Tandon, H.L.S., 2005 , Methods of Analysis of soils, plants, waters,fertilizers& Organic Manures, 2nd Edition, Fertilisers Development and Consultation Organisation, New Delhi, India, 204.(1page)
38) Vaidya V.G. and Sahastrabuddhe K.R (1973) .Itroduction to agronomy and soil water managenement Publisher Kulkarni A. A (2nd ed) Continental Prakashan, 35-41
39) Weisdorfer M., Schaaf W., Blechschmidt R., SchutzeJ.andHuettlR.f., (1998). Soil chemical response to drastic reductions in deposition and the effects on element budgets of three Scots pine ecosystems. In: HuettlR.F.andBellmann K. (Eds.)
40) Walkley, A. & Black I.A., (1934). An Examination Of the Degtjareff method For Determining Soil organic matter and a proposed modification Of The Chromic Acid Titration method, Soil Sci, **37**: 29-37.
41) Zhou H., Lu, H. and Liang B. (2006). Solubility of multi component systems in the biodiesel production by transesterification of *Jatrophacurcas*L. oil with methanol. *J. Chem. Eng. Data*, **51**: 1130–1135