International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Role of Biochar to Improve the Soil Conditions (A Study on *Trifolium Alexandrinum*)

Varinder Kaur[1], Praveen Sharma[2]

[1]Research Scholar, Department of Environment Science and Engineering, Guru Jambheshwar University, Hisar, Contact No. 01662263342, Haryana, India

[2]Professor, Department of Environment Science and Engineering, Guru Jambheshwar University, Hisar, Contact No. 01662263342, Haryana, India

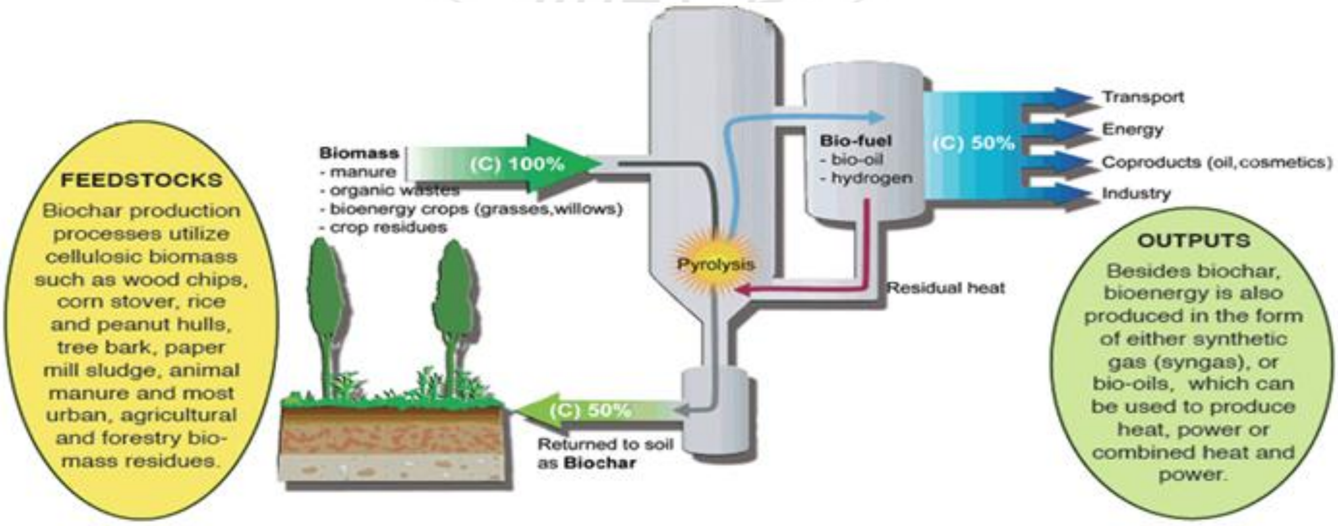
Abstract: ***Soil properties can be significantly influenced by addition of biochar and is a subject matter to enhance plant productivity and soil quality. In pot experiment, we investigated the effect of different concentrations of biochar (2%BC, 3%BC, 5%BC and 10%BC) on heavy metal (Cr) content and studied various soil physico-chemical parameters. It was observed that soil pH arising from biochar application may lead to decreased mobilization of heavy metals. Growth characteristics of Trifolium alexandrinum also varied at regular intervals. The maximum plant height and plant biomass were shown at 5% biochar and at 10% biochar and control without biochar showed little change in plant growth rate. Organic carbon content was maximum at 10% biochar application as compared to control. Hence, with the increase of biochar concentration in soil it is observed that organic carbon content also increases significantly. Different doses of chromium were also added in soil (Cr 20ppm, Cr 50ppm, and Cr 100ppm) to checkout biochar high sorption capability with the help of Trifolium alexandrinum. It is noticed that biochar adsorption capability increases with increase of biochar concentration in soil.***

Keywords: Biochar, Phytoremediation, Mobilization, Soil quality, Heavy metal

1. Introduction

Biochar improves many physical, chemical and biological properties of soils (Lehmann and Joseph, 2009). It is formed by thermal decomposition of plant biomass under oxygen limited conditions. At low temperature, biochar chemical composition is closer to the original feedstock while at high temperature biochar is closer to graphite (Masiello, 2004).

Biochar is often claimed to have several potential benefits, including bioenergy generation (Laird, 2008; Lehmann, 2007); Carbon sequestration (Laird, 2008; Zimmermann et al., 2012); adsorbing organic and inorganic pollutants (Hale et al., 2011; Jiang et al., 2012) as well as improving soil fertility (Jeffery et al., 2011; spokes et al., 2012). Applying biochar together with organic or inorganic fertilizers can even increase crop productivity (Lehmann et al., 2002). Recent studies have also highlighted the ability of biochar to supply a range of agroeconomic benefits, e.g. increased nutrient cycling, improved fertility and health (Sohi et al., 2010; Atkinson et al., 2010; Lehmann et al., 2006). High internal porosity of biochar creates a soil conditioning agent that can lower bulk density, affect pore size distribution, and potentially affects the water percolation rates and nutrient leaching (Bell and Worrall, 2011). Biochar addition can enhances soil fertility through increased biological nitrogen fixation (BNF) when legumes are present in root horizon system (Nishio, 1996; Rondon et al., 2007). Addition of biochar to soil with different application rate has shown definite increase in cation exchange capacity (CEC) and pH value (Tryon, 1948; Topoliantz et al., 2002).



Source: IBI (International biochar initiative)

In present study, the plant used to remove heavy metal from soil is Barseem also known as Egyptian clover *(Trifolium alexandrinum*), it is the traditional forage crop in Egypt. Barseem shows a good potential for Nitrogen- fixation (Average 50 – 90 lb N /acre) and sensitivity to frost. It is useful in phytoremediation of Cd, Pb, Zn and Cu. The aim of this study was to investigate the influence of variable rates of biochar addition on soil heavy metal concentration and associated plant uptake in a pot experiment with biochar and *Trifolium alexandrinum*. We hypothesized that higher rates of biochar addition would be more effective at reducing metal availability and plant uptake due to increases in cation exchange capacity (CEC), soil pH and the increased immobilization of metal contaminants. In addition, we evaluated biochar had different effects on metal distribution within the soil-plant system and bioavailability rate.

2. Materials and Methods

2.1 Soil and Biochar

Farm soil was collected and sieved to pass 9mm before filled in pots. Biochar produced by *Prosopis Juliflora* was converted in to powdered form and mixed with soil thoroughly. Pots filled with soil contain different concentrations of biochar i.e. 2% BC, 3%BC, 5%BC, 10%BC. Plants were germinated after 15 days of seeding. Soil having different concentrations of biochar represents amended soil, on the other hand unamended soil were taken as control. Selected soil and biochar properties are represented in table 1.

2.2 Experimental Set-up

The experiment was carried out from 19 November 2014 to 19 April 2015. Seeds of *Trifolium alexandrinum* was sterilized by using mercuric chloride solution. Germination percentage of seeds was calculated and it was found to be 99%. Approximately, 100 seeds/ pot were sown. Plant germination was shown after 15 days of sowing. Rhizospheric soil samples from pots having different proportion of Biochar were taken on an interval of 30days. A soil:biochar (W/W) mixture of the suitable ratio for each application was then used for filling pots. In order to manage the same final volume of pot for different treatments, the soil volume was adjusted as needed in order to retain the total volume of the soil:biochar mixture and hence the potential rooting depth of the plants is same for all treatments. An amount of 4kg soil- biochar mix about 2%, 3%, 5% and 10% was loaded into pots of 19.6cm diameter × 20.6cm height.

The pots were maintained at 71% water filled pore space throughout the experimental period. Total above ground plant biomass was harvested after 30 days and 60 days of plant growth. Data of the total biomass are used. Different concentration of chromium metal (20ppm, 50ppm, 100ppm) was added in soil at interval of 15 days till the final harvesting period i.e. 19 April 2015.

2.3 Biomass measurements

Above ground plant biomass was collected at intervals. Roots of each pot were cleaned properly with running water and plants were sorted manually. Plant biomass was dried at 60°C for 52 hrs and root and shoot dry weight was determined.

2.4 Plant analysis

Dry plant material was grind to form power and 1g powered biomass was digested using nitric acid and perchloric acid in 9:1 ratio for heavy metal detection through AAS. Total Na and K concentration in the above ground plant biomass was calculated by using Flame Photometer.

2.5 Soil analysis

Rhizospheric soil samples were collected at different time intervals from each pot having different concentration of biochar. Soil samples were dried at 40°C for 72 hrs. and sieved to pass 5mm before analysis (Mia et al., 2014). Soil pH was determined with a ratio of 2:5 (m/v) and electrical conductivity (EC) was measured with demineralised water 2:5 (m/v) (Laboratory testing procedure for soil sample analysis ISO 9001: 2000). Soil organic carbon was measured by using wet digestion method and heavy metal detection by using nitric acid and perchloric acid, after soil digestion makeup total volume 50ml by using distilled water and heavy metal was detected with the help of AAS.

2.6 Statistical analysis

All experiments were performed in three replicates of each treatment. The data were homogeneous and normal distributed. Difference in treatments were compared by one way ANOVA and Tukey HSD (for soil characteristics), LSD or Post Hoc Test (for heavy metals) by using SPSS V.18 and presented as mean of three replicates ± S.E. level of significance between treatments was checked at ($P \leq 0.05$)

3. Results and Discussion

3.1 Soil Characteristics

The soil pH was clearly modified by the amendments. The soil pH significantly increased with the concentration of biochar amendment, starting 8 in the control to 10.9 in the biochar-10% treatment (shows in Fig.1). Statistical analysis revealed a significant ($P<0.05$) increased in the soil pH and EC (Electrical conductivity). The increase in soil pH after the application of biochar may be attributing to the alkaline nature of biochar. Organic C content increases with the biochar application rate. The available organic content was 150, 155, 165 and 175 g/kg after the application of 2%, 3%, 5% and 10% biochar respectively compared to the control i.e. 146.

Biochar has high surface area, variable charge organic material, highly porous that has the potential to increase soil cation exchange capacity (CEC) and surface sorption capacity when added to soil. The analysis of variance showed that the cation exchange capacity and exchangeable bases were significantly ($P<0.05$) increased as a result of biochar application as shows in Fig.1. According, to Cheng et al., (2008), the soil CEC enhancement after biochar addition should become much more important with time due to the continuous oxidation of the biochar surface and the adsorption of organic acids by the biochar.

Potassium uptake were also significantly ($P<0.05$) increased in biochar amended soil. Potassium was the macronutrient absorbed by plants in larger amounts than any other mineral element except nitrogen and, in some cases, calcium. It helps in the building of protein, photosynthesis, fruit quality and reduction of diseases. Potassium is supplied to plants by soil minerals, organic materials, and fertilizers. Fig.1 explains the increase in Potassium level with increases biochar amendment, its available content was multiplied by 5.8, 6.7, 7.6 and 11.1g/kg after the application of 2%, 3%, 5% and 10% biochar respectively compared to the control i.e. 5.0. We conclude that with increase in biochar application rate the level of available nutrient content was also increases. According to Glaser et al., (2002), ash in biochar rapidly releases free bases such as K, Ca, and Mg ions into the soil solution thereby increasing the pH value of the soil and providing readily available nutrients for plant growth.

3.2 Effect of biochar application on chromium uptake with the help of *Trifolium alexandrinum*

Level of significance ($P<0.001$) effect of biochar observed on uptake of Cr concentrations. Applying biochar significantly reduced shoot heavy metal concentrations in barseem plants in response to increasing application rates. Lehmann et al., (2002); Radovic et al., (2000) reported that the smallest uptake of chromium in biochar amended soil could also be results from the increase in pH and cation exchange capacity (CEC) of soil. An important application of biochar (produced by plant biomass at high temperature) as a sorption medium for decontamination and decolouration also results from its high CEC.

3.3 Analysis of plant biomass

Biochar addition increased the level of significance ($P<0.05$) (Shown in Fig. 2) the above ground plant biomass as compared to control treatment. High nutrient uptake by plant is due to biochar application. When different concentrations of biochar were applied, the K and N concentration increased significantly as compared to treatments without biochar. Plant biomass is maximum in soil having 5% and 10% biochar application. Plant biomass is also maximum in soil having different Cr treatments as increased the biochar application rate shown in Fig.2, as compared to control. This reveals that due to high biochar application rate, its heavy metal sorption capacity increased and Cr uptake in plant tissue reduced. This increased the plant growth and soil fertility. Highest biomass production in the presence of 10% biochar was not only due to the increase in metal phytotoxicity but also to the enhancement of soil fertility. Uzoma et al., (2011) studied that higher plant productivity when biochar was applied and attributed this enhancement to the increase in soil available nutrients.

4. Conclusion

The results observed in this study reveal that by mixing soil with different application rate of biochar increased soil pH, EC, CEC, organic carbon and cations of Cr polluted and unpolluted soil. Uptake of K was also increased by addition of biochar. The presence of plant nutrients volatile matter and ash in the biochar, high porosity of biochar, high surface area and biochar capacity to act as a medium for Rhizospheric microorganisms growth are reported as the main reasons for increase in soil properties and highest nutrient uptake at biochar amended soils. Moreover, due to high Cr adsorption capacity of biochar i.e, produced from plant biomass, the concentration of Cr in *Trifolium alexandrinum* were reduced by addition of different concentration of biochar. Longer term experiments are needed to investigate the potential role of biochar to enhance the soil productivity, its quality and heavy metal sorption capability.

5. Acknowledgement

One of the Author Varinder kaur (Research scholar in the Department of Environmental Science and Engineering, Guru Jambheshwar University, Hisar, Haryana, India) is highly thankful to UGC-MANF for financial assistance.

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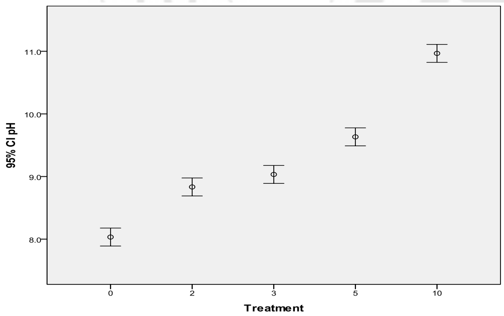
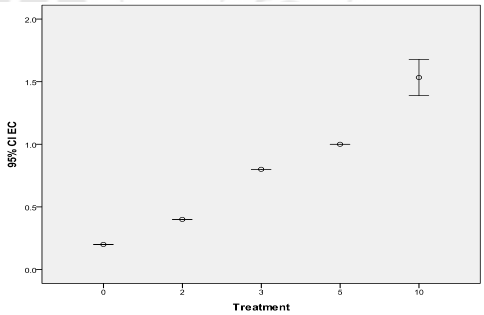
Table 1: Selected soil and biochar characteristics used for experiment

characteristics	Soil	Biochar
Soil Type	Sierozem	-
Soil Texture	Sandy Loam	-
Biochar Type	-	*Prosopis Juliflora*
Moisture %	22±0.002	1.49±0.000
pH	7.9±0.033	8.2±0.002
Electrical conductivity (EC) ds/m	0.2±0.00	1.01±0.002
Organic C (g Kg^{-1})	147±0.33	756±0.001
Total Na (g kg^{-1})	1.8±0.00	1.46±0.00
Total K (g kg^{-1})	5.1±0.00	13.5±0.00
Calcium (g kg^{-1})	31±0.002	12.5±0.001
Magnesium (g kg^{-1})	23±0.001	0.41±0.002
Cation exchange capacity (cmol/kg)	4.34±0.00	16.3±0.001



(a)



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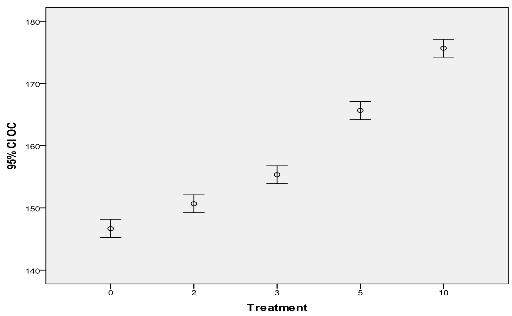
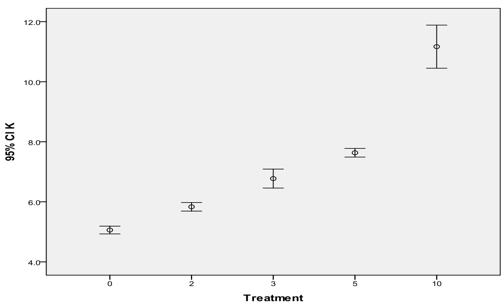
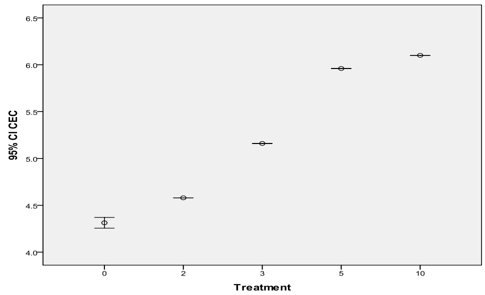


(c)



(d)



(e)

Figure 1: Mean± SE from (a), (b), (c), (d), (e) shows that pH, EC (Electrical conductivity), OC (Organic carbon), K (Potassium), CEC (Cation exchange capacity) were increased with different biochar application rate.

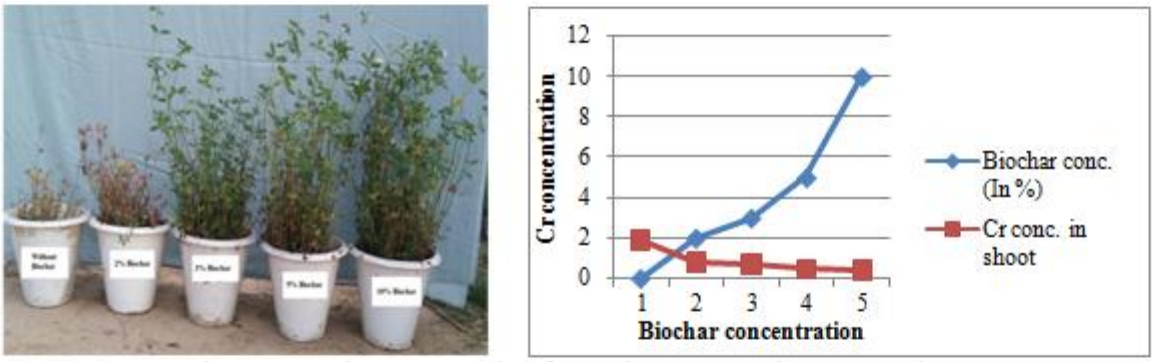


Figure 2: Total biomass production of *Trifolium alexandrinum* increased with different biochar application rates. Due to high Cr adsorption capacity of biochar produced from plant biomass, the concentration of Cr in *Trifolium alexandrinum* were reduced with addition of different concentration of biochar.