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# COMPARISON OF BIOCHAR AND UREA AMENDMENT ON GROWTH AND PRODUCTIVITY OF *GLYCINE MAX (*L.) MERR.

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## Abstract

On one hand the green revolution technologies supported by policies, machinery, agro-chemicals and irrigation are known to enhance agricultural productivity on the other hand they lead to serious environmental and health problems. It is the need of hour to intensify agricultural crop production in order to feed current existing population. The field management, crop selection and fertilization practices will need to be modified in order to reduce crop production risks. The study aims at comparison of effect of biochar and chemical fertilizer (urea) on the growth and productivity of *Glycine max* (L.) Merr. (soybean). Biochar is the carbon rich char like material produced by heating the biomass in an oxygen deficient environment and added to the soil with an intention of carbon sequestration and improving soil health (properties) leading to increase in agriculture production. Poultry biochar was prepared by the pyrolysis of chicken manure at 500ºC in a muffle furnace. The experimental study includes 3 treatments; $\mathbf{T_0}$- control, $\mathbf{T_1}$- poultry biochar treatment and $\mathbf{T_2}$- urea treatment. The soybean was grown and the physico-chemical properties of soil as well as growth and productivity of plants were recorded during the life cycle of 120 days. The data were analyzed by applying Tukey's HSD test of post hoc treatment using SPSS 16.00 software. From the study, it can be concluded that poultry biochar is more suitable for increasing the growth and productivity as compared to urea. Urea does not improve physical and chemical properties of soil. Poultry biochar increases the growth of plant, thereby increasing the physico-chemical properties of soil that ultimately increase productivity. Thus, the present study recommends the use of organic amendments *i.e.*, biochar instead of chemical fertilizers because it is not only environment friendly but also acts as a substitute for fertilizer for crop production. It is a multidisciplinary approach that provides solution to many questions regarding soil health, crop production, bioenergy, GHG's emission, C-sequestration etc and also considered as a clean development mechanism according to UN Framework Convention on Climate Change.

***Key words :*** Agro-chemicals, bioenergy, Pyrolysis, C-sequestration, IPCC, IBI, UNEP, GHG.

## Introduction

Land the major non-renewable resource is facing the threat of degradation at an alarming rate. Soil is the foundation of sustainable agro-ecosystem (UNEP, 2012). The continuous cultivation disturbs the soil ecosystem including nutrient cycling *i.e.*, the release and uptake of nutrients (Bot and Benites, 2005). Green revolution technologies supported by policies, agro-chemicals, machinery and irrigation are known to enhance agricultural productivity at the same time leading to serious environmental and health problems (Reddy, 2010). It may be due to these input issues and their negative impacts that the Intergovernmental Panel on Climate Change (IPCC) has noted that agriculture accounts for about one-fifth of anthropogenic green house effect producing about 50% $CH_4$ and 70% nitrogen oxides emission. Over the past few decades modern agricultural practices in combination with the use of chemical additions have resulted in loss of natural habitat balance, deterioration of soil health, soil erosion, soil salinization, decreased ground water level, pollution due to fertilizers and pesticides, climate change, reduced food quality, increased cost of cultivation, rendering the farmer poorer year by year (Ram, 2003). Thus, it is the need of hour to intensify agricultural crop production in order to feed current existing population (Thornton *et al*., 2014). The field management, crop selection and fertilization practices will need to be modified in order to reduce crop production risks (Bozzola and Swanson, 2014; Smith *et al*., 2014;

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Wood *et al.*, 2014). The soil nutrient pools need to become closed loop cycles along with the source and sink of nutrients (Oktem, 2008). To cope up with all the above issues a new technique *i.e.*, biochar is introduced. Biochar is the carbon rich char like material produced by heating the biomass in an oxygen deficient environment and added to the soil with an intention of carbon sequestration and improving soil health (properties) leading to increase in agriculture production. The properties of biochar depend on the type of feedstock and pyrolysis temperature. The ability to store carbon and improve fertility will depend on physico-chemical properties of soil, which later depends on pyrolysis temperature and choice of feedstock (Lattao *et al.*, 2014; Mašek *et al.*, 2013; Zhao *et al.*, 2013). The variety of feedstock include woodchips, wood pellets, crop residue, switchgrass, organic wastes including paper sludge and sugarcane derived bagasse, distillers grain, olive waste (Yaman, 2004), chicken litter (Das *et al.*, 2008), dairy manure and sewage sludge (Shinogi *et al.*, 2002). It has been reported that biochar has potential to boost soil fertility and improve soil quality when applied to soil. Soil benefits include increase in pH, WHC (water holding capacity), improving CEC (cation exchange capacity) and retaining nutrients (Lehmann *et al.*, 2006; Lehmann, 2007). These benefits have been shown to increase yield in biomass and crops under varied conditions (Steiner *et al.*, 2007; Rondon *et al.*, 2007; Chan *et al.*, 2007; Yamato *et al.*, 2006; Lehmann *et al.*, 2003). Positive yield effects were reported from biochar amendment by Kimetu *et al.* (2008). In the international world trade markets soybean is ranked number one among the major oil crops (Chung and Singh, 2008). According to US Food and Drug Administration soy protein products can be good substitutes for animal products because soy offers a complete protein profile. The study has been done to compare the effectiveness of biochar and chemical fertilizer *i.e.*, urea on the growth and productivity of soybean.

## Methodology

### Biochar preparation

In this study, biochar was prepared from chicken manure, collected from poultry farm, Rishikesh. The chicken manure contains bedding used in poultry operations- wood shavings, sawdust, straw or other organic materials as well as feathers, feed spillage and mortalities. The feedstock was grinded with the help of a grinder. Later the feedstock was dried at 105ºC in an oven for 24 hours to remove surface moisture. The feedstock was then packed in a tin box having lid. A 1mm hole was drilled in the lid. This provides a small opening for steam and gas to escape to avoid explosion. The feedstock was then pyrolyzed at 500ºC under the recommendation of Lehmann *et al.* (2003) in a muffle furnace MAC PMTC for 1 hour. After the pyrolysis the sample was cooled, crushed and sieved with 2mm mesh. The biochar produced from chicken manure is known as poultry biochar.

### Soil sampling

For the experimental plot, the soil was collected from 10-20cm below the top soil layer of Botanical Garden of Government P.G. College, Rishikesh. The soil was air-dried for 24 hours and then sieved through a 2mm mesh to remove plant debris, stones and other unwanted material prior to plantation. The physico-chemical parameters of soil are given in table 1.

### Experimental site and plot

The study was conducted during the period June 2014-October 2014 and June 2015-October 2015 at Botanical Garden of Government P. G. College, Rishikesh, geographically located in the foothills of the Himalayas in northern India. Pot trials were conducted and 10% biochar was applied as per big biochar experiment of IBI. The seeds were sown in plastic bags that had many holes at their base so that excess water could drain out and for aeration. 100mg of urea was applied after one week of germination. Thus, following 3 treatments were used:

$\mathbf{T_0}$- Control

$\mathbf{T_1}$- Poultry biochar treatment

$\mathbf{T_2}$- Urea treatment

### Laboratory analysis

The soil samples were subjected to physico-chemical analysis before and after treatment. The physico-chemical parameters include WHC, BD, pH, EC, OC, N, P, K, Ca, Mg, Na, S and CEC.

### Recording data and statistical analysis

Fresh weight of root, shoot and plant, dry weight of root and shoot, height of plant and leaf area were recorded after every 30 days *i.e.*, at the 30, 60, 90 and 120 day of lifecycle representing 1, 2, 3 and 4 crop age, respectively. The dry weight was recorded after drying the plant material in an oven at 70ºC for 24 hrs. After harvesting the yield and productivity parameters *i.e.*, number of pods per plant, number of seeds per pod, length of pod and seed dry weight were recorded. For analyzing the data obtained through experiment ANOVA was applied. For comparison of means in order to assess their performance regarding growth and productivity. Tukey's HSD test was applied at p=0.05 using SPSS 16.00 Software package.

## Results and Discussion

### Effect on physico-chemical properties of soil

The physico chemical properties of control and treated soil are given in table 2.

### Effect on root biomass, shoot biomass and total plant biomass

The fresh weight of root, shoot, plant, dry weight of root shoot and plant have been given in tables 3 to 8.

The perusal of data in tables 3 to 8 reveals that biochar application significantly increased growth of plant. However, urea application to soybean also increased growth of plant but less than biochar. Table 2 reveals that urea amendment did not improves soil physical and chemical properties however it only affected total N, P, K and other chemical parameters remained least affected. On the other hand biochar is best suited for reclamation of acidic soil, increasing CEC, exchangeable cations and bicarbonate and chloride ions. Urea showed almost similar bulk density to control. The higher bulk density deteriorates the soil structure, while it has been found that poultry biochar decreased bulk density. Thus, poultry biochar increased the growth of plant thereby improved the physico-chemical properties of soil. Presently most of the developing nations are using chemical fertilizers (like urea) based cropping system whose excessive use has lead to other harmful effects like deterioration of soil structure, nitrate in the ground water, adulteration of food materials, eutrophication etc. Novak *et al*. (2009) also reported that poultry biochar has high fertilizer components *i.e.*, N, P, K. Manure derived biochar is rich in soil nutrients such as N, P, Ca, Mg and K (Tsai *et al*., 2012; Cao and Harris, 2010; Dias *et al*., 2010; Uzoma *et al*., 2011; Cantrell *et al*., 2012; Cantrell and Martin, 2012).

### Effect on Height of plant, leaf area and productivity

The height of plant and leaf area are given in tables 9 and 10 and productivity is given in table 11.

The data of tables 8 and 9 showed that biochar application increased height of plant and leaf area more as compared to urea application. The biochar application increased productivity of *Glycine max*, while urea slightly increased productivity but less than biochar. The better results of poultry biochar treatment regarding growth and productivity are in conformity with IBI (International Biochar Initiative).

## Conclusion

From the above study, it can be concluded that biochar

**Table 1 :** Physico-chemical properties of soil used for experimental study before experiment.

| WHC | BD | pH | EC ($dsm^{-1}$) | N(%) | P(ppm) | K(ppm) | Ca (ppm) | Mg (ppm) | S(ppm) | CEC(C mol/Kg) | Na (ppm) | OC (%) | Fe (ppm) | $HCO_3^-$ (ppm) | $Cl^-$(ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15.65± 1.02 | 1.34 ± 0.22 | 6.21 ± 0.70 | 0.48± 0.23 | 0.06 ± 0.004 | 3.7± 0.41 | 83.35± 0.32 | 126.24± 1.82 | 63.10± 1.47 | 78± 0.12 | 0.31 ± 0.1 | 54.21± 0.18 | 0.69± 0.04 | 1.35± 0.2 | 341± 0.5 | 275± 0.14 |

**Table 2 :** Physico-chemical parameters of control, biochar treatment and urea treatment.

| Treatment | WHC | BD | pH | EC ($dsm^{-1}$) | N (%) | P(ppm) | K(ppm) | Ca (ppm) | Mg (ppm) | S (ppm) | CEC(C (mol/Kg) | Na (ppm) | OC(%) | Fe (ppm) | $HCO_3^-$ (ppm) | $Cl^-$ (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $T_0$ | 15.80 | 1.32 | 6.57 | 0.51 | 0.06 | 3.63 | 81.03 | 129.77 | 61.50 | 94.07 | 0.42 | 51.83 | 0.77 | 1.37 | 353.78 | 250.33 |
| $T_1$ | 19.39 | 1.03 | 8.20 | 0.63 | 0.19 | 67.22 | 727.67 | 142.81 | 101.50 | 104.26 | 1.46 | 71.50 | 1.73 | 2.97 | 416.83 | 323.74 |
| $T_2$ | 16.17 | 1.29 | 7.17 | 0.54 | 0.07 | 9.35 | 121.37 | 132.66 | 70.44 | 96.15 | 0.53 | 53.17 | 0.85 | 1.68 | 358.16 | 263.70 |

**Table 3 :** Effect on fresh weight of root.

| Treatment | Crop age | | | | Mean |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| $T_0$ | 0.35 | 0.99 | 1.28 | 1.22 | 0.96 |
| $T_1$ | 0.83 | 1.27 | 1.41 | 1.35 | 1.21 |
| $T_2$ | 0.73 | 1.32 | 1.39 | 1.32 | 1.19 |
| Mean | 0.64 | 1.19 | 1.36 | 1.30 | |

**Table 4 :** Effect on dry weight of root.

| Treatment | Crop age | | | | Mean |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| $T_0$ | 0.13 | 0.32 | 0.37 | 0.31 | 0.28 |
| $T_1$ | 0.37 | 0.39 | 0.53 | 0.50 | 0.45 |
| $T_2$ | 0.32 | 0.47 | 0.52 | 0.43 | 0.43 |
| Mean | 0.27 | 0.39 | 0.47 | 0.41 | |

**Table 5 :** Effect on fresh weight of shoot.

| Treatment | Crop age | | | | Mean |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| $T_0$ | 0.53 | 1.25 | 1.55 | 1.40 | 1.18 |
| $T_1$ | 1.45 | 1.76 | 2.18 | 1.98 | 1.84 |
| $T_2$ | 1.39 | 1.56 | 1.74 | 1.54 | 1.56 |
| Mean | 1.12 | 1.52 | 1.82 | 1.64 | |

**Table 6 :** Effect on dry weight of shoot.

| Treatment | Crop age | | | | Mean |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| $T_0$ | 0.12 | 0.34 | 0.49 | 0.35 | 0.32 |
| $T_1$ | 0.43 | 0.54 | 0.58 | 0.55 | 0.52 |
| $T_2$ | 0.41 | 0.48 | 0.59 | 0.57 | 0.51 |
| Mean | 0.32 | 0.45 | 0.55 | 0.49 | |

**Table 7:** Effect on fresh weight of plant.

| Treatment | Crop age | | | | Mean |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| $T_0$ | 0.85 | 2.21 | 2.76 | 2.56 | 2.09 |
| $T_1$ | 2.28 | 3.05 | 3.57 | 3.34 | 3.06 |
| $T_2$ | 2.23 | 2.88 | 3.13 | 2.89 | 2.78 |
| Mean | 1.79 | 2.71 | 3.15 | 2.93 | |

application to soil can be regarded as a substitute for increasing the yield along with the maintenance of soil health. Chicken manure can be used as a feedstock for biochar production to reduce the pollution of ground or surface waters and to reduce the odour and risk of flies that may cause epidemic, however storage and direct land application of untreated poultry litter has serious disadvantages. Thus, the present study recommends the use of organic amendments *i.e.*, biochar instead of chemical fertilizers because, it is not only environment-friendly but also acts as a substitute for fertilizer for crop production. It is a multidisciplinary approach that provides solution to many questions regarding soil health, crop production, bioenergy, GHG's (green house gases) emission, C-sequestration etc and also considered as a clean development mechanism according to UN framework convention on climate change.

**Table 8 :** Effect on dry weight of shoot.

| Treatment | Crop age | | | | Mean |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| $T_0$ | 0.26 | 0.67 | 0.85 | 0.66 | 0.61 |
| $T_1$ | 0.80 | 0.93 | 1.10 | 1.08 | 0.98 |
| $T_2$ | 0.73 | 0.95 | 1.11 | 1.08 | 0.97 |
| Mean | 0.60 | 0.85 | 1.02 | 0.94 | |

**Table 9 :** Effect on height of plant.

| Treatment | Crop age | | | | Mean |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| $T_0$ | 39.33 | 65.17 | 96.50 | 108.67 | 77.42 |
| $T_1$ | 64.00 | 95.50 | 129.67 | 141.67 | 107.71 |
| $T_2$ | 57.83 | 82.17 | 121.83 | 129.50 | 97.83 |
| Mean | 53.72 | 80.95 | 116 | 126.61 | |

**Table 10 :** Effect on leaf area.

| Treatment | Crop age | | | | Mean |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| $T_0$ | 3.80 | 6.81 | 9.06 | 10.71 | 7.59 |
| $T_1$ | 14.12 | 21.48 | 39.14 | 51.96 | 31.67 |
| $T_2$ | 6.79 | 11.66 | 15.56 | 21.49 | 13.87 |
| Mean | 8.24 | 13.32 | 21.25 | 28.05 | |

**Table 11 :** Effect on productivity of *Glycine max*.

| Treatment | No. of pods/plant | No. of seeds per pod | Length of pod | 100 seed dry weight |
|---|---|---|---|---|
| $T_0$ | 6.50 | 2.83 | 3.25 | 10.34 |
| $T_1$ | 15.00 | 6.33 | 6.33 | 18.24 |
| $T_2$ | 11.83 | 3.83 | 4.73 | 16.38 |

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