*Original Research Article*

# Characterization of biochars and their application rates on soil moisture retention in light textured soil of Assam


## Abstract:

"Biochar" is a relatively new term, yet it is not a new substance. Biochars, product of thermal decomposition or incomplete combustion of biomass or bio-wastes under limited oxygen supply, are fine-grained highly porous charcoal substances that are distinguished from other charcoals in its intended use as soil amendments. Recent estimate suggests that nearly 16, 12, 2.78, 58, and 188 lakh tons of rice straw, rice husk, toria stover, and bamboo leaves, respectively, remain unutilized annually and these farm wastes have the potential of further reutilization through production of biochar, which may effectively be used in sustainable production system. Characterization of biochar with respect to physico-chemical properties determines the suitability of biochar to conserve soil moisture, which is again regulated by kind and source of feed stock materials. Keeping these aspects in view, a study on characterization of biochars prepared from four different feed stocks, namely rice straw, rice husk, toria stover, and bamboo leaves was conducted at Assam Agricultural University during 2014?15 and 2015?16 to validate i efficiency. After determining the physicochemical properties of the four biochars, a set of pot culture experiment in poly house taking toria as test crop was conducted with four biochars. Fourhundred gram of soil (preferably light textured) in 500 g capacity of plastic pot replicated thrice was designed statistically (factorial CRD) with four doses of biochars (0, 0.5, 1.0, and 1.5% wt/wt). Initially, a moisture level at field capacity was maintained and periodical volumetric soil moisture content (upto 70 days) was monitored to evaluate their efficiency. Gravimetric soil moisture content decreased significantly with the progress in days of experimentation irrespective of types of biochar used. However, increase in biochar doses increased the soil moisture content significantly over the one where no biochar was applied. Highest efficiency to conserve soil moisture over the days of study period was due to the application of bamboo leaves biochar.


*Keywords*: Biochar, Gravimetric water, Pyrolysis



## Introduction:

Biochar, a product of thermal decomposition or incomplete combustion of biomass or biowastes under limited oxygen supply, are fine-grained highly porous charcoal substances that can be used as soil amendments. The state of Assam produces surplus quantities of biowastes and leaves behind bulk quantity of wastes soon after harvest of the main crop(s). It has been estimated that nearly 16, 12, 2.78, 58,188 lakh tons of rice straw, rice husk, *toria* stover and bamboo leaves, respectively remain unutilized annually. Considering the rich potential source of these bio-resources, there is enough scope for revitalizing technology backstopping for biochar production in increasing the production potential of crop through efficient use of such bio-resources in agriculture. Biochar's physical, chemical and nutritional properties depend on the chemical composition of the feedstock used, pyrolysis system and production conditions. Due to biochar's surface area and porosity, bulk density, nutrient content, cation exchange capacity (CEC), pH value and carbon content it is expected to improve water retention, nutrient retention and plant uptake of nutrients. The present research was carried out at Assam agricultural University, Jorhat with two main objectives, *viz.* characterization of the physico-chemical properties of biochars produced under slow pyrolysis system and suitability assessment of biochars to conserve soil moisture.

## Methods and Materials:

### Biochar unit

A biochar production unit, fabricated in AICRP on Irrigation Water Management Laboratory, AAU, Jorhat, for small scale production of biochars from bio-wastes of agricultural field was used in the present study on trial basis. Until recently much progress has been made in designing aspects of biochar production unit but in most of the cases a number of drawbacks ranging from loading rate, maintenance of temperatures, low production rate *etc*. were observed. The present design of biochars unit has the potential for easy handling with faster production rate. In designing the kiln, a much emphasis was laid on the requirement to control the loading rate of biochar for optimum churning efficacy without compromising the temperature fluctuation during the process of pyrolysis. The biochar kiln functions on top-draft principle with top ignition system. It consists of iron drum modified from oil tank with capacity of 0.08478 $m^3$.

Biochar production from rice husk, rice straw, *toria* stover and bamboo leaf was carried out using pyrolysis chamber fabricated at AICRP on Water Management AAU.

Biochars was pyrolysed at 300-350ºC with residence time of approximately three hours duration.

**Biochar preparation**

The unit was filled with feedstock, covered with a fitting lid, and pyrolyzed under oxygen-limiting conditions. After pyrolysis, biochar in the unit was allowed to cool overnight to room temperature. The weights of the biochar collected were measured to obtain pyrolysis yields. The yield of each bio-product was defined as the ratio of the weight of the product to that of the original feedstock. After the pyrolysis process, the biochar was grounded to small granules and pass through 2000 μm sieve in order to have the same particle size as that of the soil. All physico-chemical characterization will be done as per the protocol described by IBI.

**Laboratory analysis**

**Physical parameter**

**Moisture Content Determination**

A 1.0 g of the activated carbon sample was collected and dried in an oven for four hours at 150°C, until the weight of the sample became constant. The moisture content was calculated from the relationship.

$$X0=\frac{W1-W2}{W1}\times 100$$

where,

$X_o$ = Moisture content on weight basis

$W_1$ = Initial weight of sample, (g)

$W_2$ = Final weight of sample after drying (g)

**Ash content**

Dry (Activated Carbon) sample (1.0g) was placed in to a porcelain crucible and transferred into a preheated muffle furnace set at a temperature of $1000^0$C. The furnace was left on for one hour after which the crucible and its content was transferred to desiccator and allowed to cool. The crucible and content was reweighed and the weight lost was recorded as the ash content of the sample. The per cent ash content (dry basis) was calculated from the equation

$$\text{Ash}(\%) = \frac{Wash}{W'0} \times 100$$

Where,

$W_{ash}$= Weight of ash (grams).

$W_0$ = is the dry weight of carbon sample before ashing.

**Particle Size**

Particle size of the biochar was determined with the help of microscope ZEISS (Stemi 2000c). For the particle size determination, 2-3 biochar particles in each biochar samples were placed on the slide of the microscope and determined the particle size of biochar in µm.

**Determination of Porosity and Bulk Density**

One gram sample was dispersed in 20 ml water in a graduated cylinder with the aid of a shaker; this was further centrifuged for 10 minutes. The resulting volume of the water was read as VT and recorded. The equation below was used for the calculation of the porosity and bulk density as the case may be.

Porosity = Vw/VT,

Density = $\rho/(1 - \alpha)$ while

$\rho$ = Ma/Vw

**Pore Volume**

The sample (1 g) was collected and transferred completely into a 10 ml measuring cylinder in order to get the total volume of the sample. The sample was then poured into a beaker containing 20 ml of deionized water and boiled for 5 min. The content in the beaker was then filtered, superficially dried, and weighed. The pore volume of the sample was determined by dividing the increase in weight of the sample by the density of water (Aneke and Okafor, 2005).

**Specific surface area ($m^{2/}$gm)**

The specific surface areas of the samples were determined using the European Spot Method as described by Santamarina *et al.* (2002) according to the following formula

$$S_s = \frac{1}{319.87} \times \frac{1}{200} \times (0.5N) \times Av \times AMB \times \frac{1}{10}$$

where,

$N$ = the number of Methyle Blue (MB) increments added to the soil suspension solution,

$A$v = Avogadro's number ($6.02\times10^{23}$/mol), and $A_{MB}$ is the area covered by one MB molecule.

## Chemical properties

### pH

One gram of the sample was weighed and dissolved in 10 ml of de-ionized water. The mixture was heated and stirred for 3 minutes to ensure proper dilution of the sample. The solution was filtered and pH was determined using a digital pH meter.

### EC

One gram of the sample was weighed and dissolved in 10 ml of de-ionized water. The mixture was heated and stirred for 3 minutes to ensure proper dilution of the sample. The solution was filtered and its EC was determined using a digital EC meter

### Cation Exchange Capacity

CEC was determined by leaching the biochars with neutral normal ammonium acetate solution followed by distillation method (Blake, 1965).

### Total carbon (%)

0.5 g of sample was weight and pre digest with 5 ml Nitric acid ($HNO_3$) for 24 hour and complete digestion was performed after addition of 10 ml of diacid mixture in the digest. Taking the total carbon (%) content was estimated by wet digestion method (Walkley and Black, 1934) as described by Jackson (1973).

### Total N

Total N was determined by the Kjeldahl method (Bremner, 1960).

### Total P

Total P was determined by Vanadomolybdate method.

### Total S

Total S was determined by Turbidimetric Method.

**Heavy Metals**

Calcium, Magnesium, Zinc, Iron, and Copper was determined by Atomic Absorption Spectophotometer using DTPA (diethylene triamine penta-acetic acid) method (Lindsay and Norvell, 1978).

**Heavy Metal (K)**

0.5 g of sample was weighed and pre digested with 5 ml Nitric acid ($HNO_3$) for 24 hour followed by addition of 10 ml of diacid mixture for complete digestion. Total K was determined by flame photometer.

**Iodine Adsorption Number (IAN)**

One gram sample was weighed into a beaker and 25 ml of standard iodine solution (0.023 M) added. The mixture was swirled vigorously for 10 minutes and filtered by means of a funnel impregnated with clean ashless glass wool. 20 ml of the clear filtrate was titrated with the standard (0.1095 M) thiosulphate solution to the persistent of a pale yellow colour. 5 ml of freshly prepared starch indicator was added and titration resumed slowly until a colourless solution appeared, the procedure was carried out two more times. The titrations were also repeated with 20 ml portions of the standard iodine solution not treated with the sample to serve as the blank titration. The iodine number (IAN) was calculated from the relationship

$$IAN = \frac{12.69\ N\ (V_2 - V_1)\ \text{mole iodine/g sample}}{W}$$

where:

**N** = the normality of thiosulphate solution

**$V_1$** = the volume of the thiosulphate (ml) used for the titration of the sample –treated aliquot.

**$V_2$** = the volume of the thiosulphate (ml) used for the blank titration,

**W** i= the mass of the sample used (g).

**Biochar for soil moisture conservation**

A set of pot culture experiment in poly house taking *toria* as test crop was conducted with four biochars produced from (i) rice straw, (ii) rice husk, (iii) *toria* stover and (iv) bamboo leaves. Four hundred gram of soil (preferably light textured) in 500 gram capacity of plastic pot replicated thrice was designed statistically (fac*toria*l CRD) with four doses of biochars (0 0.5, 1.0 and 1.5% $wt.wt^{-1}$). Initially, a moisture level at field capacity was maintained and periodical volumetric soil moisture content (upto 70 days) was monitored to evaluate their efficiency.

The periodical moisture status of the pot is measured to evaluate their efficiency.

## Results and Discussion:

The efficiency of four types of biochars *viz*. rice husk, rice straw, *toria* stover and bamboo leaves to retain soil moisture content was evaluated with graded doses of biochars at 15 days interval up to 75 days of experimentation. Gravimetric soil moisture content decreased significantly with the progress in days of experimentation irrespective of types of biochar used. However, increase in biochar doses increased the soil moisture content significantly over the one where no biochar was applied. Soil water retention capacity is dependent on the distribution of soil pores, which are largely regulated by soil particle sizes (texture), structural characteristics (aggregation), and soil organic matter (SOM) content (Verheijen *et al*. 2009). Therefore, with high porosity, large inner surface area, and the potential ability of affecting soil aggregation through interactions with SOM, minerals, and microorganisms, biochar applied to soils also could change soil moisture retention capacity (Asai *et al*. 2009; Brockhoff *et al*. 2010). Highest efficiency to conserve soil moisture over the days of study period was due to application of bamboo leaves biochar. This might be attributed to low BD, less dimension of particle size, high porosity and high pore volume of bamboo leaves derived biochar. Similar results were reported by Novak *et al.* (2009), Chan *et al.* (2007), Asai *et al.* (2009), Major *et al.* (2009) etc. All the biochars, except rice husk, maintained soil moisture content above PWP at 75 days, maximum being recorded at bamboo leaves biochar.

## Conclusion:

As expected, the application of biochar had effects on plant available water in soil. Highest efficiency to conserve soil moisture over the days of study period was due to application of bamboo leaves biochar. All the biochars, except rice husk, maintained soil moisture content above PWP at 75 days, maximum being recorded at bamboo leaves biochar. The characteristics and reactivity of biochars with soil are highly heterogeneous with batches of production using similar feedstock and pyrolytic conditions and the findings of a study could not be applied universally to all biochar materials. However, for accurate prediction of the effects of biochar towards soil characteristics, moisture content and nutrient availability, a deeper understanding of interactions between soil type, biochar production method, biochar feedstock, application rate and field crops is essential

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## Tables and photographs

Table 1: CHEMICAL PROPERTIES

| | Rice Straw | Rice Husk | Toria Stover | Bamboo leaf |
|---|---|---|---|---|
| pH | 9.46 ± 0.332 | 7.74 ± 0.188 | 8.68 ± 0.154 | 7.96 ± 0.050 |
| EC (dS $m^{-1}$) | 1.005 ± 0.07 | 0.457 ± 0.041 | 1.001 ± 0.09 | 0.27 ± 0.093 |
| CEC [cmol($p^+$)$kg^{-1}$] | 15.67 ± 0.86 | 12.74 ± 1.30 | 14.72 ± 0.69 | 16.68 ± 1.15 |
| T C (%) | 41.16 ± 4.54 | 36.63 ± 1.88 | 39.26 ± 0.38 | 49.42 ± 0.26 |
| T N (%) | 0.526 ± 0.04 | 0.473 ± 0.017 | 0.049± 0.005 | 0.60 ± 0.003 |
| T P (%) | 0.52 ± 0.04 | 0.023 ± 0.002 | 0.032 ± 0.002 | 0.01 ± 0.002 |
| T K (%) | 0.420± 0.028 | 0.237 ± 0.014 | 0.453 ± 0.057 | 0.33± 0.041 |
| T S (%) | 0.05 ± 0.013 | 0.099 ± 0.017 | 0.018 ± 0.005 | 0.06± 0.008 |
| T Ca [(p+)$kg^{-1}$] | 5.234 ± 0.37 | 2.19 ± 0.13 | 3.767± 0.154 | 1.111 ± 0.07 |
| T Mg[(p+)$kg^{-1}$] | 1.32 ± 0.118 | 0.822 ± 0.092 | 1.062 ± 0.074 | 0.14 ± 0.047 |
| T Cu [(p+)$kg^{-1}$] | 43 ± 4.35 | 17.3 ± 2.91 | 8.6 ± 2.01 | 11.6 ± 2.27 |
| T Zn [(p+)$kg^{-1}$] | 162.6 ± 6.80 | 66 ± 3.50 | 54.6 ± 4.40 | 30 ± 5.73 |

| | | | | |
|---|---|---|---|---|
| **T Fe [(p+)kg$^{-1}$]** | **5.49 ± 0.50** | **2.918 ± 0.213** | **16.655 ± 0.39** | **4.64± 0.246** |

**Table 2: PHYSICAL PARAMETERS**

| | | | | | |
|---|---|---|---|---|---|
| **Moisture (%)** | | **3.38 ± 0.33** | **4.9 ± 0.60** | **4.88 ± 0.49** | **3.26 ± 0.53** |
| **Ash content (%)** | | **24.9 ± 3.05** | **13.17±1.44** | **5.63 ± 0.38** | **3.70 ± 0.30** |
| **BD g/cm3** | | **0.72 ± 0.09** | **0.629 ± 0.06** | **0.370± 0.30** | **0.178 ± 0.04** |
| **PD g/cm3** | | **1.91 ± 0.11** | **1.92 ± 0.07** | **2.02 ± 0.20** | **0.85 ± 0.04** |
| **Porosity (%)** | | **61.5 ± 6.15** | **67.25 ± 3.57** | **68.08 ± 3.95** | **78.90 ± 5.30** |
| **Pore Vol.(ml)** | | **0.83 ± 0.09** | **1.05 ± 0.12** | **0.96 ± 0.17** | **1.15 ± 0.11** |
| **Particle Size (µm)** | **L** | **326 ± 26.9** | **153 ± 8.38** | **331 ± 11.62** | **310 ± 8.27** |
| | **B** | **350 ± 18.3** | **209 ± 8.38** | **197 ± 12.17** | **147 ± 5.75** |

**Table 3: Moisture retention capacity of rice straw biochar**

| **Biochar dose** | **Rice straw biochar** | | | | | |
|---|---|---|---|---|---|---|
| | Periods (days) | | | | | |
| | 15 | 30 | 45 | 60 | 75 | **Mean** |

| | | | | | | |
|---|---|---|---|---|---|---|
| $B_0$ | 22.3 | 18.4 | 14.2 | 10.1 | 8.7 | **14.7** |
| $B_{0.5}$ | 23.9 | 21.2 | 17.4 | 14.7 | 12.1 | **17.9** |
| $B_{1.0}$ | 24. | 22.0 | 18.5 | 15.2 | 13.2 | **18.7** |
| B1.5 | 25.9 | 22.9 | 19.3 | 15.9 | 13.9 | **19.6** |
| **Mean** | **24.2** | **21.1** | **17.4** | **14.0** | **11.9** | |
| **CD (0.05) 1.38 (B), CD (0.05) 2.68 (P)**<br>**CV (%) 7.15** | | | | | | |

**Table 4: Moisture retention capacity of Toria stover biochar**

| **Biochar dose** | ***Toria* stover biochar** | | | | | |
|---|---|---|---|---|---|---|
| | Periods (days) | | | | | |
| | 15 | 30 | 45 | 60 | 75 | **Mean** |
| $B_0$ | 21.3 | 16.8 | 14.4 | 11.6 | 8.9 | **14.6** |
| $B_{0.5}$ | 23.4 | 20.3 | 17.4 | 14.0 | 11.8 | **17.4** |
| $B_{1.0}$ | 24.1 | 20.9 | 17.9 | 14.5 | 12.3 | **17.9** |
| $B_{1.5}$ | 24.8 | 21.5 | 18.4 | 14.9 | 12.9 | **18.5** |
| **Mean** | **23.4** | **19.9** | **17.0** | **13.8** | **11.4** | |
| **CD (0.05) 1.79 (B), CD (0.05) 3.15 (P)**<br>**CV (%) 6.15** | | | | | | |

**Table 5: Moisture retention capacity of rice husk biochar**

| **Biochar** | **Rice husk biochar** |
|---|---|

| dose | Periods (days) | | | | | |
|---|---|---|---|---|---|---|
| | 15 | 30 | 45 | 60 | 75 | **Mean** |
| $B_0$ | 20.7 | 15.2 | 13.0 | 11.2 | 8.70 | **13.7** |
| $B_{0.5}$ | 21.9 | 17.0 | 14.8 | 13.1 | 11.1 | **15.6** |
| $B_{1.0}$ | 22.3 | 17.8 | 15.1 | 13.3 | 11.9 | **16.1** |
| B1.5 | 23.3 | 18.6 | 15.8 | 13.9 | 12.4 | **16.8** |
| **Mean** | **22.0** | **17.2** | **14.7** | **12.9** | **11.0** | |
| **CD (0.05) 1.19 (B), CD(0.05) 2.48(P)**<br>**CV (%) 8.97** | | | | | | |

**Table 6: Moisture retention capacity of bamboo leaf biochar**

| **Biochar dose** | **Bamboo leaves biochar** | | | | | |
|---|---|---|---|---|---|---|
| | Periods (days) | | | | | |
| | 15 | 30 | 45 | 60 | 75 | **Mean** |
| $B_0$ | 23.4 | 20.7 | 17.5 | 14.2 | 8.8 | **16.9** |
| $B_{0.5}$ | 24.3 | 21.5 | 18.2 | 14.8 | 12.3 | **18.2** |
| $B_{1.0}$ | 25.7 | 22.8 | 19.2 | 15.6 | 13.4 | **19.3** |
| B1.5 | 26.8 | 23.7 | 20.1 | 16.3 | 13.9 | **20.1** |
| **Mean** | **25.0** | **22.2** | **18.8** | **15.2** | **12.1** | |
| **CD(0.05) 1.17(B), CD(0.05) 2.63 (P)**<br>**CV (%) 6.47** | | | | | | |

**Plates:**

Pyrolysis chamber, process and sieving

Rice straw biochar

**TORIA STOVER BIOCHAR**

**RICE HUSK BIOCHAR**

**BAMBOO LEAF BIOCHAR**

**POT CULTURE FOR SOIL MOISTURE ANALYSIS**