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**Research article**

# Effect of biochar on seed germination, early growth of *Oryza sativa* L. and soil nutrients

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**Abstract:** Biochar application to soil has been recognized worldwide for enhancing plant productivity, soil properties as well as long term carbon storage. But very few studies related to biochar have been undertaken in the tropical region. This study has been undertaken in the nursery of Department of Forestry and Environmental Science, Shahjalal University of Science and Technology in Sylhet, Bangladesh to assess the impact of various treatments of three different biochar on germination and early growth of paddy (*Oryza sativa*). The selected species used as feedstock for biochar production are *Albizia saman* (Raintree), *Neolamarckia cadamba* (Kadam), and *Albizia richardiana* (Chambul). Biochar was produced by using Kon-Tiki kiln. Two treatments *viz*. 10 t ha$^{-1}$ and 15 t ha$^{-1}$ for each biochar were applied along with Control. Complete Randomized Block Design (CRBD) was followed as experimental design. Data were analyzed by using Tukey HSD post hoc test and ANOVA. In the case of germination percentage biochar treatments did not show significant ($P < 0.05$) increase compared to control. The 15 t ha$^{-1}$ application rate of Raintree biochar showed significant ($P < 0.05$) increase in root length compared to control. For shoot dry weight 15 t ha$^{-1}$ application rate of Raintree and 10 t ha$^{-1}$ application rate of Chambul showed significant ($P < 0.05$) increase than control. While 10 t ha$^{-1}$ of Kadam biochar showed significant ($P < 0.05$) increase in RWC than control. Soil chemical test showed that Chambul biochar's 15 t ha$^{-1}$ application rate shows strongly significant ($P < 0.001$) increase of NPK than control.

**Keywords:** Biochar - Germination - Early growth - *Oryza sativa* - Soil NPK.

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## INTRODUCTION

Biochar is a product of pyrolysis which is rich in carbon content and produced by heating biomass such as wood, manure or leaves in a closed container with little or no available air. In other words, it is produced by the thermal decomposition of organic material under a limited supply of oxygen ($O_2$), and at relatively low temperatures (< 700$^{o}$C) (Lehmann & Joseph 2009). Biochar has a high stability potential, can remain in the soil for a very long period of time and can contribute in sequestration of atmospheric carbon. Thus the longer period of the stability of biochar can play an important role in reducing the emission of $CO_2$ to the atmosphere (Ahmed *et al.* 2014). Biochar contains a high concentration of stable organic carbon (C) as well as eluated carbon and ash. Several macro and microelements can be stored in the mineral fraction of biochar which may act as a source of mineral substances for microorganisms in soil (Saletnik *et al.* 2016).

Biochar has been accepted for having the potentiality to sequestrated carbon (C) as well as having a beneficial impact on soil quality parameters (Free *et al.* 2010). Biochar application to soil has been reported to increase soil pH, cation exchange capacity (CEC) and soil nutrient availability (Kamara *et al.* 2014). Biochar has also been reported to increase water holding capacity (WHC) of sandy soils, improve soil structure and enhance soil chemical fertility (Free *et al.* 2010).

Generally, biochar can act as a renewable bio resource and has the potentiality to exhibit positive impact on plant growth (Kamara *et al.* 2014). However, some biochar may have unexpected materials such as crystalline


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silica, dioxin, polyaromatic hydrocarbons (PAHs), phenolic compounds and heavy metals that can be harmful to plants, microorganisms and human (Solaiman *et al.* 2012).

Early growth is an important factor for the survival and production of any plant species. Biochar application significantly increases the early growth of seedlings (Thomas & Gale 2015). So it is crucial to study the impact of biochar on early growth of seedlings. Generally, biochar has the ability to enhance crop productivity. But some biochar may have substances that can negatively affect seed germination and early growth of seedlings (Solaiman *et al.* 2012). So it is necessary to test the impact of any biochar on seed germination and early growth, before large scale use. The objective of the study is to assess the effect the various dosages of biochar from different feedstocks on the germination and early growth of paddy and to evaluate the impact of biochar on soil nutrients availability.

## MATERIALS AND METHODS

The study was conducted at the nursery of the Department of Forestry and Environmental Science in Shahjalal University of Science and Technology, Sylhet, Bangladesh. For the preparation of biochar, the selected tropical tree species were *Albizia saman* (Jacq.) Merr. (Raintree), *Neolamarckia cadamba* (Roxb.) Bosser (Kadam) and *Albizia richardiana* (Voigt) King & Prain (Chambul). The wood of these three species were collected from sawmill and dried in sunlight to reduce excess moisture. The biochar kiln which was used to produce biochar was an open fire kiln. Its name is Kon-Tiki biochar kiln which was invented by Ithaka Institute.

The soil was collected from an agricultural field near the University campus. Germination of Paddy seeds were done in clay pots. In each pot 10 paddy seeds were sown. Each biochar application has been applied in three treatments for the study and these are control (c), 10 t $ha^{-1}$ and 15 t $ha^{-1}$. Each treatment had three replications. The treatments were named according to table 1. The Complete Randomized Block Design (CRBD) was used in this study.

**Table 1.** Biochar treatments name with application rate.

| Treatment Name | Feedstock Name of the Biochar | Application rate (t $ha^{-1}$) |
|---|---|---|
| Cont. | Control | 0 |
| R 10 | *Albizia saman* (Jacq.) Merr. | 10 |
| R 15 | *Albizia saman* (Jacq.) Merr. | 15 |
| K 10 | *Neolamarckia cadamba* (Roxb.) Bosser | 10 |
| K15 | *Neolamarckia cadamba* (Roxb.) Bosser | 15 |
| C 10 | *Albizia richardiana* (Voigt) King & Prain | 10 |
| C 15 | *Albizia richardiana* (Voigt) King & Prain | 15 |

Germination data was collected at three days interval and in this study germination data of $7^{th}$ day was used. Shoot length, root length was measured by measuring the scale and fresh and oven dry weight of seedling were measured by digital balance.

Germination percentage was determined by the formula of Close & Wilson (2002) formula:

$$\text{Germination percentage} = \frac{\text{Number of seed germinated during the time interval}}{\text{Total number seeds sown}}$$

Seed vigor of the seedling was calculated by following Abdul & Anderson (1973) formula:

$$\text{Seed vigor} = \frac{\text{germination percentage } \times \text{mean of seedling length}}{100}$$

The water content respective to the fresh weight was determined by following Weatherley (1950) formula:

$$\text{RWC (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

At the end of the initial data collection, soil samples were collected from each plot and analysed in the laboratory of Soil Research Development Institute (SRDI) in Sylhet, Bangladesh to measure the amount of NPK in each soil sample.

Data was analysed statistically at 5% probability level by using one way ANOVA test in SPSS (IBM SPSS Version 23, Armonk, NY; IBM Corp) and Microsoft Excel 2013. In case of obtaining a significant result, multiple comparisons of the mean was obtained by Tukey Honest Significant Difference (HSD) post hoc test.

## RESULTS

*Germination percentage*

Results from Tukey HSD post hoc test shows that there is no significant difference in seed germination of paddy between the treatments and control (Fig. 1).

*Shoot and root length*

The result shows that there is no significant increase in shoot length compared to control (Fig. 2). On the other hand a significant ($P < 0.05$) increase in root length of paddy was observed in case of 15 t $ha^{-1}$ application rate of Raintree biochar compared to control (Fig. 3).

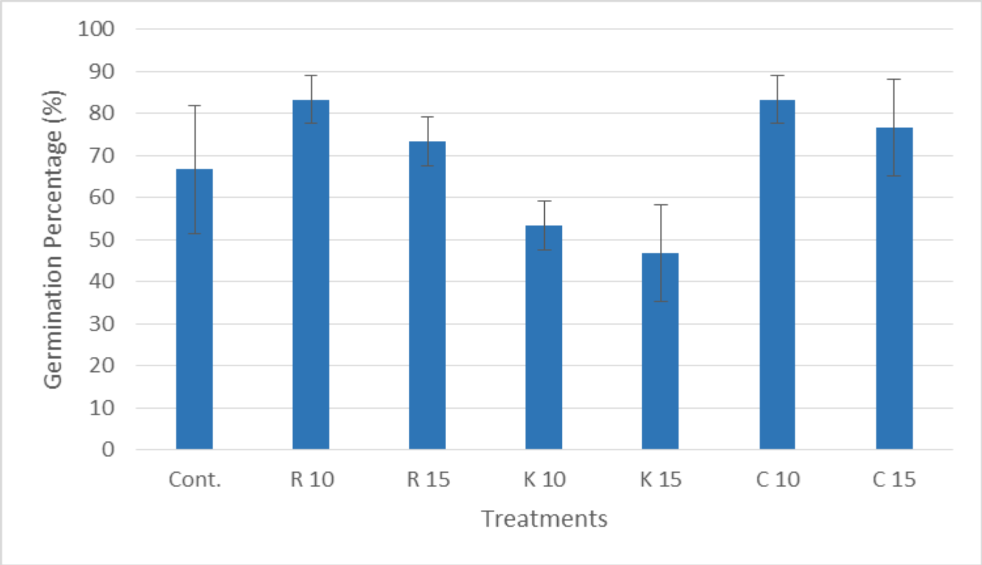


**Figure 1.** Biochar impact on seed germination percentage. [Cont.= Control, R 10= 10 t $ha^{-1}$ of Raintree biochar, R 15= 15 t $ha^{-1}$ of Raintree biochar, K 10= 10 t $ha^{-1}$ of Kadam biochar, K 15= 15 t $ha^{-1}$ of Kadam biochar, C 10= 10 t $ha^{-1}$ of Chambul biochar, C 15= 15 t $ha^{-1}$ of Chambul biochar]

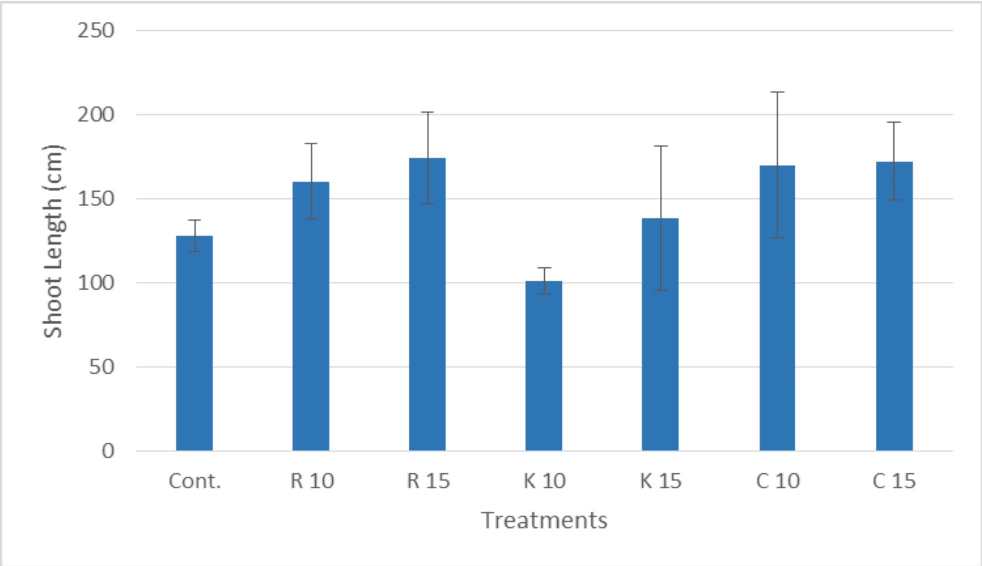


**Figure 2.** Biochar impact on shoot length of Paddy seedlings. [Cont.= Control, R 10= 10 $tha^{-1}$ of Raintree biochar, R 15= 15 t $ha^{-1}$ of Raintree biochar, K 10= 10 t $ha^{-1}$ of Kadam biochar, K 15= 15 t $ha^{-1}$ of Kadam biochar, C 10= 10 t $ha^{-1}$ of Chambul biochar, C 15= 15 t $ha^{-1}$ of Chambul biochar]

*Shoot and root dry weight*

The result shows that 15 t $ha^{-1}$ application rate of Raintree ($P < 0.05$) and 10 t $ha^{-1}$ application rate of Chambul ($P < 0.01$) biochar have a significant increase in shoot dry weight compared to control (Fig. 4). But biochar application did not show any significant impact ($\alpha > 0.05$) on root dry weight of paddy.

*Seed vigor*

The application rate of Raintree biochar (10 t $ha^{-1}$ and 15 t $ha^{-1}$) have significant ($P < 0.05$) increase in seed vigor compared to control treatment (Fig. 5).

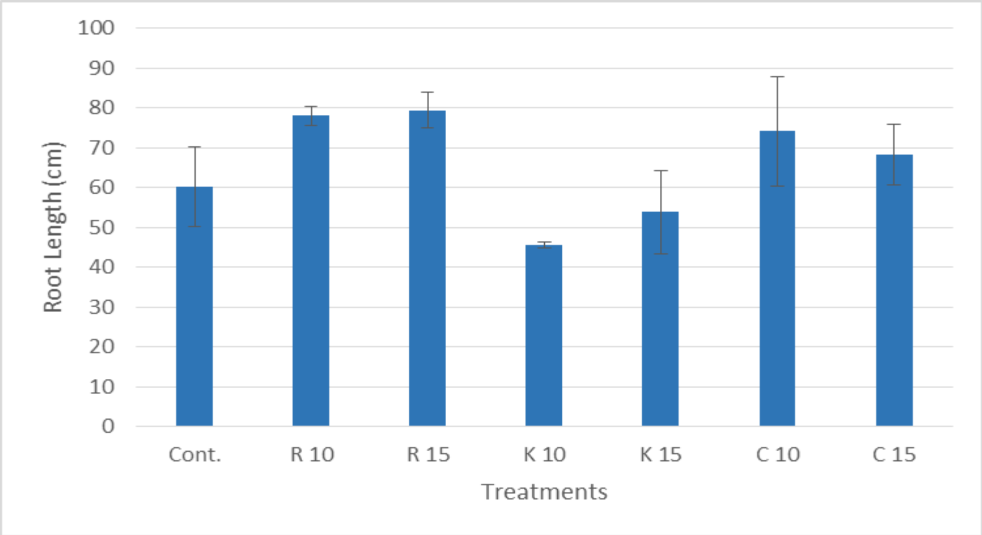


**Figure 3.** Biochar impact on root length of Paddy seedlings. [Cont.= Control, R 10= 10 t $ha^{-1}$ of Raintree biochar, R 15= 15 t $ha^{-1}$ of Raintree biochar, K 10= 10 t $ha^{-1}$ of Kadam biochar, K 15= 15 t $ha^{-1}$ of Kadam biochar, C 10= 10 t $ha^{-1}$ of Chambul biochar, C 15= 15 t $ha^{-1}$ of Chambul biochar]

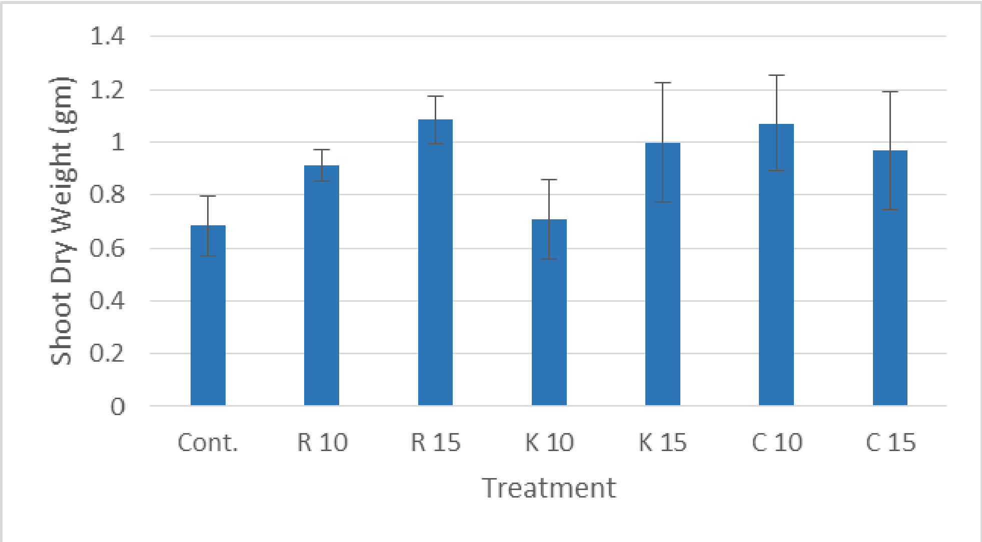


**Figure 4.** Biochar impact on shoot dry weight of Paddy seedlings. [Cont.= Control, R 10= 10 t $ha^{-1}$ of Raintree biochar, R 15= 15 t $ha^{-1}$ of Raintree biochar, K 10= 10 t $ha^{-1}$ of Kadam biochar, K 15= 15 t $ha^{-1}$ of Kadam biochar, C 10= 10 t $ha^{-1}$ of Chambul biochar, C 15= 15 t $ha^{-1}$ of Chambul biochar]

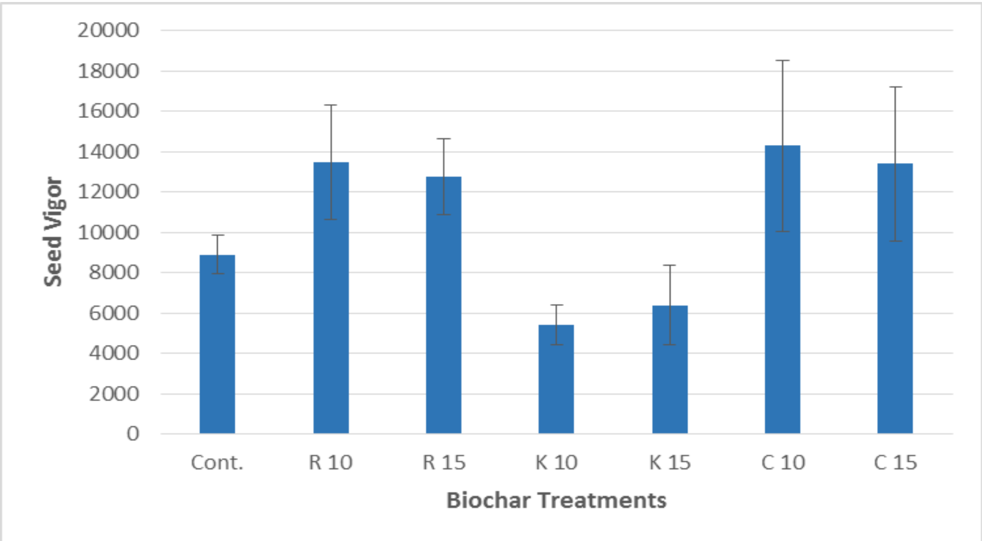


**Figure 5.** Biochar impact on seed vigor of paddy. . [Cont.= Control, R 10= 10 t $ha^{-1}$ of Raintree biochar, R 15= 15 t $ha^{-1}$ of Raintree biochar, K 10= 10 t $ha^{-1}$ of Kadam biochar, K 15= 15 t $ha^{-1}$ of Kadam biochar, C 10= 10 t $ha^{-1}$ of Chambul biochar, C 15= 15 t $ha^{-1}$ of Chambul biochar]

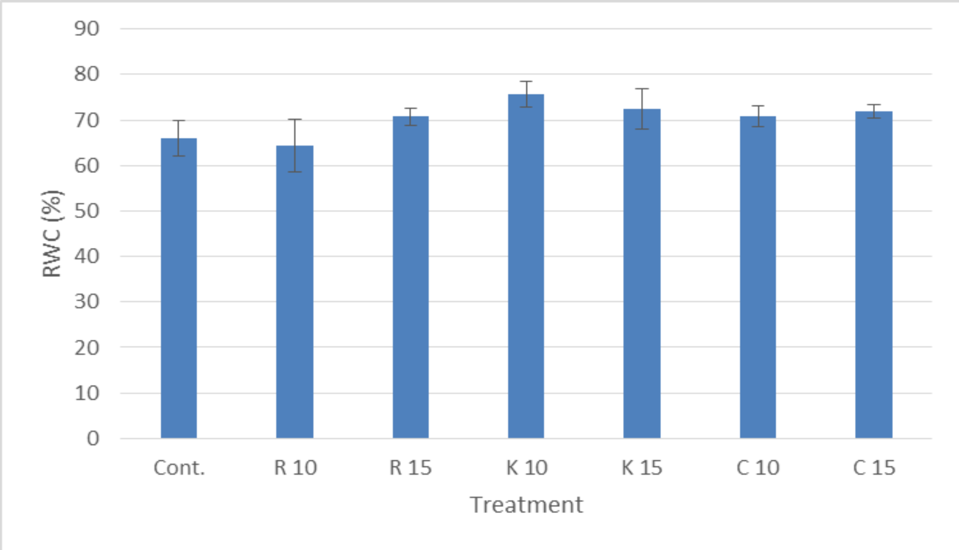


**Figure 6.** Biochar impact on RWC of paddy seedlings. [Cont.= Control, R 10= 10 t ha$^{-1}$ of Raintree biochar, R 15= 15 t ha$^{-1}$ of Raintree biochar, K 10= 10 t ha$^{-1}$ of Kadam biochar, K 15= 15 t ha$^{-1}$ of Kadam biochar, C 10= 10 t ha$^{-1}$ of Chambul biochar, C 15= 15 t ha$^{-1}$ of Chambul biochar]

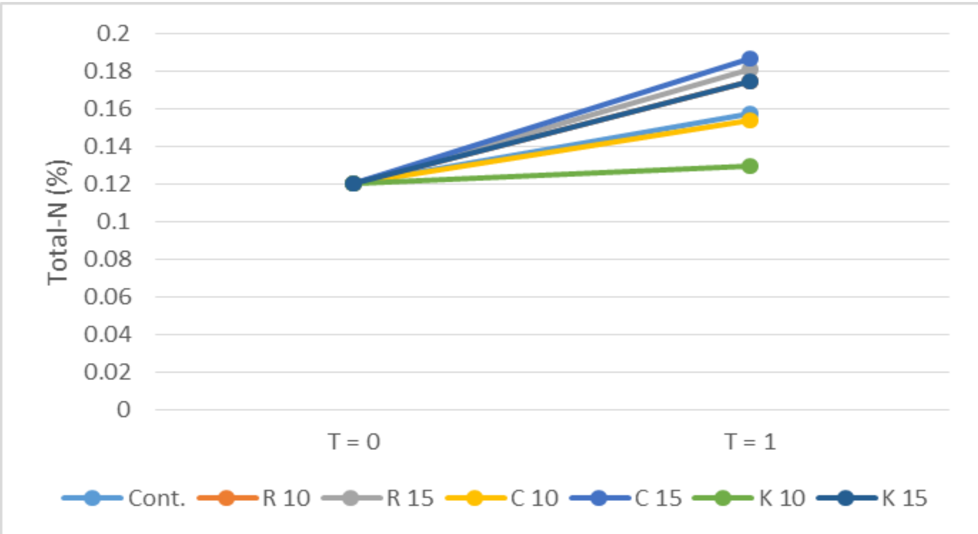


**Figure 7.** Impact of time and treatment on soil N. [T= 0 means beginning of the experiment and T= 1 means end of the experiment. Cont.= Control, R 10= 10 t ha$^{-1}$ of Raintree biochar, R 15= 15 t ha$^{-1}$ of Raintree biochar, K 10= 10 t ha$^{-1}$ of Kadam biochar, K 15= 15 t ha$^{-1}$ of Kadam biochar, C 10= 10 t ha$^{-1}$ of Chambul biochar, C 15= 15 t ha$^{-1}$ of Chambul biochar]

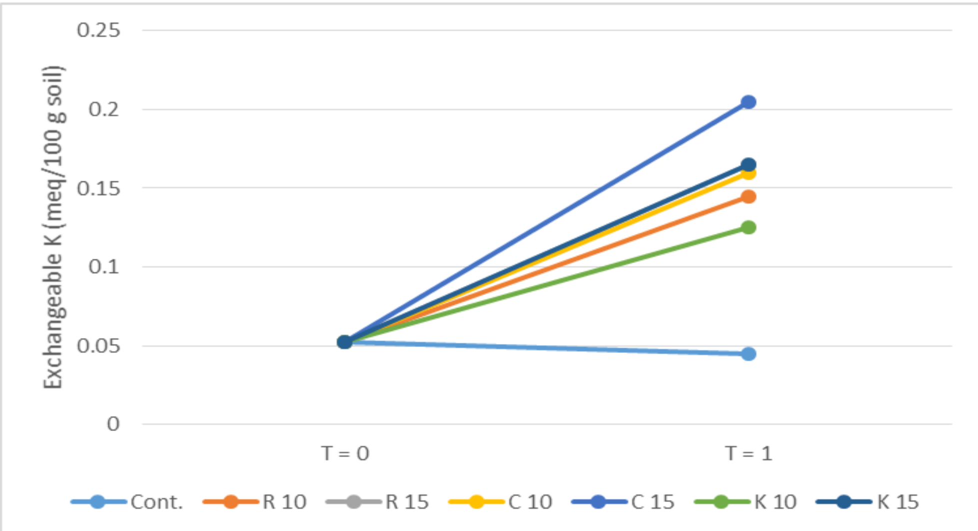


**Figure 8.** Impact of time and treatment on soil K. [T= 0 means beginning of the experiment and T= 1 means end of the experiment. Cont.= Control, R 10= 10 t ha$^{-1}$ of Raintree biochar, R 15= 15 t ha$^{-1}$ of Raintree biochar, K 10= 10 t ha$^{-1}$ of Kadam biochar, K 15= 15 t ha$^{-1}$ of Kadam biochar, C 10= 10 t ha$^{-1}$ of Chambul biochar, C 15= 15 t ha$^{-1}$ of Chambul biochar]

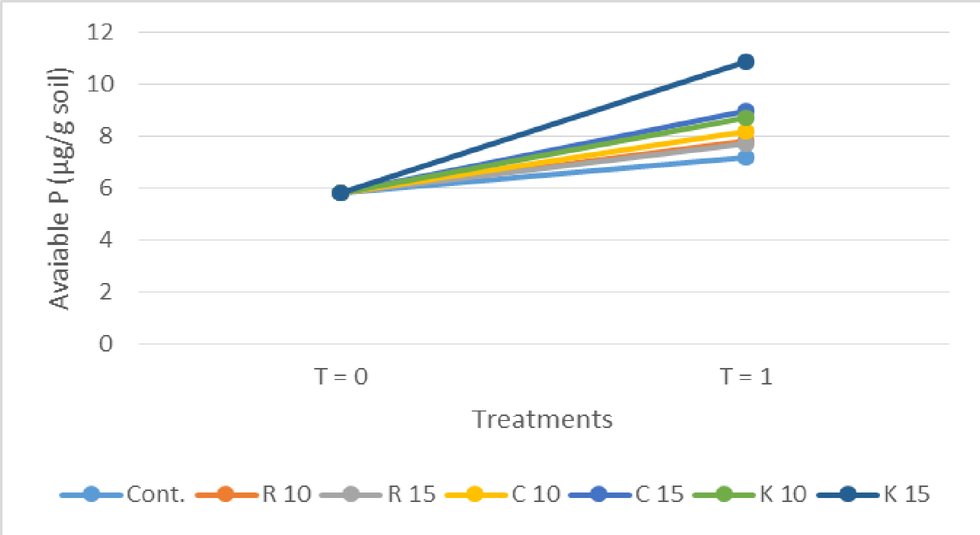


**Figure 9.** Impact of time and treatment on soil P. [T= 0 means beginning of the experiment and T= 1 means end of the experiment. Cont.= Control, R 10= 10 t $ha^{-1}$ of Raintree biochar, R 15= 15 t $ha^{-1}$ of Raintree biochar, K 10= 10 t $ha^{-1}$ of Kadam biochar, K 15= 15 t $ha^{-1}$ of Kadam biochar, C 10= 10 t $ha^{-1}$ of Chambul biochar, C 15= 15 t $ha^{-1}$ of Chambul biochar]

*Relative water content (RWC)*

The result from Tukey HSD post hoc test shows that 10 t $ha^{-1}$ application rate of Kadam biochar shows significant ($P < 0.05$) increase in comparison with control (Fig. 6).

*Soil NPK changes over time*

Results shows that all the treatment has shown an increase soil N where 15 t $ha^{-1}$ application rate of Chambul biochar shows highest changes in soil N and 10 t $ha^{-1}$ application rate of Kadam biochar shows lowest changes in soil N over time.

Except 10 t $ha^{-1}$ of Chambul and Kadam biochar, every biochar treatment shows an increase in soil N in comparison to control treatment (Fig. 7).

In case of soil K, all biochar treatment has shown a better increase over time compared to control, among them 15 t $ha^{-1}$ of Chambul biochar shows the highest increase in soil K over time (Fig. 8).

Besides all the treatments of biochar has shown the better increase in soil P over time compared to control. Among this treatment, 15 t $ha^{-1}$ of Chambul biochar shows the highest increase over time compared to the other biochar treatments (Fig. 9).

## DISCUSSION

Seed germination is very crucial for the production of the crop. Some biochar may contain phytotoxic substances like dioxins, furans, polyaromatic hydrocarbons, phenolic compounds and heavy metals which can be harmful to crop, soil and even human (Solaiman *et al.* 2012).

In this study, the germination percentage of paddy increased in case of Raintree and Chambul biochar was above the control level but the difference was not significant. On the other hand, Kadam biochar shows decrease in germination percentage than control. The study revealed that Raintree and Chambul biochar did not show any negative impact on seed germination while Kadam biochar caused a decrease in germination of paddy seeds.

Other reports on the related study found that there is no negative impact of biochar on the germination of paddy seeds (Kamara *et al.* 2014). Other report based on forest seeds found that biochar application increases germination of seeds (Robertson *et al.* 2012).

The greatest increase in early growth was observed in the case of 15 t $ha^{-1}$ application of Raintree biochar. The root length, shoot dry weight, and seed vigor increased with the application of 15 t $ha^{-1}$ of Raintree biochar. On the other hand, 10 t $ha^{-1}$ application rate of Chambul biochar showed a significant increase in shoot dry weight of paddy.

The Kadam biochar had shown a decrease in germination percentage, shoot length and root length than control but it had shown significantly higher RWC compared to control.

The study found that both the application rate of Raintree and Chambul biochar showed an increase in root length and Kadam biochar show slightly decrease over control. Report of the relevant study showed that root length of paddy seedlings decreased with the application of biochar (Kamara *et al.* 2014). Although the difference between the treatments were not significant.

A significant effect of treatments was found on soil Potassium (K) and Phosphorus (P) and Nitrogen (N). The 15 t $ha^{-1}$ application rate of Chambul biochar showed an increase in soil N, K and P.

On the other hand, Kadam biochar showed relatively less changes in soil NPK compared to other two biochar. The study also revealed that there is no significant difference among the application rates of each biochar.

Other related study found that biochar application increase soil NPK compared to control (Abdul & Abdul 2017). On the other hand (Ghosh *et al.* 2015) found that biochar had no significant effect on soil N.

## CONCLUSION

Germination percentage of paddy was not affected by biochar application. However, results showed that application of Raintree and Chambul biochar significantly affect the early growth of paddy seedlings. On the other hand, Kadam biochar showed a decrease in the early growth of paddy seedlings compared to control. But, the soil analysis showed that biochar had a significant impact on soil nutrient properties.

It seems that biochar has the potentiality to enhance seed germination and plants growth and can increase soil nutrient, while some biochar could have a negative influence. More research is needed to identify the biochars and also their application rates which have beneficial impacts on plant and soil.

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