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BIOCHAR APPLICATION ENHANCES GERMINATION AND GROWTH OF SOME FOREST TREE SEEDLING IN THE NURSERY

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Abstract

Current study assessed the effect of different doses of biochar application on germination and growth of some forest tree seedlings in Bangladesh. Seedlings of the test species were raised in a nursery and treatments were applied for three months. Four doses of biochar concentration including control, 5t/ha, 10t/ha and leachate were applied to the test species seedlings grown following a randomised complete block design experimental setting with three replications. Germination percentage, germination rate index, shoot height, root height, leaf number, leaf area and nodule formation of the test species were monitored and recorded. Collected data were analysed using Microsoft Excel and ImageJ software packages. Results showed that, compared to the control, biochar application had a significant positive effect on germination and growth of all test species. Of the three biochar treatments, leachate was found to be most effective in enhancing germination of the majority of the test species. Results suggest that the use of biochar in nursery soil would ensure better seed germination and seedling growth.

Keywords
Biochar, treatment, leachate, test species, seed germination

1 Introduction

Biochar is a pyrolysis product, a product left over after biomass is heated to temperatures between 300^0 C to 700^0 C under oxygenless environment. Biochar can be produced from any kind feedstock containing biomass, such as rice husk, agricultural waste, paper products, bagasse, animal manures and even urban green waste (GreenFacts 2019).

Biomass (Solid) → Biochar + Liquid or oil (tars, water, etc.) + Volatile gases (CO_2, CO, H_2) (Sarauer, Page- Dumroese & Coleman 2019)

Biochar application was reported to have a significant effect on plant growth and development through alteration of soil properties (Thomas & Gale 2015). Significant changes in soil quality, including increases in pH, organic carbon, exchangeable cations and decrease in tensile strength were observed at higher rates of biochar application (>50 t/ha) (Sohi et al. 2010). Biochar application particularly improved physical properties soil by reducing the tensile strength and increasing the field capacity (Sohi et al. 2010). Application of biochar to soil may alter mineralization of organic matter (Steiner et al. 2008; Wardle et al.1998). This, in turn, is related to the release of nutrients in the soil such as nitrogen (Manzoni et al. 2008; (Mia, Singh & Dijkstra 2017) Murphy et al. 2003). Ultimately, change in the nutrient status of soil may affect the status of seed germination seedling growth. Moreover, the addition of biochar to soil enhances the Phosphorous (P) content of the soil and makes it available to the trees which stimulate early growth. As P is a limiting factor for plant growth in the tropics, the addition of biochar augments the growth of species (Gaskin et al. 2008). A higher dose of biochar application to acidic soils were reported to alter soil pH level to alkaline condition, which also alters soil cation exchange capacity (Ogawa1994).

Biochar application to forest trees was reported having both effects on their growth; increase (Chan et al. 2008; Yamato et al. 2006) or decrease (Deenik et al. 2010). Relatively lesser number of studies have explained the effect of biochar on the growth and development of trees and other woody vegetation, although the literature on this aspect is increasing (Thomas & Gale 2015). A good number of studies recorded the positive impact of biochar on tree growth in the boreal and sub-boreal ecosystems (Pluchon et al. 2014; Robertson 2012), but such studies are limited in tropical and temperate regions (Fagbenro, Oshunsanya & Onawumi 2013; Thomas & Gale 2015). Moreover, the necessity of investigations to examine the effect of biochar application to species level response at the local environmental setting has not been diminished (Thomas & Gale 2015).

The present study assessed the effect of the application of biochar on seed germination success of five selected forest tree species in a local environmental condition in Bangladesh. It also assessed the effects of biochar application on germination and early seedling growth (shoot length, collar diameter, leaf number, root length, and root diameter) of the test species.

2 Materials and methods

2.1 Study location

The experiment was carried out in the nursery of the Department of Forestry and Environmental Science (FES) at Shahjalal University of Science and Technology (SUST), Bangladesh. Geographically, SUST (24°54'39"-24°55'38" N and 91°49'35"-91°50'17" E) is located in the Sylhet city in north-eastern Bangladesh (Figure 1). The area is warm and humid in summer and cooler in winter. The annual temperature is generally as high as 33.2º C and the minimum is as low as 13.6º C. The annual rainfall is approximately 3335 mm. Soil is loam to clayey loam with reddish-brown hue.

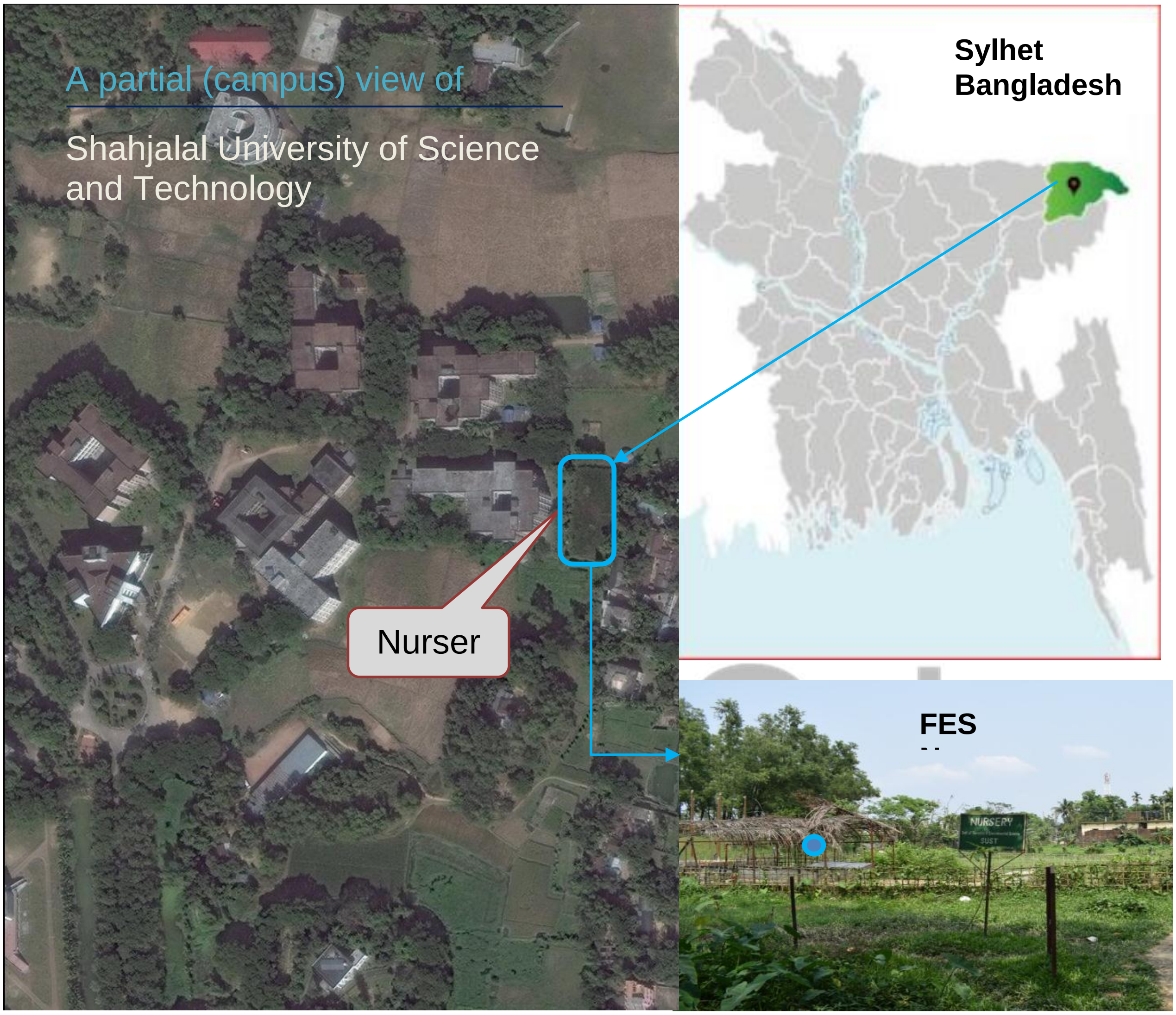

Figure 1: Location of the study site on the Google Earth image in Sylhet district in Bangladesh

2.2 Biochar and leachate preparation

Biochar was prepared in June 2016 in the nursery of the Department of Forestry and Environmental Science at Shahjalal University of Science and Technology (SUST), Sylhet, Bangladesh, following a traditional method. The organic material that is transformed to biochar is referred to as feedstock. Any organic material can be used as feedstock. Different feedstock can produce different types of biochar having a different level of nutrient content. We used chips of Acacia wood as feedstock at medium temperature (350ºC-400ºC) to produce biochar (Figure 2).

Biochar leachate was prepared by washing biochar with water. To get the leachate, we firstly measured the volume of biochar in cm^3 and then washed with an equal amount of water. For example, 500 cm^3 of biochar was washed with 500 ml of water to it. In the experiment, a total 1800ml biochar leachate for 60 pots was prepared and used.

Figure 2: Biochar preparation from chips of Acacia wood

2.3 Potting media preparation with treatments

Seedlings of five purposively selected forest trees were used as test species to examine the effect of biochar on germination and early growth. Of the five species, four were native (indigenous) leguminous species and one was an exotic species (Table 1). These tree species are widely used in Bangladesh mainly for timber, fuelwood and fodder. Seedlings of these five species were raised and exposed to treatments during the experiment.

Table 1: Name of the test species used in this research

Species scientific name	Species local name	Status	Family
Acacia auriculiformis	Akashmoni	Native	Mimosaceae
Albizia procera	Sil koroi	Native	Mimosaceae
Acacia mangium	Mangium	Native	Fabaceae
Pongamia pinnata	Kroch	Native	Fabaceae
Hevea brasiliensis	Rubber	Exotic	Euphorbiaceae

Collection and preparation of potting soil: For preparing the potting media, fresh forest soil (up to 5 cm depth) from the plantation of SUST campus was collected 3-4 weeks prior to filling the tubs (15 cm). The soil was properly sieved using a sieve (<3mm) to remove the gravels, stones or any other large particles. The sieved soil was mixed up thoroughly and freed from any types of grass and organic wastes. This soil at this stage was termed as fresh soil which was used to fill the seedling pots. Some samples of the fresh soil were analyzed in the laboratory of Soil Research Development Institute (SRDI), Bangladesh, to find the soil elements. The soil was added with biochar and used as media in the pots to grow seedlings.

Specifying treatments: The soil was thoroughly mixed with different doses of biochar referred to as treatments. Four treatments were specified namely control, 5t/ha biochar, 10t/ha biochar and biochar leachate. For 5t/ha and 10t/ha treatments, the calculated amount of biochar needed was 90g and 180g respectively.

Collection of nursery pots: Seedlings for this research were raised in regular-sized pots. Sixty pots were collected from the local market. Each circular pot had a radius of 12 cm. So, the surface area of pot was $A = \pi r^2 = 3.1416 \times (12 \times 12) = 452.39$ cm^2.

Potting media preparation corresponding to treatments: Mixture of soil and biochar put on the pots for seedling growth is referred to as potting media. Fifteen pots were filled with fresh soil without adding biochar which was maintained as control. Another 30 pots were filled with soil and 90g and 180g of biochar which was nominated as 5t/ha and 10t/ha treatments respectively. Other fifteen pots were used for biochar leachate treatment. The biochar was added into the upper 10cm of the pot since seedlings roots absorb most of the nutrients from this layer. The leachates were applied three times, once in every week since seeds sowing. After the third week, normal water was used for irrigation. Thus, in the 1st week, (during the beginning of the experiment), 10 ml leachate/tub was used. After 1 week, another 10ml leachate/tub was used. The same continued for the 3rd week. After the 3rd week, no leachate was added anymore.

Experimental design: The pots in the nursery bed were arranged following a Complete Randomized Block Design (CRBD) approach. As this research devised four treatments (control, 5t/ha, 10t/ha and biochar leachate), pots were arranged in four blocks in the nursery. In every block, there were four treatments for a single species. Treatment for each species was replicated three times. Thus, for four blocks, the total numbers of experimental units were 60.

Figure 3: Layout of the pots in a Complete Randomized Block Design setting for data collection

2.4 **Seed sowing, seedling raising and tending**

Seed collection and pre-sowing treatment: Healthy and disease-free seeds of the selected species were collected from the SUST campus and the Rubber garden located in Sylhet. Collected seeds were carried to the nursery in airtight polybags. The collected seeds of the test species required some pre-sowing treatments. After removing the seeds from the fruits, they were washed to clean off the fruit residues. The seeds were then sanded lightly with sandpaper or nicked at the sides with a sharp knife. Afterwards, hot water bath treatment was applied and keeping the seeds in water for 24 hours. *Hevea brasiliensis* seeds were soaked in water for 8-10 hours.

Figure 4: Pre-sowing treatment of seeds used in the experiment

Seed sowing: For obtaining data on germination success and growth analysis, 5-8 pretreated good and healthy seeds were sown in each potting media replicating thrice. After three weeks, when seedlings were grown, thinning of the seedlings were done weeks keeping 3 seedlings per pot.

Tending the seedlings in the nursery: Maintenance of the seedlings through tending operations was an essential practice in the nursery for their proper growth and development. After the germination, the pesticide was used to protect the seedlings from the insect attack. Watering was carried out regularly in the morning or the afternoon. Watering was done using a fine shower so that the seedlings did not get physically damaged. Weeds compete with the crops for nutrients, which ultimately results in poor seedling growth. Weeds and grasses from the pot were regularly removed during the experimental period.

Soil analysis: Biochar treated soil was analyzed for soil pH value (5.5-6), soil total Nitrogen (0.078%), organic matter content (1.72%), and soil Potassium (0.05(mq/100g)) content following standard methods.

2.5 **Harvesting, data collection and analysis**

After the germination of seedlings in the treatment pots, several physical parameters of the seedlings were measured. Plants were harvested after the fourth month of their appearance. To assess the effect of biochar application on germination and early seedling growth, data were collected on some physical parameters including shoot length, collar diameter, leaf number, root diameter and root length.

Germination percentage estimation: Emergence of the seedlings from the seeds were recorded daily for each test species till the last germination. The performance of germination was analyzed using the formulae by Rho and Kil (1986) as follows:

1. Relative germination ratio (RGR) = $\frac{\text{Germination of tested plant}}{\text{Germination ratio of control}} \times 100$

2. Relative germination ratio (RGR) of shoot = $\frac{\text{Mean length of shoot of tested plant}}{\text{Mean length of control}} \times 100$

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3. Relative germination ratio (RGR) of collar diameter = $\frac{\text{Mean collar diameter of tested plant}}{\text{Mean diameter of control}} \times 100$

4. Relative germination ratio (RGR) of leaf = $\frac{\text{Mean number of leaf of tested plant}}{\text{Mean leaf number of control}} \times 100$

5. Relative germination ratio (RGR) of root = $\frac{\text{Mean length of root of tested plant}}{\text{Mean length of control}} \times 100$

6. Relative germination ratio (RGR) of root diameter = $\frac{\text{Mean diameter of root of tested plant}}{\text{Mean diameter of control}} \times 100$

For the growth analysis, data on the following parameters were obtained.

Shoot length (cm): For determining the early growth of tropical seedlings, a tape was used for measuring the height of shoot. Data were collected periodically so that the periodical growth in height could be measured.

Leaf number: Leaf numbers of each species were measured, and data were recorded in a notebook.

Leaf area (cm²): For obtaining the area of the individual leaves, leaf images were analysed using ImageJ software.

Root length (cm): After the end of the experiment, primary root length was measured for each seedling and data were recorded in a notebook.

Root nodules: Leguminous species formed root nodules (Figure 5). The total number of root nodule was measured and recorded.

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Figure 5: Root nodule formation of leguminous species grown under the experimental conditions

Seedling height (cm): Seedling height was measured by using (cm) measuring scale in every week for each individual species and data was recorded in a notebook.

Shoot length, collar diameter, leaf number, root length, root diameter, seedling height were recorded every week, and monthly mean shoot length of seedling was calculated for each species in each treatment.

Statistical Analysis: The collected data were analyzed using MS Excel statistical worksheet. To get a decision on the significant difference between the treatments, means of the observations were compared with the control.

3 Results

3.1 Effect of biochar on seed germination

Effects of different proportion of biochar and its leachate on seed germination of five multipurpose tree species were investigated in this study. Germination potential (%) and Germination rate index (%) were calculated for different treatments.

3.1.1 **Germination Potential (%)**

The emergence of radical for each seed was observed every day to calculate the germination potential by dividing the number of seed germination by the total number of seeds. The germination potential of each species for different treatments is shown in Figure 6. Biochar leachate treated seeds showed the highest germination potential for all the species except Rubber (Figure 6). Highest germination potential (%) under leachates treatment was found for Sil Koroi (73%) followed by Akashmoni (67%), Koroch (60%) and Mangium (58%) respectively. Overall germination potential of Rubber was not accelerated under any treatments compared to control. It only slightly increased for the treatment of 5t/ha biochar (Figure 6). The lowest germination potential percentage was found for Mangium (30%) and the highest for Koroch (46%) at the control media. Indeed, Koroch was found to show better GP under control and no dramatic increase of its germination potential was found under any treatment though treated seeds showed increased germination potential.

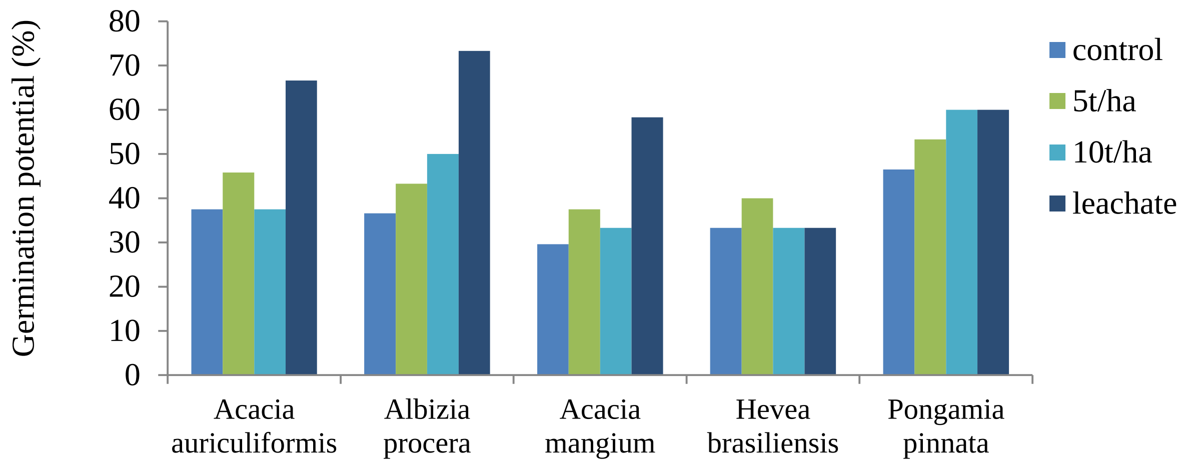

Figure 6: Germination percentage of the test species at 7th day in response to the biochar treatments conducted at the nursery of DFES, SUST

3.1.2 **Germination Rate Index (%):**

Highest seed germination rate index was calculated in biochar leachate treatment for Akashmoni, Sil Koroi and Mangium except for Koroch and Rubber (Figure 7). Koroch

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showed the highest germination rate index under in 5t/ha biochar treatment and Rubber under in 10t/ha biochar treatment. For all species in all treatment, highest seed germination rate index was calculated for Sil Koroi (90%) in biochar leachate treatment followed by Koroch (58%) in biochar 5t/ha treatment, Akashmoni and Mangium (57%) in biochar leachate treatment, and Rubber (39%) in 10t/ha biochar treatment (Figure 7). The lowest seed germination rate index was calculated for Rubber (24%) in the control media.

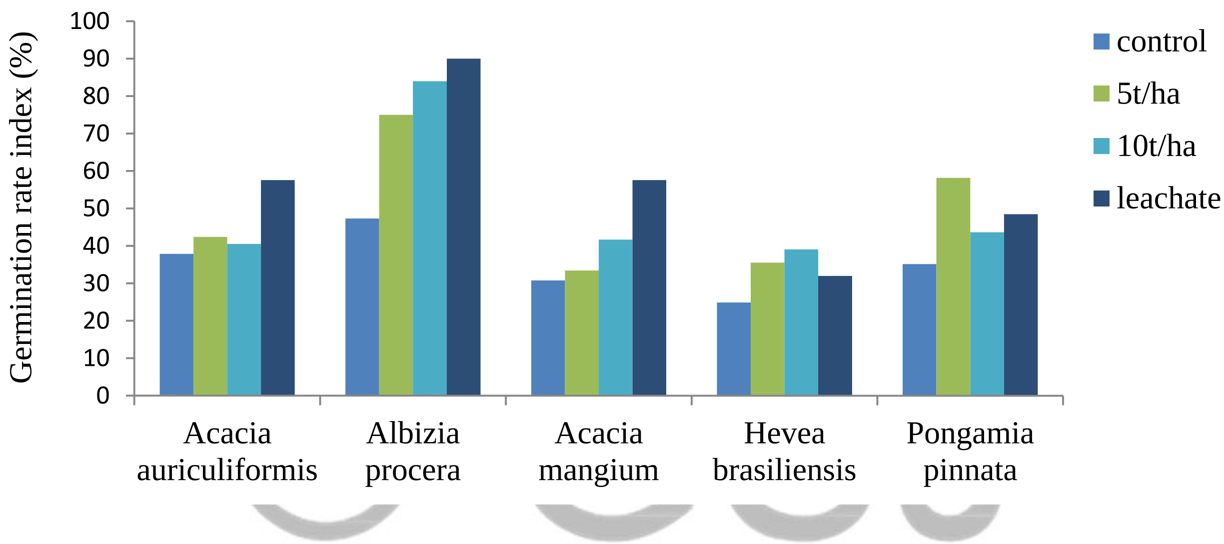
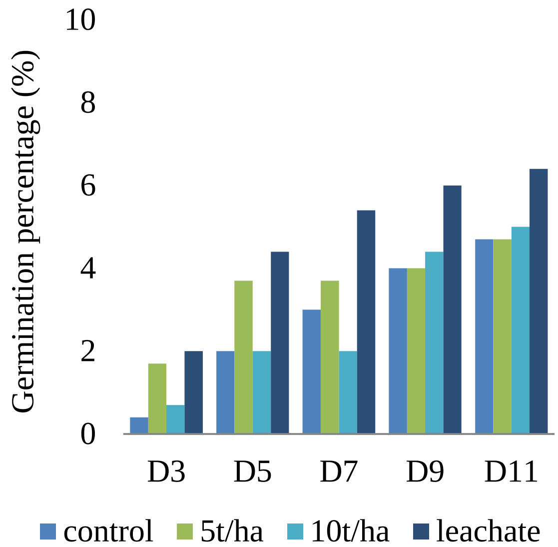


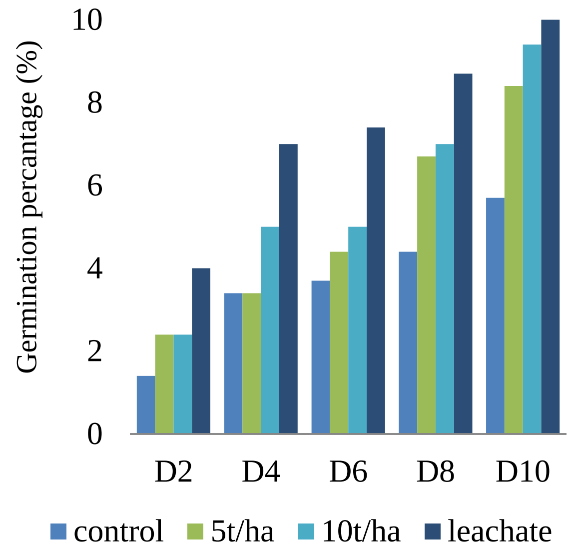
Figure 7: Germination rate index of selected species in response to biochar application

3.1.3 **Seed germination percentage (%) of the test species**

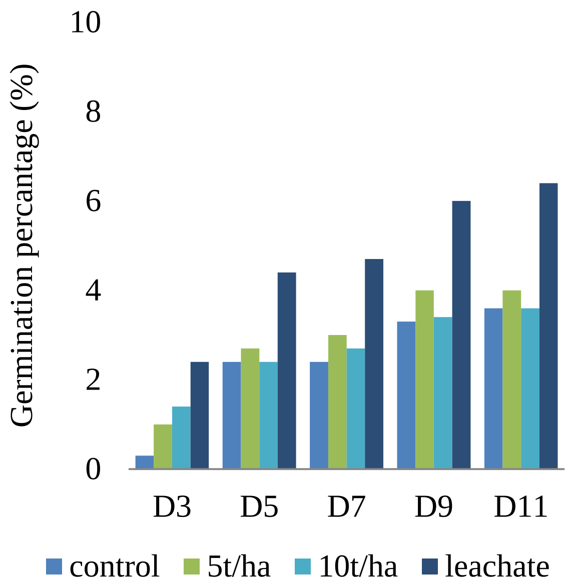
Germination of the seedlings was counted every day during the experimental period to calculate the germination percentage. The highest stimulating effect on germination over the days (3-11 d) was found for leachate treated seeds compared to control except rubber and Koroch (Figure 8). The germination rate at the initial stage of counting at day 3 was 20% for leachates which was 5 fold more than the control, and 10 t/ha biochar, while it was very close to the rate of 5 t/ha biochar, treated seeds (Figure 8). After day 3, the total germination increased for all species through the rate varied with the treatments (Figure 8). Highest germination percentage (%) under leachate treatment was found for Sil Koroi (100%) followed by Akashmoni (65%) and Mangium (64%) respectively. Overall germination percentage of Rubber and Koroch was not accelerated under leachate treatment compared to 5t/ha and 10t/ha treatments of raw biochar. Application of 5 t/ha was found enough to induce the highest germination for both species (Figure 8). The lowest germination percentage was found for Rubber and Koroch (~27%) and highest for Sil Koroi (65%) in the control media.



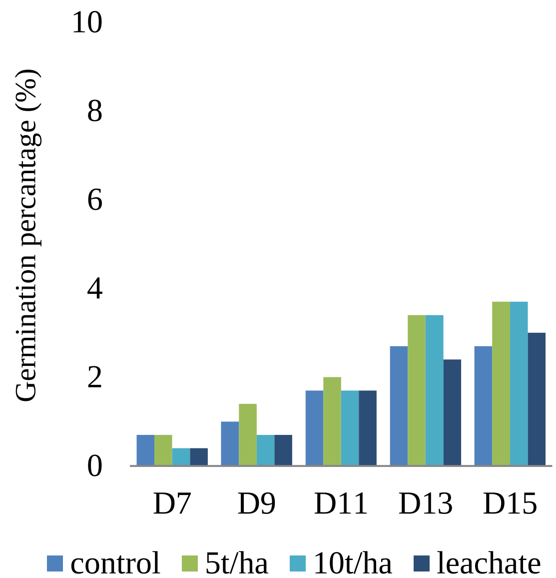
(a) *Acacia auriculiformis*



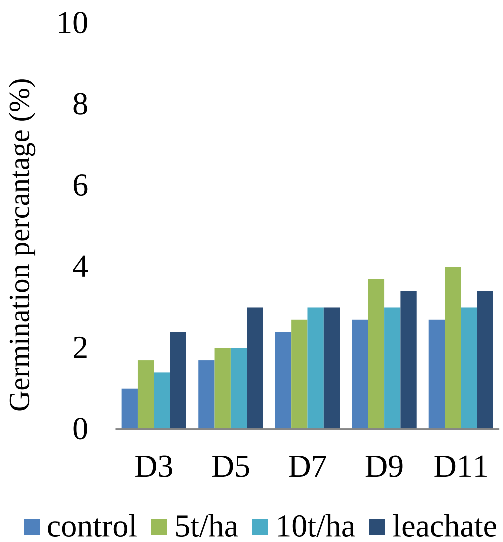
(b) *Albizia procera*



(c) *Acacia mangium*



(d) *Hevea brasiliensis*



(e) *Pongamia pinnata*

Figure 8: Germination percentage (%) of the test seedlings in response to biochar applications

3.2 Effect of biochar on growth parameters

3.2.1 Shoot length of Akashmoni (*Acacia auriculiformis*)

Weekly mean shoot length (cm) of Akashmoni seedlings treated with different doses of biochar was shown in Figure 9. Biochar leachate treated seeds showed the highest shoot length and leaf number while the control (no treatment) showed the lowest shoot length and leaf number (Figure 9). Leachates induced the variation especially after the 5^{rd} week of sowing. However, there was no or very slight variation of shoot length and leaf number for the 5t/ha and 10 t/ha compared to control throughout the period (1^{st} to 9^{th} week). The highest shoot length (19 cm) was recorded in leachate treatment followed by 10t/ha (16cm), 5t/ha (15cm) and control (13 cm). There is a variation of leaf number was observed in the treatment. Among the treatment, the highest mean leaf number was found in the leachate treatment (9), followed by 5t/ha (7), 10t/ha treatments (6).

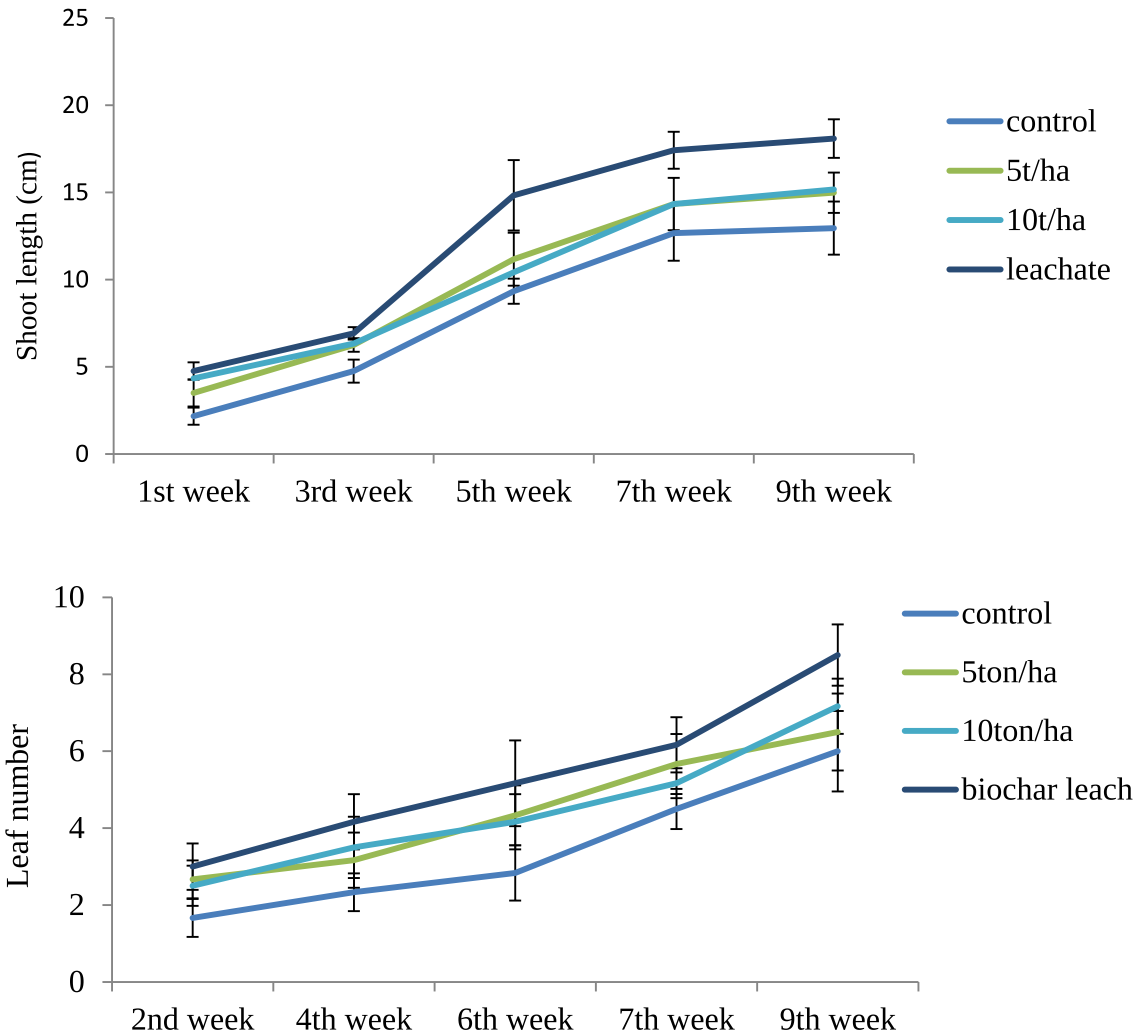


Figure 9: Shoot length and leaf number of *Acacia auriculiformis* in response to biochar applications

3.2.2 **Shoot length of Sil Koroi (*Albizia procera*)**

Effect of different doses of biochar on weakly mean shoot length and leaf number of Sil Koroi was evaluated (Figure 10). Biochar leachate treated seeds showed the highest shoot length and leaf number while the control (no treatment) showed the lowest shoot length and leaf number (Figure 10). Leachate induced the variation especially after the 3rd week of sowing. However, there was no or very slight variation of shoot length and leaf number for the 5t/ha and 10 t/ha treatments compared to control throughout the period (3rd to 8th week). Further, leachate had a remarkable effect on the shoot length of Sil Koroi (15cm), while the similar effect on shoot length (13cm) was found in response to biochar application (both 5 and 10t/ha) compared to control. A little variation was observed in case of leaf number in leachate, 5t/ha and 10t/ha treatments although they showed higher results than the control media. The highest mean leaf number was recorded for leachate treatment (15) followed by, 10t/ha (13) and 5t/ha (12) treatments.

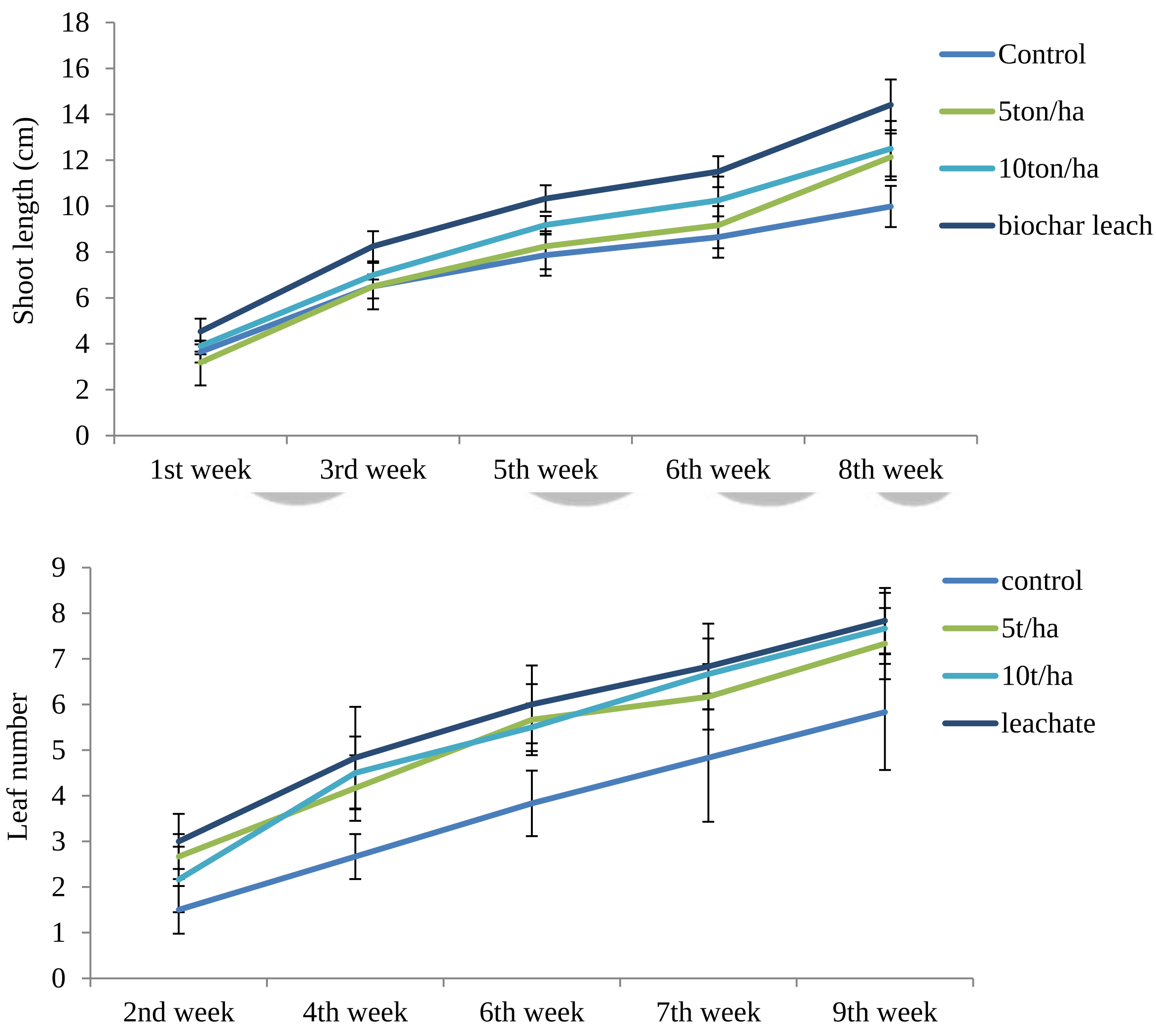
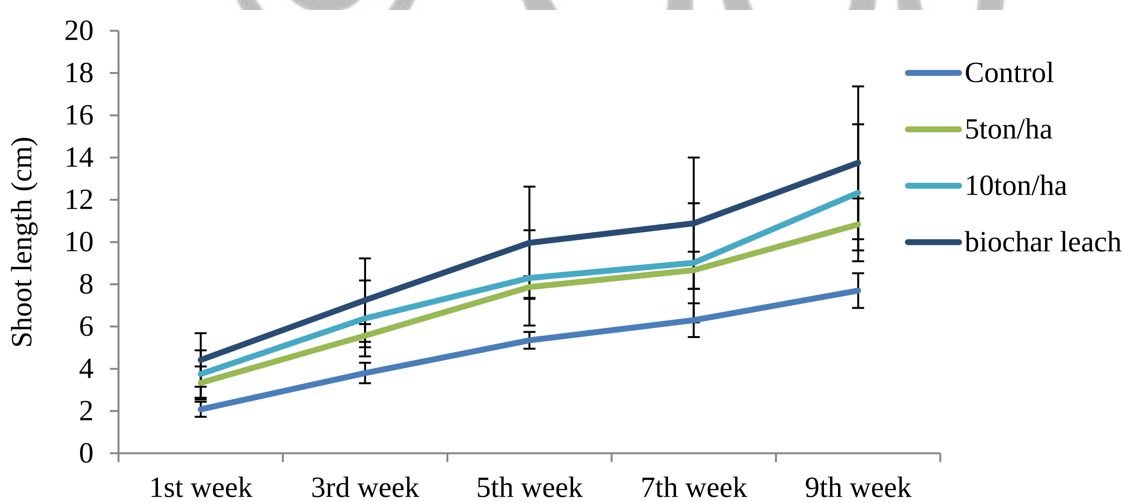


Figure 10: Shoot length and leaf number of *Albizia procera* in response to biochar applications

3.2.3 Shoot length of Mangium (*Acacia mangium)*

Effect of different doses of biochar on weakly mean shoot length and leaf number of Mangium was evaluated (Figure 11). Biochar leachate treated seeds showed the highest shoot length and leaf number while the control (no treatment) showed the lowest shoot length and leaf number. There was no or very slight variation of shoot length and leaf number was found for the 5t/ha and 10 t/ha treatments compared to control throughout the period (3rd to 9th week). The highest mean shoot length was recorded in leachate treatment (14cm) followed by 10t/ha (12cm), 5t/ha (10cm). The lowest number was recorded in control media (7cm). The effect of biochar doses in leaf number showed a different result in different treatment. Highest leaf number was recorded in leachate treatment (9) followed by 10t/ha (8) 5t/ha (7) treatments and the lowest was recorded in control (5).



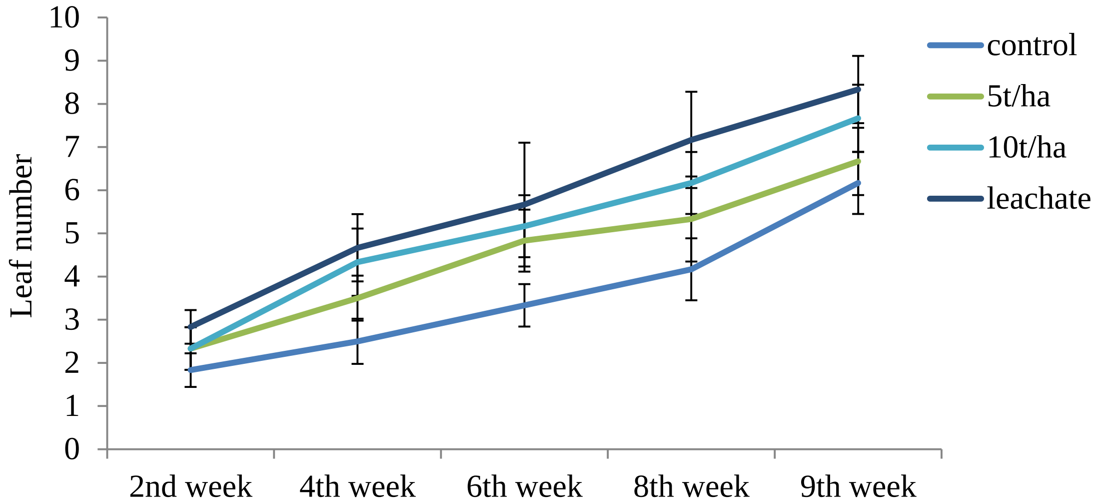


Figure 11: Shoot length and leaf number of *Acacia mangium* in response to biochar applications

3.2.4 **Shoot length of Rubber (*Hevea brasiliensis*)**

Effect of different doses of biochar on weakly mean shoot length and leaf number of Rubber was evaluated (Figure 12). Biochar leachate and 5t/ha treated seeds showed the highest shoot length and highest leaf number. There was no or very slight variation of shoot length and leaf number was found for the 5t/ha and leachate compared to control throughout the period (^{5th} to 9th week). Compared to control, leachate and 5t/ha had a remarkable effect on the shoot length of Rubber (36cm) while the lowest was recorded in 10t/ha (26cm) and control treatment (24cm).

A little variation of leaf number was observed in leachate, 5t/ha, 10t/ha treatments although they showed higher result than the control media. The highest leaf number was recorded for leachate (5) treatment followed by, 10t/ha (4) and 5t/ha (3) treatments.

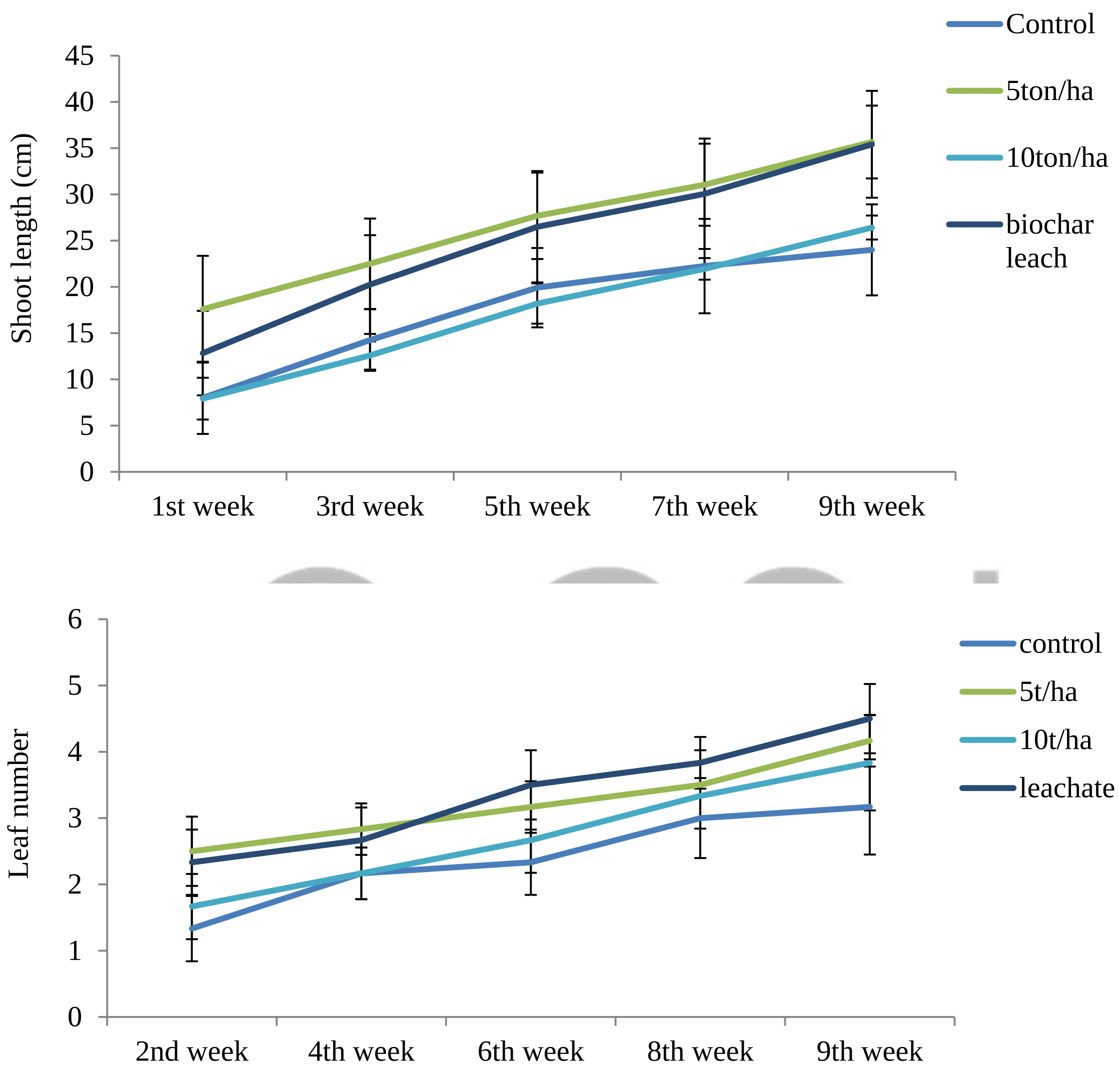
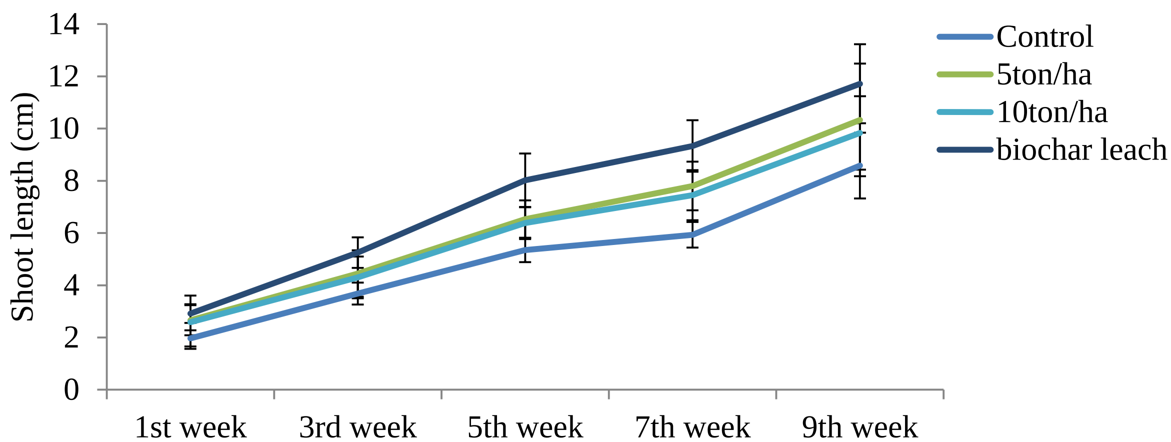


Figure 12: Shoot length and leaf number of *Hevea brasiliensis* in response to biochar applications

3.2.5 **Shoot length of Koroch (*Pongamia pinnata*)**

Effect of different doses of biochar on weakly mean shoot length and leaf number of Koroch was shown in Figure 13. Biochar leachate treated seeds showed the highest shoot length and highest leaf number while the control (no treatment) showed the lowest shoot length and leaf number. Leachates induced the variation especially after the 3rd week of sowing. However, there was no or very slight variation of shoot length and leaf number was found for the 5t/ha and 10 t/ha compared to control throughout the period (3rd to 9th week). The highest shoot length was recorded in leachate treatment (12cm) followed by 5t/ha (10cm), 10t/ha (9cm). The lowest number was recorded in control media (7cm). The effect of biochar doses in leaf number (fig: 4.8) shown a different result in different treatment. The highest leaf number was recorded in leachate treatment (8) and the lowest in control (5). The leaf number at the initial stage of counting at 3rd -8th week shown different result but at the end stage 5t/ha and 10t/ha treatments showed similar result in case of Koroch.



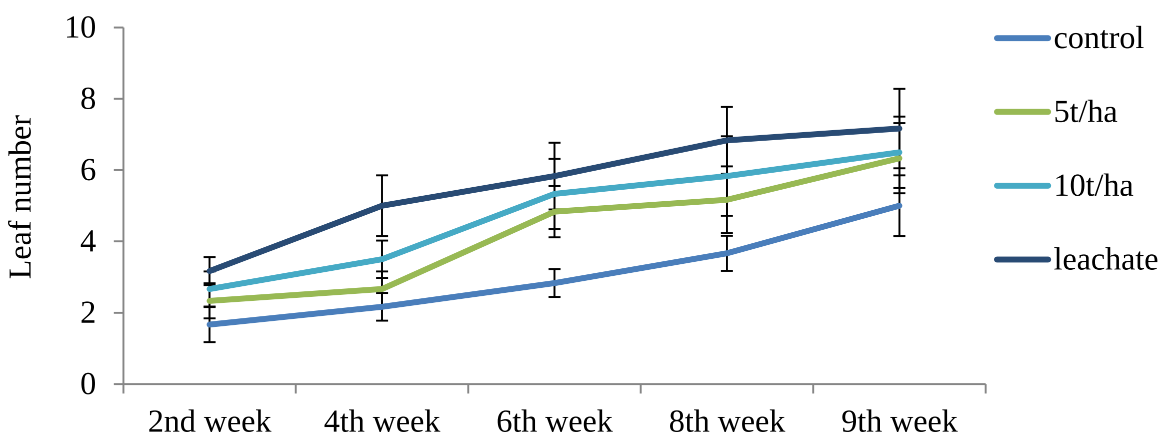


Figure 13: Shoot length and leaf number of *Pongamia pinnata* in response to biochar applications

3.2.6 Mean root length (cm) for test species

Mean root length (cm) of test species in different treatment was given in Figure 14. The result shows the stimulatory effect of root length by biochar treatment on all five test species compared to control. It was observed that the highest root length was calculated in biochar leachate treatment for all test species. The highest mean root length (cm) was calculated for Acacia (46cm), followed by Sil Koroi (38cm), Rubber (32cm), Mangium (31cm) and Koroch (23cm) in leachate treatment. The effect of 5t/ha and 10t/ha treatments for five species were comparatively less different except for Acacia and Koroch. For Koroch, the highest mean root length was founded in both 5t/ha and biochar leachate treatments (23cm). In all species for all treatments, the lowest root length (cm) was recorded for Koroch (23cm) at 10t/ha treatment.

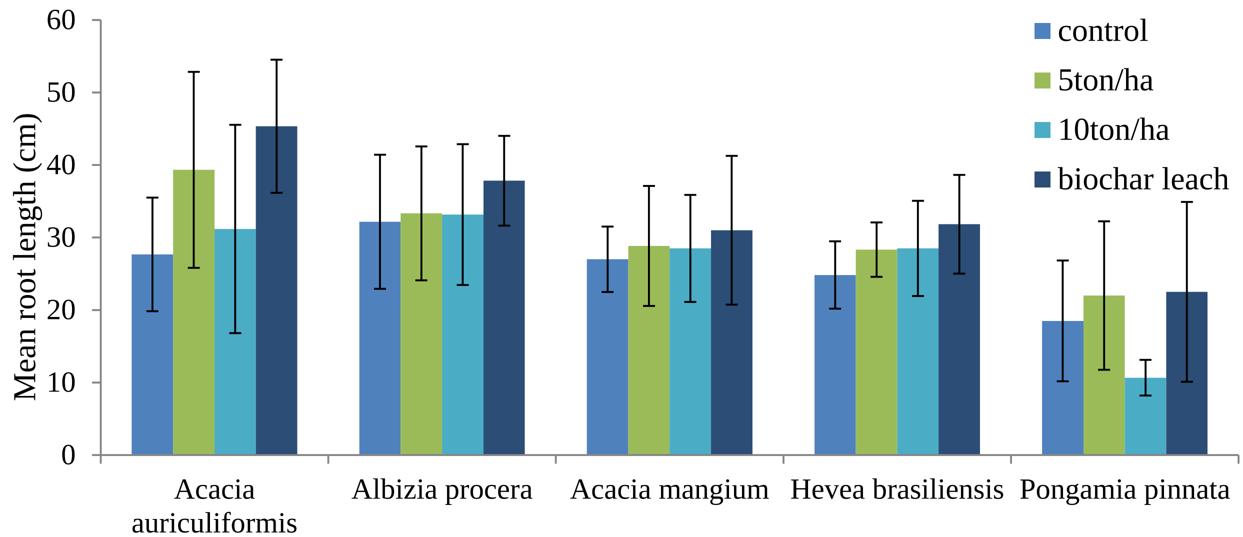


Figure 14: Mean root length (cm) of different species in different treatments of bochar

3.2.7 Root nodules formation of test species

Formations of nodules (%) by test species were shown in Figure 15. The results showed biochar treatment had a stimulatory effect on nodule formation for all four test species compared to control. However, the effect was dose and type dependent. Application of 10t/ha biochar had a more stimulatory effect than the 5t/ha, while the leachates showed an intermediate effect. Particularly, the nodule formations of Acacia, Sil Koroi and Korch were almost double in 10t/ha than the control (Figure 15).

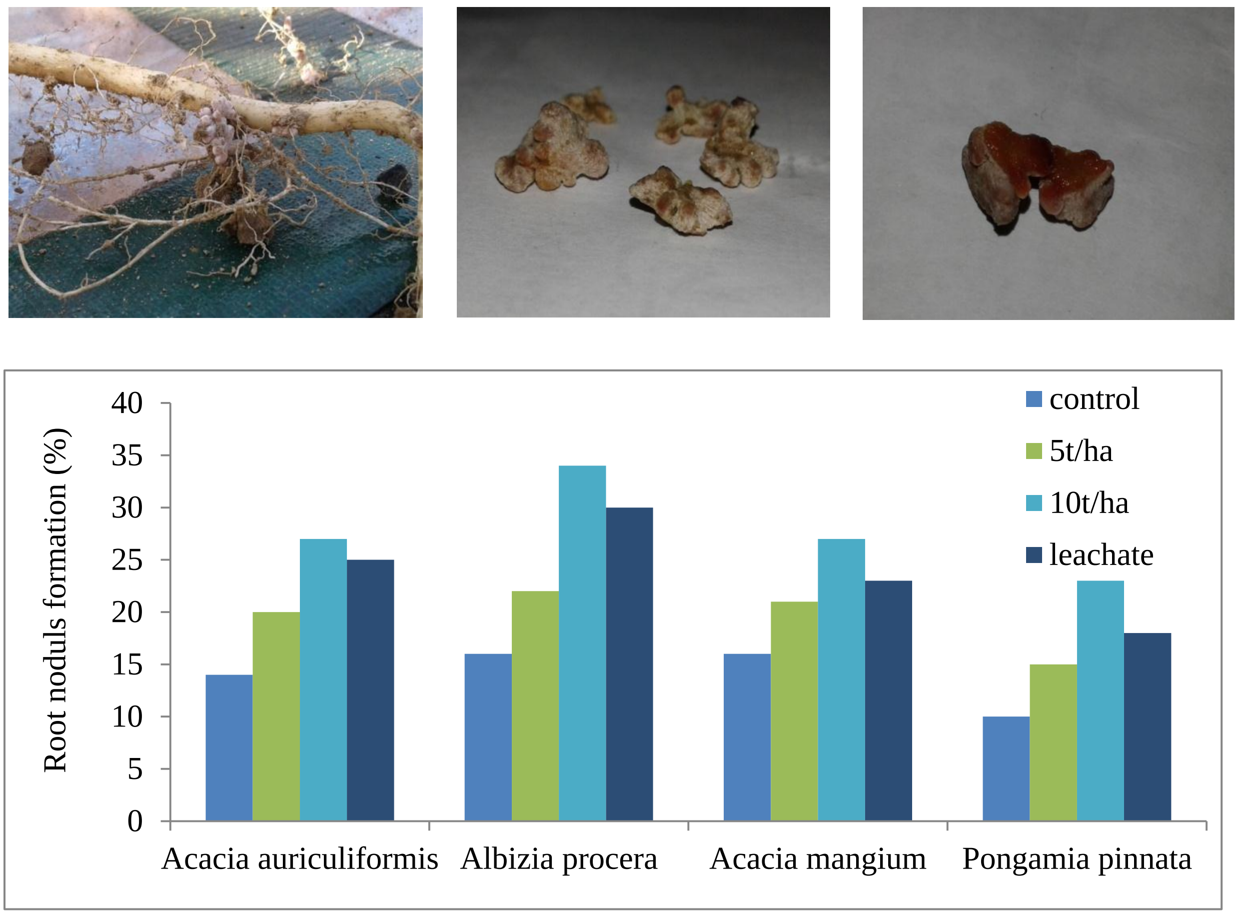


Figure 15: Root nodules formation of the leguminous species in response to biochar applications

3.2.8 **Leaf area (cm²) measurement for test species**

Leaf area (cm²) of test species in different treatment is given in Figure 16. The result demonstrated the stimulatory effect of leaf area by biochar treatment on all five test species compared to control. The effect varied depending on the biochar concentration. Highest leaf area was calculated in biochar leachate treatment for all test species except Koroch. Koroch showed the highest leaf area in 5t/ha treatment (11cm²). The lowest leaf area was found for Sil Koroi (9cm²) and highest for Rubber (12 cm²) in the control media.

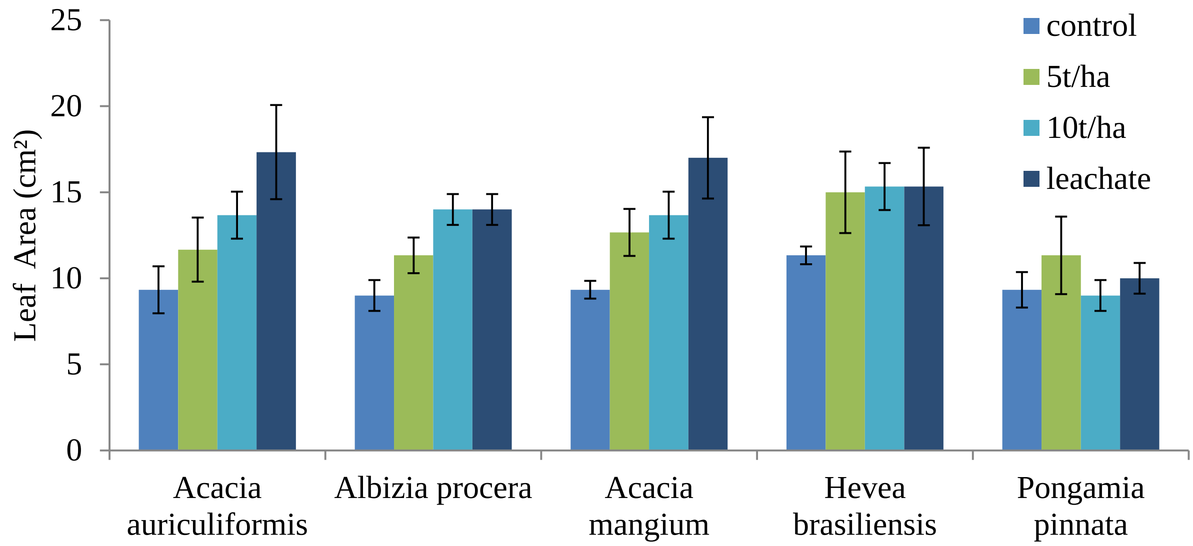


Figure 16: Leaf area (cm²) of the test species in response to biochar applications

3.3 Effect biochar on soil parameters

3.3.1 Soil pH

Soil pH analysis revealed that treatment, block and family had no significant effect on soil pH. It's varied between 5.5 -6.6.

3.3.2 Soil potassium (K)

Potassium (mg/100g) was calculated by the Modified Olsen method. The result showed that biochar had a significant effect on soil K (%). Application of biochar increased the K (0.25 mg/100g) compared to the control (0.05 mg/100g). Potassium (%) had founded very low in control media, but after the application of biochar, it's turned into the optimum stage. It was needed to do further analysis to determine how the categories of treatments and family vary.

3.3.3 Soil nitrogen (N)

Nitrogen (%) was calculated by the KjeJdahl method. The result showed that biochar had a significant effect on soil N (%). Application of biochar increased the nitrogen (0.089%) compared to the control (0.078%). N was found very low in control media, but biochar treated soil showed the optimum result.

3.3.4 Soil phosphorus (P) and organic matter

Biochar application had no significant effect on the treated soil in comparison to the control. Similarly, a fixed variable had no significant effect on soil organic matter.

4 Discussion

4.1 Effect of biochar on seed germination

The seed germination performance studies are important for improved and quality seedling production of many tree species. The present study revealed that biochar treatment influenced the germination period (days) and the percentage of five studied species at different treatment or doses of biochar. It was observed that the application of biochar treatment increased the seed germination percentage and the highest seed germination percentage was found in biochar leachate treatment. The study hypothesized that seed germination performance of five study species would be better in biochar treatment compared to control. Our results indicated that the initial hypothesis proved to be true.

Biochar application enhances plant productivity and yields through a number of mechanisms. As a result of biochar application, the physical condition of soil changes. For example, the blackish colour of biochar modifies the thermal dynamics which enhances the germination process, providing more time in comparison to the control (Genesio et al. 2012). Biochar was also reported to ameliorate the water-holding capacity of the soil (Laird et al. 2010) and promote a gain in vegetation biomass (Kammann et al. 2011). Biochar application was also reported to bring changes in the soil nutrient condition, particularly P and K cycling (Dempster et al. 2011).

Most increases in seedling growth were observed with biochar leachate treatment for all the species except Rubber and Koroch. Rubber and Koroch showed the highest growth in 5t\ha biochar treatment followed by leachate, and 10t\ha treatment respectively compared to control. This finding conforms with other published reports (Budi & Setyaningsih 2013).

Significant effect of biochar application was detected for leguminous species (Budi & Setyaningsih 2013). In the current study, significant increases in germination percentage, germination rate index and shoot height were observed for leguminous species. Such results were expected as leguminous species tend to fix soil nitrogen with the formation of root nodules. These study findings are in line with other reports. Such as, Maraseni (2010) reported that the application of biochar to crops that have a symbiotic relationship with bacteria and fungi could be more beneficial than applying biochar for non-symbiotic crops.

4.2 **Effect of biochar on growth parameters**

The physical or visually determinable attributes of tree seedling are its morphological characteristics. The major morphological criteria often used to describe seedling qualities are shoot height or soot length, stem diameter or collar diameter, leaf number, root height and root diameter. There are some of the bases of qualify good seedling for nursery establishment. These morphological characteristics of plant growth were correlated with the effect of biochar in this study.

Significant effect of biochar on shoot length, root length, leaf number and leaf area of selected five species of this study were recorded among the treatment (5t/ha, 10t/ha and leachate). In every treatment of five species, biochar leachate and 5t/ha showed the highest value and the control showed the lowest value. The study revealed that the growth parameter increased with the application of biochar than the control treatment.

The study revealed significant treatment effects for leguminous species. The result showed the stimulatory effect of nodule formation by biochar treatment on all four test species compared to control. However, the effect was found to be dose and type dependent. Application of 10t/ha biochar had a more stimulatory effect than the 5t/ha while the leachate showed an intermediate effect. Particularly, the nodule formations of Acacia, Sil Koroi, Mangium and Korch were almost double in 10t/ha than the control. Thus, biochar has the potential to shorten the required time to make compost through the proliferation mechanism on symbiont bacteria and fungi, and the ability to increase N levels which promotes the responsiveness of the soil to various concentration of biochar to support higher crop yield (Maraseni 2010).

4.3 **Effect of biochar on soil parameters**

In the current study, no significant effect of biochar treatment was found on soil pH and soil organic matter. This result was obtained because the biochar was produced at low temperature (350ºC - 400ºC) which possessed the same pH value as the fresh soil. Some other studies also revealed a similar impact. Such as Spokas et. Al. (2012) reported biochar production from wood chips of *Eucalyptus saligna* at low temperature (400ºC) had pH value of 7.7, and the value of that of the biochar feedstock and the resulting qualities (pH, C: N ratio, and nutrient content) was inconsistent.

A significant effect was found on soil N and K values compared to the control. However, control showed greater values in soil P. Such results were obtained due to testing the soil at the end of the experiment, and the values of the soil nutrients were detected at that specific time. This study could not analyse how soil nutrients varied at each time of data collection. As a result, at the end of the experiment, it was found that control showed a better result for P.

During the experiment, no blocking effect was found. The reason was that the place of the experiment was very small, and it was conducted on the pots filled with the soil collected from the same area.

5 Conclusions and recommendations

The present study evaluated the effects of biochar on germination and early growth parameter of five forest tree seedlings, including Akashmoni, Mangium, Sil Koroi, Rubber and Koroch. The application of biochar in the soil stimulated the seed germination process. Biochar application also enhanced the growth parameters of five studied tree seedlings in comparison to the control. Findings of this study may be helpful for the Forest Department of Bangladesh, Nursery owner, NGOs, Forestry students and Researchers to know the effects of biochar on germination and early growth parameters. Further studies can evaluate the effects of biochar on germination and early growth of other indigenous and medicinal tree species under both nursery and forest conditions.

6 Contribution of authors

Zinat Rehana Parvin conducted the experiment including biochar preparation, pot setting following the experimental design and nursery data collection. Misbahul Huda helped in data collection and analysis. Mohammad Redowan contributed to conceptualizing the experiment, edited the graphics and manuscript. Mohammad Mostufa Kamal contributed to the conceptualization and write up.

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