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Impact of charcoal on fiber crop, Jute (*Corchorus capsularis* L) as natural polymer with morphological features, biomass production and root development under natural condition at roof top garden

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Abstract

A pot experiment was conducted to evaluate the effect of charcoal as soil amendment on morphological features, biomass production, and root development of Jute plant (Corchorus capsularis L), BJRI Deshi Pat- 10 at roof top garden. Charcoal was applied at the rate of control, 1g, 2g, 3g, 4g, and 5g as the treatments, T0, T1, T2, T3, T4, and T5, respectively. The results show that after 5-weeks of treatment, the highest leaf no, shoot length, shoot dry weight, including root length and root dry weight, were found higher at treatment T3. Charcoal shows the potential to increase the availability of nutrients and stimulate plant performance. From this research, it can be concluded that charcoal alone may be enough for improving growth and biomass development of the jute plant. The study suggests that biomass production of jute can be maximized by applying a medium level of soil amendment, such as charcoal, which is T3.

Keywords: *Jute, Natural polymer, Charcoal, Soil amendment, Pot experiment, Growth, Shoot length, root length, root shoot ratio.*

Introduction

Jute (Corchorus capsularis L- white Jute) is a potential cash crop and natural polymer that belongs to the Mavaceae family, known to Bangladesh as "Golden Fiber" because of earning foreign currency by exporting it. This cash crop strengthens the national GDP and holds economic significance in our country [1], [2], [16], [21]. It is cultivated in an area of about 9,93,000 acres and produces 46,19,000 m. tons in 2005- 2006 [12]. Among the growing countries, Bangladesh ranks in second position in terms of fiber production. In recent years, it has been well focused as considered as natural polymer and a vital sector in the context of economic, commercial, agricultural, industrial, and, more importantly, environmental aspects in Bangladesh as well as the global markets [69],[58], [6], [13]. Thus, the rising demand for jute production is increasing day by day in national and international markets as the products from jute are environmentally friendly and biodegradable. Farmers are also now interested in production and marketing of raw jute because of its economic importance as well as for future potential of global jute market [5] [30], [31], [32],[33],[36], [39], [42], [44], [46] and [55].

As an eco-friendly, annual and major fiber crop, grown well in tropical and subtropical climates, which attains a height of approximately 3-6 meters, with a thickness of about 2- 2.5 cm, and completes its life cycle in 3 months or 90 days. Its 2 important parts, leaves and stalk, could be used in our daily life for consumption and as biomass resources. Besides the potential for fiber, it could be used commercially and exported to foreign countries.

As a sustainable and abiotic stress tolerant and integrated plant biomass, the extraction of fiber could be done in a ecofriendly manner [8],[11],[64], and the extracted fiber from the matured plant used in various types of household products like, bag, carpet, mat, crafts, clothing etc [14], [51]. Besides the fiber, jute sticks are largely used for various domestic purposes as fencing, roofing material, and biomass fuel for cooking purposes, particularly in suburban and rural areas of Bangladesh. In addition, the leaves locally called 'Pat Shak" are consumed as a vegetable by a major part of our population in urban, suburban and rural areas as well as other Asian countries in the world, which contain different types of vitamins, minerals, protein, including antioxidants [30],[56] and [40]. Furthermore, it contains several metabolites that are important to consider for pharmacological research and human health issues, too [3]. Thus, it is not only considered or used as an economic fiber and cash crop, but it has a tremendous demand as a healthy and nutritious vegetable as well as has medicinal values. The plant has immense adaptability, including sustainability, as it is more water-tolerant and can generally be grown in lowlands and also in waterlogging conditions [68]. Besides, it can be grown in different soil types, ranging from clay to sandy loam with medium to lower fertility status.

To evaluate the plant production and maintain the adequate growth, adaptability and yield of Jute production in natural conditions, proper application of amendment is essential to get better biomass yield [7]. In this context, different soil amendments could be used. Jute as an important cash crop that prefers a carbon source.

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Thus, charcoal could be used as a good amendment and carbon-rich soil conditioner for the production of biomass. It is considered a valuable carbon-rich organic matter that serves as a soil conditioner when applied to soil to improve the fertility status of the soil. It has a synergistic effect that promotes plant growth and development. Besides, its application in soil allows better soil management by increasing microbial activities with the release of essential nutrients required by the plant. Thus, charcoal as a good soil amendment, could be added to soil to increase its fertility, water retention capacity, carbon storage[4],[15],[28] and [29], including improvement of the soil health and fertility status of soil.

Jute plants need a number of nutrients for their growth and proper development [66],[70],[71] although applying inorganic fertilizers increases crop yield, but deteriorate soil health as well, resulting in a decrease in crop yield. Charcoal is a carbonized material, which is used to improve soil health and creates a scope to release nutrients slowly as slow releasing amendment. In this present study, charcoal was applied at various rates.

Carbonized materials such as charcoal are responsible for the stability of soil carbon, and their application have a ameliorating effect on increasing nutrient holding capacity, including supply in addition of reduction of soil acidity. Thus, maintains soil organic matter in the tropical and subtropical climate due to rapid rates of decomposition. Furthermore, charcoal as a carbonized material and is a cheap source of carbon in soil. However, the varying levels of amendment treatment had diverse effects on seedling and plant growth enhancement [60]. Some of the amendments increased plant height significantly at low levels but decreased with increasing levels of application. However, medium levels of fertilizer as soil amendment promote growth and yield of plants [19]. Charcoal as a carbon source as well as organic fertilizer, is important as it promotes the growth and development of the jute plant. Therefore, an experiment was conducted to investigate the influence of different levels of charcoal as carbon rich amendment on the growth and development of Corchorus capsularis.

Materials and Methods

A pot experiment was carried out to study the response of jute (Corchorus capsularis) with the variety, BJRI Deshi pat -10, at the rooftop of 3 storied building in Dhaka, Bangladesh. The experiment was conducted to evaluate the impact of various rates of carbon source, such as charcoal, a potential soil amendment, on morphological features, biomass production, and root development of the mentioned Jute plant as a natural polymer or fiber crop. In the experiment, 6 treatments of charcoal were applied at the rate of control, 1g, 2g, 3g, 4g, and 5g as the treatments, T0, T1, T2, T3, T4, and T5, respectively for a period of 5 weeks.

The treatment consisted of 6 levels of charcoal treatments (0.5, 1.0, 1.5, 2.0, and 2.5% of charcoal by soil weight per pot). For the experiment plastic cups were used and each cup was filled with 200g of air-dried soil. The seeds of Deshi pat 10, were collected from the Bangladesh Jute Research Institute (BJRI), Dhaka.

The soil sample used in this experiment was collected from Potuakhali district, Kalapara, Upazela of coastal areas of Bangladesh, at a depth of 0 – 15cm by the composite soil sampling method. The soil was then dried and passed through a 2mm sieve at the laboratory to remove the gravel and fractions of roots.

The sample was then analyzed in the laboratory before setting up the experiment to check the nutrient status and other physiochemical properties of the soil.

The soil has the following properties

Textural Class: Silty Clam Loam, Sand- 11%, Silt- 50%, Clay-39%. EC - 289µS/cm, pH- 6.0, Moisture - 4.7%, Organic carbon-0.43%, OM – 0.74%, Total N- 0.04%, available P-19.81 ppm, available Na- 0.69 ppm, exchangeable K 0.5 meq/100 g, Exchangeable Ca- 18.09 meq/100 g, and exchangeable Mg - 5 meq/100g soil.

The experiment was laid out in Randomized Block Design (RBD) with 6 treatments and 3 replications during the season March to May 2024 at Dhaka, Bangladesh, where treatment consisted of six levels of charcoal (0%, 0.5%, 1.0%, 1.5%, 2.0% and 2.5% per weight of soil) application.

After 5 weeks old jute plants in the cup were sampled manually by carefully uprooting the plants and washing them with tap water. Immediately after harvesting, the plants were then taken to measure fresh weight and separated into root and shoot, and dry weight, which were dried in an oven at at 65°C in the laboratory for 24 hours. The dry weight of the below and aboveground samples was then recorded.

In the present research the following measurements were used as indicators of plant growth and development assessment of the mentioned plant in terms of shoot and root lengths, leaf number per plant, dry weight of aboveground and belowground parts, including root shoot ratio parameter of the entire plants at the end of the experiment.

Fig 1. Plant biomass in plastic cup. T0 – T5 treatment (Left to right)

Fig. 2. Plant biomass with shoot and root

Fig: 3. Root structures at different treatments (Left to right: T0- T5)

Results and Discussion

This experimental study shows the response of jute (Corchorus capsularis) to the application of various levels of charcoal, to the soil, showing different morphological features. The research shows that the morphological parameters such as plant height, root length, total dry weight and leaf numbers were significantly affected by the different levels of charcoal application.

The results from the experiment indicated that most of the treatments increased the plant growth parameters as compared to the control. In the experiment, the highest height of the plant was recorded at T3 treatment of 37 DAS, and the least height was recorded at T4 treatment compared to the others. However, there is no significant difference in root length between the treatments T3 and control after 5 weeks of sowing. The increasing charcoal levels at 1.5% by wt. of soil significantly increased mostly the aboveground and below-ground biomass. In case of aboveground parts as no of leaves, the length of the shoot, dry wt. of the shoot including the below ground parts of the root length and dry weight. The maximum leaf no per plant was found at application of 3gms of charcoal means highest at T3 treatment and lowest at T0 treatment. Thus, the application of moderate levels of charcoal significantly improves aboveground and belowground biomass yield. However, in the case of root length, both the T3 and T0 showed the same results, found to be higher compared to other entities.

In terms of morphological features, charcoal showed a significant effect on different growth and yield parameters, whereas application at the rate of 1.5 % of soil wt per pot showed significantly the maximum number of leaves (9), shoot length (22 cm), root length (6.75 or 7.0 cm), root dry wt (0.18g/plant) and shoot dry wt (0.53g/plant), however the root shoot ratio was found higher at T1 (0.36) followed by T3, T0, T4, T2 and lowest value was found at the highest treatment, while the addition of no charcoal as 0% charcoal by soil wt produced the minimum no of leaves (7) per plant.

The yields of dry weights of root and shoot are presented individually in figures 6 and 8. Control pots had the least dry matter content, whereas T3 showed the highest total dry weights of g/plant, which are 0.18 g/plant and 0.53 g/plant respectively. The highest length of the root is shown by the T3 and T0, and the lowest length at T4 (Figure 7). In the case of the root-shoot ratio, the highest value is 0.36 at T1 followed by 0.34 at T3 and the lowest value is 0.21 of T5, whereas showed almost the same root-shoot ratio in T2 and T4, including little bit higher than these 2 in T0 (Figure 9). In case of leaf showed the same leaf numbers in T1, T2, T4, and T5, whereas the highest was found in T3 (Figure 5). Also, the shoot length was found the highest at T3 treatment (Figure 4), followed by T2, T1, T5, and T0, whereas the lowest was found at T4.

In the experiment, leaf no was also found to be higher at T3, leaf nos were same at T1, T2, T4, and T5 (Figure 5), where it was found to be lowest at T0 compared to other entities.

Results revealed that increasing charcoal levels from 0 to 1.5% of soil weight significantly increased the aboveground and belowground biomass yield. The application of moderately increasing levels of charcoal significantly improved root length, shoot length, shoot and root dry wt, including the number of leaves. Thus, carbonized material application in soil shows positive effects in terms of soil properties and ultimately plant growth. This result also confirms the findings of [50] and [53], who postulates that charcoal and other carbonized materials as soil amendments improve soil fertility, nutrient cycling, and most importantly, plant growth and yield.

Research conducted in the study also indicates that carbonized material, such as charcoal, is responsible for the persistent fertility of soil if compared with control or no application of charcoal. It is observed that there is a significant negative performance of 0% on plant biomass production and other morphological parameters compared with the application or treatments of varying charcoal rates. This result also consists of [57], those who confirm that application of charcoal increases and shows positive effects on carbon amendments of soil organic carbon and improves plant growth & development, including productivity and yield, in consistent with the findings of [54],[63],[59], [35] and [38].

From the current result it is also evident that application of charcoal at medium levels had significant effect on most of the vegetative growth of jute, however, some of the parameters as root length with control treatment showed a positive effect as the moderate level of application. Organic amendment enhances soil organic carbon, promotes crop growth and development and ultimately improves productivity of the crop and promotes plant biomass, as confirmed by the findings of [48], [27], [62],[52].

Thus, treatment T3 increased shoot length, including root and shoot dry weight. In addition, 0% treatment gave the highest belowground part as root length was significantly affected by the interaction of T0 treatment. In the experiment, T3 treated plant showed the highest number of leaves as leaves/plant. It was observed that the control had the lowest production of leaves compared to other treatments. This result also confirms the finding of [43], who found the same result that organic amendment improves the biomass yield.

The result showed that charcoal acts as soil conditioner, has agricultural uses, and helps in plant growth, can be used for carbon capture and storage. Also, the findings of [18] found that soil amendment is used to store carbon in soil which improves plant health.

It is observed from Fig. 2 and 3 those roots show the highest length towards treatment T3. The Root system improves with more fibrous roots in plants at T3 increased with increasing rates of charcoal application from 0-1.5% of soil weight. Our findings suggest that charcoal affect its suitability in the soil as a perfect soil amendment, as it shows significant improvement in medium level of application. The optimum level of carbonized material helps in the growth of plants or productivity, dry matter production, and improves the soil condition. The application of increasing levels of charcoal significantly improved the important morphological parameters, which confirmed the finding of [17], [65] and [25]. Carbonized material in soil enhances organic carbon and optimizing carbonized material as charcoal application improves soil properties, including improved plant growth with development and yield of plants is in consistent with the findings of [22],[47],[20], [18] and [62].

Charcoal has many direct benefits, greatly increasing soil fertility through its capacity to retain water, carbon, nutrients and activate microorganisms, improve soil fertility by reducing nutrient leaching, increasing above and below ground biomass growth, reduce the release of nitrous oxide and methane from soil. Microbial activities ultimately improve and help faster in the organic matter decomposition process in the soil, which helps to release the nutrients in the soil. In the experiment, the addition of carbon in the form of charcoal in soil could help to provide additional material of this symbiotic relationship to play out in the container grown of plant. Thus, it could be used as a potential soil amendment both in greenhouse and agricultural field as it has great absorbing and neutralizing capabilities which make it excellent for improving the health of soil. This result also confirms the findings of [24] and [26], who found that charcoal as soil amendment is good absorber to improve nutrient availability in the soil, improving soil fertility and crop production. Besides soil amendment, charcoal increased Soil Organic Carbon (SOC) is the key component of soil health in agroecosystem as improving SOC reserves improving fertility of soil which improves N availability through physical, chemical and biological properties of soil, which in consistent with the findings of [14], [26],[45], [41]. Also, the result of the experiment showing higher root shoot ration at T1 and T3, indicating moderate amount of charcoal application increases the root shoot ratio compared to control, T2, T4 and T5 treatments. Thus, implies that moderate application of charcoal improves root shoot ratio in plants. This result also confirms the previous findings of [37], who found that the root/shoot ratio is proportional to nutrient supply, with a greater ratio at low nutrient supply. This result also confirms the previous research that found that root shoot ratio is a key indicator of plant growth and a strategy to adapt to the environment. In the experiment Root shoot ratio increased as the charcoal level increased from 0% to 1.5% as the root-shoot ratio is also affected by the nutritional status of the of plants. The optimum amount of charcoal as carbon source improves the biomass ratio. Furthermore, the study indicated that charcoal application rate of 1.5% would be adequate to improve the availability of soil nutrients and hence significantly induce a better plant growth response. This result also confirms the findings of other researchers, such as [9], who found that carbon sources in soil provides better plant growth and development responses. The results also postulate the findings of [43] and [10], who found that medium level of soil amendment improves the vegetative growth and biomass yield. The highest values recorded at moderate treatments for most of the parameters both at vegetative growth and post harvesting.

It is evident from the results that charcoal application to the soil significantly increased plant height, biomass weight, root shoot ratio and leaf no. Thus, in this experiment, the BJRI Deshi pat-10, showed better performances among the 6 treatments and found T3 is the best.

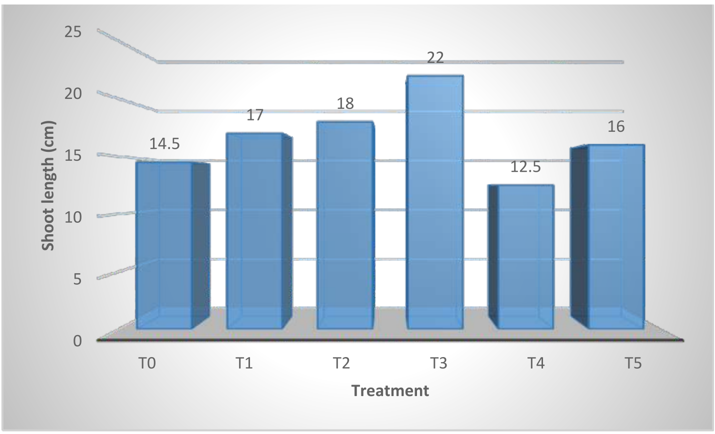

Figure 4. Effect of charcoal on shoot length of Jute plant

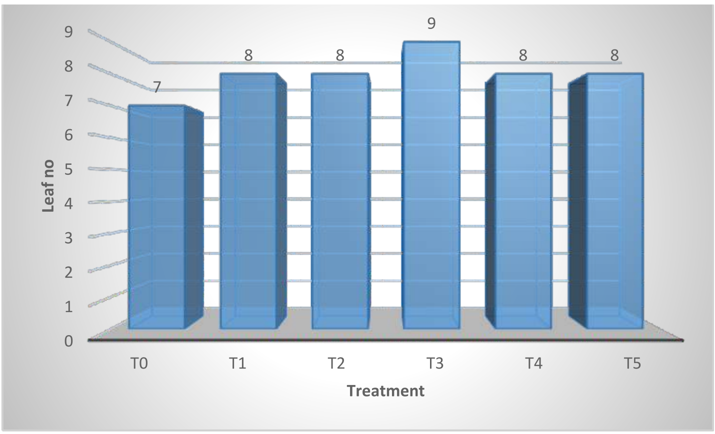

Figure 5. Effect of charcoal on number of leaves of Jute plant

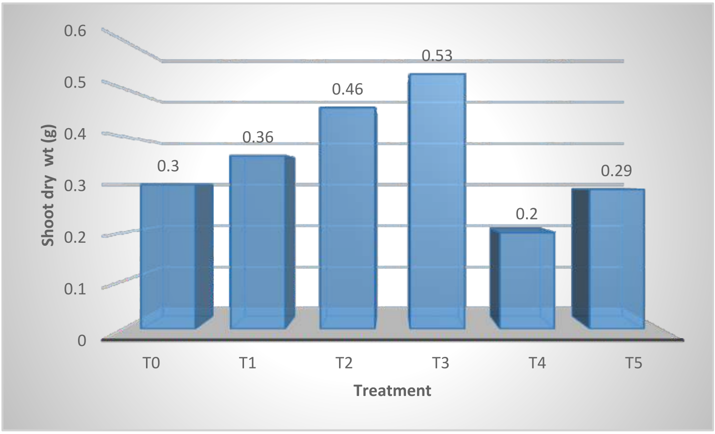

Figure 6. Effect of charcoal on shoot dry weight of Jute plant

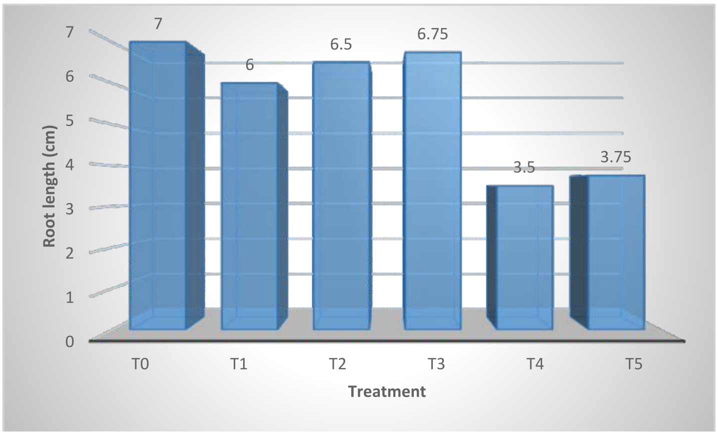

Figure 7. Effect of charcoal on root length of Jute plant

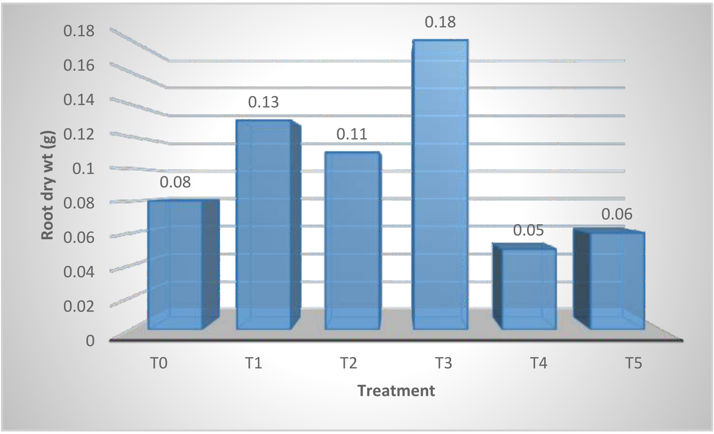

Figure 8. Effect of charcoal on root dry weight of Jute plant

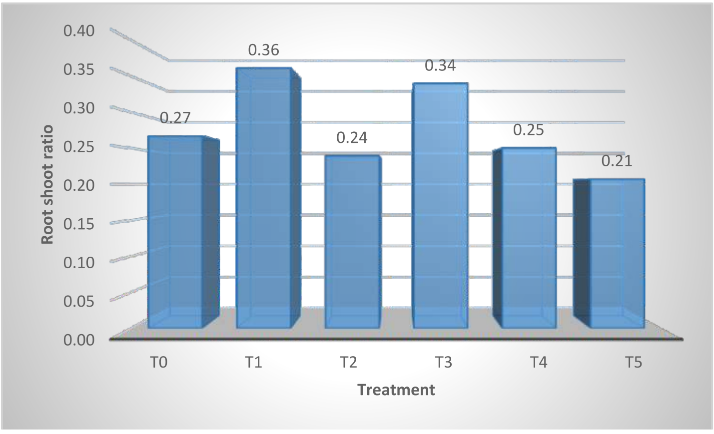

Figure 9. Effect of charcoal on root shoot ratio of Jute plant

Conclusion

From the result it is evident that the addition of charcoal in the soil acts as a potential and suitable soil amendment for the growth and development of the plants, due to its ability to boost soil fertility and improve soil quality by retaining water and nutrients in the soil. In addition, charcoal improves the physiochemical properties of soil and strengthens the root architecture by improving root length and by developing additional fibrous roots for the transmission of nutrients and water. Furthermore, root including shoot height and other development from the medium level of amendment treated plant had longer root length than comperatively lower and higher levels of amendment, which indicates that the medium level of charcoal may stimulate fine and more adventitious root development to absorb soil solution for the treated soil. The incorporation of charcoal thus improves the soil structure, which could potentially be a good strategy to tackle water and nutrient loss, particularly in poorly structured soil.

Thus, the experiment revealed that moderate application of charcoal has a direct effect to improve soil fertility through its capacity to retain essential nutrients as well as water, thus improving soil productivity by reducing leaching of nutrients from the soil, which ultimately helps to increase the aboveground and belowground plant biomass growth. The results revealed that the optimum charcoal level for fibre crop production could be T3 treatment compared to lower and higher levels of application of the mentioned carbon source in the soil, meaning the best performances of all the plant traits recorded against the addition of a medium level of charcoal.

It was concluded from the results that a moderate amount of charcoal application is the optimum charcoal level for jute production which could be T3 or 1.5% per pot. of the soil. Our results support the general conclusion that charcoal improves biomass responses at a moderate amount of application.

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CONFLICT OF INTEREST: The author declares that there is no conflict of interest regarding the publication of this manuscript.

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