Short Research Article

Evaluating Biochar as a Potting Mixture Substitute: Impacts on Coffee Seedling Growth and Soil Properties

ABSTRACT

Biochar is a carbon rich product derived from agricultural waste biomasses through pyrolysis widely reported to enhance the soil fertility. Coffee cherry husk, a by-product of the hulling process in coffee curing factories presents an opportunity for biochar production. While previous studies have explored biochar as a peat substitute in growth media, research on its role in nursery potting mixtures for coffee seedlings is lacking. This study aimed to evaluate the effects of biochar derived from cherry husk on the growth of coffee seedlings and soil properties. Biochar was produced using an electric biomass pyrolyzer at 500°C for one hour and incorporated into the nursery potting medium. The experiment included four treatments: T1 (jungle soil: farmyard manure: sand, control), T2 (biochar: farmyard manure: sand), T3 (jungle soil: biochar: sand), and T4 (jungle soil: farmyard manure: biochar). Results showed that seedling growth in T1 and T4 was statistically similar (CD-0.05%), while growth in T2 and T3 was comparatively lower. Substitution of biochar at the rate of 2% in the potting mixture was found to be optimal for the better growth of coffee seedlings. These findings suggest that biochar can serve as a viable alternative to sand in nursery potting mixtures, potentially improving soil properties and promoting sustainable seedling production.

Key words: Coffee; Cherry husk; Biochar; Coffee seedlings.

1. INTRODUCTION

Coffee is believed to be originated in Ethiopia. Currently, coffee is grown over eighty countries in the world with Brazil, Vietnam and Colombia being the largest coffee producers accounting for over half of the world's coffee production. Although there are more than eighty coffee species under the genus *Coffea*, arabica (*Coffea arabica* L.) and robusta (*Coffea canephora* Pierre ex Froehner) are commonly grown *Coffea* species worldwide on commercial scale. In India, coffee is grown to an extent of 4.70 lakh hectares (Arabica-2.42 lakh hectares; Robusta-2.28 lakh hectares) with the total production of 3.43 lakh metric tonne of green coffee bean in 2022-23 crop year (Anonymous, 2024).

Coffee being the second largest traded commodity in the world market, it generates copious amount of solid waste biomasses. According to International Coffee Organization (ICO), global coffee industry generates about 39 million tons of biological waste biomasses each year (Anonymous, 2023). While in India, approximately 8 lakh tonnes of waste biomass are produced yearly from coffee processing (Anonymous 2024). Coffee processing generates various solid waste biomasses *viz.*, pulp (fruit skin), parchment husk, cherry husk, coffee silver skin and spent coffee ground. Coffee pulp is a good starter material for the production of compost or vermi-compost. The other waste biomasses are transformed into fuel briquettes. In our earlier work, biochar was produced from cherry husk, parchment husk, uprooted diseased coffee stem and pepper stem waste using biomass pyrolyzer unit besides the physicochemical characterization of biochar obtained from these coffee farm waste biomasses (Gopinandhan et al., 2022).

In recent years, biochar is drawing attention worldwide due to its potential to improve soil fertility. Biochar is produced from the combustion of various agri-waste biomasses under limited or nil oxygen condition and considered as soil ameliorant. Biochar is rich in carbon content that are more stable in the soil (Effa and Otie, 2023). Due to the versatile physicochemical characteristics of biochar, its application in soil is reported to influence several attributes of soil and the changes brought out by the biochar in the edaphic environment reported to improve agricultural productivity (Biederman and Harpole, 2013; Sheng and Zhu, 2018; Dai et al., 2020). Further, owing to its unique specific surface area and cation exchange capacity, biochar exhibits remarkable efficiency in removing pollutants like antibiotics, dyes, heavy metals, herbicides and pesticides (Xie et al., 2015; Oliveira, 2017). Biochar has also been used as a management tool to control various plant diseases (Navdeep and Adesh, 2020) and plant parasitic nematode (Dwi and Niken, 2017).

The successful establishment coffee husbandry starts with the production of healthy and vigorous seedlings. Under Indian condition, raising of coffee seedlings involves two stages *viz.,* sowing of coffee seeds in the germination bed and transplanting of sprouted seedlings into polybag containing nursery growth medium and this stage is known as polybag (basket) nursery. The well-developed seedlings which are normally four to six to months old are planted in the field during August and September months. The composition of growth medium for the successful establishment of coffee seedlings normally consists of jungle soil, compost and sand in a judicious proportion. However, due to slow decline in the availability of jungle soil caused by gradual shrinking of forest cover, non-availability of good quality farm yard manure (or) compost and escalating of cost of sand are compelling to look for alternate growth medium.

Though several studies on biochar have been focussed on its application in the soil system of various crops, only limited reports are available about its application in coffee farming (Samuel et al., 2019; Herviyanti et al., 2020; Jessica et al., 2022; Leta et al., 2022; Sanchez-Reinoso et al., 2022; Sanchez-Reinoso et al., 2023[ab]). Furthermore, published reports regarding biochar as a substitute mostly pertains to replacement of peat substrate in the growth medium (Ostos et al., 2008; Li et al., 2009; Tian et al., 2012; Vaughn et al., 2013; Zhang et al., 2014; Dispenza et al., 2016; Nieto et al., 2016; Picca et al., 2023). There are no reports pertaining to use of biochar as substitute in the nursery potting mixture to grow coffee seedlings. Biochar being a low-cost and carbon rich natural product, the present study aimed to explores the potential of biochar as a sustainable substitute in nursery potting mixtures, particularly for coffee seedling growth and soil improvement.

2. MATERIALS AND METHODS

The study was carried out in a poly house nursery available at the research farm in central coffee research institute (CCRI) located at Chikkamagaluru district in Karnataka state during 2023-24 season. The institute is situated in the southern hill zone of Karnataka state at $13^0 34$ north latitude and $75^0 48$ east longitudes with an elevation of 825 meter above mean sea level. In general, CCRI receives an annual average rainfall of 2,500 mm distributed over 4 to 5 months from June to September with a total annual rainy day ranging from 113 to 133 days.

The temperature and relative humidity ranges from 18^0C to 34^0C and 60% to 90%, respectively.

The coffee cherry husk (CCH) was collected from a coffee curing factory at Chikkamagaluru district in Karnataka State. The biochar from CCH was prepared using a biomass pyrolyzer unit. The temperature of the furnace was ramped at a rate of 10^0C in 60 minutes to the reach pyrolysis holding temperature (500^0C). The pyrolysis holding temperature was then sustained for 120 minutes and the furnace was allowed to cool at an average rate of approximately 30^0C in 60 minutes. Later, the biochar was grounded to pass through 2 mm test sieve (M/s. Techno Instruments Company, Bangalore, India) and the fine biochar powder was used for the nursery trails.

The preparation of nursery mixture/growth medium started with the sieving of sun-dried jungle soil and well-rotted farm yard manure (FYM). The fine biochar powder was mixed to the sieved jungle soil and FYM according to the treatment levels. The treatments included in the current study were control T_1 (growth medium consisting of jungle soil: farmyard manure: sand in 6:2:1 proportion), T_2 (growth medium with biochar: farmyard manure: sand in 6:2:1 proportion), T_3 (growth medium with jungle soil: biochar: sand in 6:2:1 proportion) and T_4 (growth medium with jungle soil: farm yard manure: biochar in 6:2:1 proportion). The biochar was mixed with other constituents of nursery mixture based on the bulk density of biochar (213 kg/m^3). Accordingly, the percentage of biochar in T_2, T_3 and T_4 treatments was 14%, 10% and 1.8%, respectively.

The nursery mixture was filled up into the nursery bags (one liter capacity polybag of 22.5 x 15 cm size with 150-gauge thickness and eight to ten holes of 3 mm size at the bottom half of the polybag to facilitate drainage of excess water). The nursery mixture was moistened with water and filled into nursery bags firmly. The bags were arranged within the rectangular frames of bamboo reapers (ten to twelve bags per row). These frames are held in position with bamboo (or) wooden props driven firmly into the ground at suitable distances. The experiment was carried out with five replications per treatment and fifty seedlings per replication.

The sprouted seedlings of *Coffea arabica* (variety no.13) and *Coffea canephora* (variety no.3) were transplanted from germination bed to polybags. The sprouted seedlings were gently lifted from the primary bed using a stick to avoid the roots from breaking. Then, the root portion of seedlings dipped in Carbendazim 50 WP (one gram/liter) to prevent fungal infestation followed by dipping the root portion in cow dung slurry to avoid desiccation of root tips. Prior to transplanting, the polybags were watered and a vertical hole about 5 cm deep was made at the center of the basket. Seedlings were planted into the hole after nipping off the tip of the tap root and then lifted slightly to open out the roots. Care was exercised to keep the shoot system of the seedlings just above soil surface. After transplanting, the seedlings were maintained following the standard nursery management practices.

The percent mortality of seedlings in each treatment was recorded by visual assessment. Three seedlings from each replication were sampled for analysis purpose on every two months up to six months. The shoot length was measured as the distance from the collar region to the apex of the plant. The root length was measured as the distance from the collar region to the end of the longest root. Then, the stem and root portions were separated for biomass estimation. The fresh weight of stem and root portions were determined. Then, the shoot and root portions were dried separately at 70^0C until constant weight was achieved. A representative soil sample was collected from all the four treatments after four and six months of seedlings growth in the polybag nursery. The air-dried soil samples were analysed for pH, EC and percent organic carbon following standard protocols (Jackson, 1973; Walkley and Black, 1934).

The data were subjected to analysis of variance (ANOVA) according to LSD test to indicate statistically significant differences between variables following the Agress package (version 3.01 data entry module and version 7.01 ANOVA package for researchers).

3. RESULTS AND DISCUSSION

The data on growth parameters *viz.*, shoot length, root length, fresh shoot weight, fresh root weight, dry shoot biomass weight and dry root biomass weight recorded in the present investigation showed that the growth of coffee seedlings steadily increased as the period of growth extended regardless of treatments (growth mediums) and coffee varieties (Tables 1 a, b, c).

The data on above-ground biomass (shoot length, fresh shoot biomass and dry shoot biomass weights) indicated that in case of arabica, among the four growth mediums evaluated, the T_4

growth medium recorded statistically (CD-0.05) highest shoot length (29.72 cm), fresh shoot weight (11.18 gram) and dry shoot weight (2.84 gram) in six months old seedling followed by T_1 growth medium (21.46 cm; 7.84 gram; 1.92 gram; respectively). While in Robusta, the T_4 growth medium recorded the highest shoot length, fresh shoot weight and dry shoot biomass weight in six months old seedling followed by T_1 growth medium and these two treatments were statistically on par to each other (CD-0.05). Regardless of coffee varieties, the lowest above-ground biomasses were witnessed in T_2 growth medium in six months old seedling. In the current study, the reduction of above ground biomass observed in T_2 and T_3 growth mediums was in good agreement with the report of Dispenza et al., (2016) who observed that increased level of biochar resulted in reduction of shoots production in ornamental *Euphorbia* plant.

The data on below ground biomass (root length, fresh root biomass and dry root biomass weights) showed that in case of arabica, of the four growth medium studied, the T_4 growth medium recorded the highest root length and fresh root weight in six months old seedling followed by T_1 growth medium and these two treatments were statistically similar (CD-0.05%). While, the T_4 growth medium recorded statistically (CD-0.05%) highest dry root weight followed by T_1 growth medium. In Robusta, the T_4 growth medium recorded the highest root length and dry root weight in six months old seedling followed by T_1 growth medium and these two treatments were statistically similar. Whilst, the T_4 growth medium recorded statistically highest fresh root weight followed by T_1 growth medium. Irrespective of coffee varieties, the lowest below ground biomasses were seen in T_2 growth medium in six months old seedling. The reduction of below ground biomass as seen in T_2 and T_3 growth mediums was similar to those of Samuel et al., (2019) who demonstrated that excess level of biochar increases the pH of growth medium which tends to cause copper and boron deficiencies. Boron deficiency results in stunted root growth and premature death of thin root tips in coffee.

Table 1a: Influence of biochar on growth parameters of arabica and robusta seedlings (2 months old seedlings)

Treatments	Arabica						Robusta					
	SL	RL	FSW	FRW	DSW	DRW	SL	RL	FSW	FRW	DSW	DRW
T_1	14.12^{a} (±2.4)	8.67^{b} (±1.5)	2.32^{a} (±0.7)	0.21^{b} (±0.08)	0.59^{a} (±0.1)	0.06 (±0.01)	12.25^{a} (±1.8)	12.25^{a} (±2.3)	2.83^{a} (±0.8)	0.65^{a} (±0.1)	0.72^{a} (±0.13)	0.16^{a} (±0.06)
T_2	5.09^{b} (±1.1)	4.23^{c} (±0.9)	0.48^{c} (±0.1)	0.16^{b} (±0.04)	0.16^{c} (±0.04)	0.05 (±0.02)	8.52^{c} (±1.7)	7.65^{b} (±1.2)	0.31^{c} (±0.07)	0.12^{c} (±0.04)	0.22^{c} (±0.08)	0.10^{b} (±0.03)
T_3	4.48^{b} (±0.7)	4.51^{c} (±0.8)	0.47^{c} (±0.1)	0.10^{bc} (±0.03)	0.13^{c} (±0.02)	0.10 (±0.01)	7.83^{c} (±0.5)	6.41^{b} (±1.1)	0.35^{c} (±0.06)	0.13^{c} (±0.04)	0.23^{c} (±0.04)	0.09^{b} (±0.02)
T_4	13.18^{a} (±1.8)	11.03^{a} (±2.2)	1.69^{b} (±.0.8)	0.33^{a} (±0.09)	0.40^{b} (±0.07)	0.09 (±0.02)	9.88^{b} (±1.7)	12.44^{a} (±2.4)	1.31^{b} (±0.4)	0.24^{b} (±0.06)	0.57^{b} (± 0.15)	0.14^{a} (±0.04)
CD (5%)	2.01	1.86	0.49	0.07	0.09	NS	2.40	2.01	0.52	0.12	0.12	0.03

Table 1b: Influence of biochar on growth parameters of arabica and robusta seedlings (4 months old seedlings)

Treatments	Arabica						Robusta					
	SL	RL	FSW	FRW	DSW	DRW	SL	RL	FSW	FRW	DSW	DRW
T_1	20.91^{a} (±2.8)	16.20^{a} (±2.6)	5.15^{a} (±1.7)	1.03^{a} (±0.3)	1.43^{a} (±0.4)	0.39^{a} (±0.12)	19.41^{a} (±2.8)	17.69^{a} (±2.61)	9.02^{a} (±1.68)	1.35^{a} (±0.27)	1.89^{a} (±0.42)	0.49^{a} (±0.13)
T_2	7.67^{b} (±1.2)	8.97^{b} (±1.4)	1.69^{b} (±0.3)	0.29^{c} (±0.08)	0.52^{c} (±0.1)	0.14^{c} (±0.02)	8.89^{c} (±1.27)	9.48^{b} (±1.44)	1.64^{c} (±0.08)	0.63^{b} (±0.12)	0.49^{c} (±0.17)	0.16^{b} (±0.04)
T_3	7.33^{b} (±0.9)	5.81^{c} (±1.6)	1.28^{b} (±0.2)	0.23^{c} (±0.1)	0.34^{c} (±0.08)	0.10^{c} (±0.02)	8.01^{c} (±1.9)	8.09^{b} (±1.6)	0.88^{c} (±0.2)	0.35^{b} (±0.1)	0.22^{c} (±0.08)	0.12^{b} (±0.03)
T_4	19.86^{a} (±3.3)	17.41^{a} (±1.9)	4.20^{a} (±0.9)	0.58^{b} (±0.1)	1.11^{b} (±0.25)	0.30^{b} (±0.2)	15.86^{b} (±2.4)	17.39^{a} (±2.9)	5.59^{b} (±1.2)	1.10^{a} (±0.4)	1.30^{b} (±0.23)	0.35^{a} (±0.08)
CD (5%)	2.31	2.69	1.10	0.10	0.27	0.08	2.61	4.43	0.88	0.32	0.23	0.15

Table 1c: Influence of biochar on growth parameters of arabica and robusta seedlings (6 months old seedlings)

Treatments	Arabica						Robusta					
	SL	RL	FSW	FRW	DSW	DRW	SL	RL	FSW	FRW	DSW	DRW
T_1	21.46^{b} (±4.7)	17.21^{a} (±3.9)	7.84^{b} (±2.9)	1.68^{a} (±0.05)	1.92^{b} (±0.65)	0.37^{b} (±0.03)	26.44^{a} (±4.45)	17.74^{a} (±2.61)	11.54^{a} (±2.58)	2.30^{b} (±0.42)	3.22^{a} (±1.05)	0.95^{a} (±0.19)
T_2	7.01^{c} (±1.8)	6.19^{b} (±2.1)	1.22^{c} (±0.75)	0.34^{b} (±0.15)	0.30^{c} (±0.13)	0.11^{c} (±0.1)	8.65^{b} (±1.2)	12.52^{b} (±1.5)	0.61^{c} (±0.1)	0.28^{c} (±0.08)	0.21^{b} (±0.03)	0.15^{b} (± 0.04)
T_3	10.47^{c} (±1.8)	13.81^{c} (±216)	1.89^{c} (±0.34)	0.81^{b} (±0.09)	0.52^{c} (±0.07)	0.21^{c} (±0.04)	11.48^{b} (±1.8)	13.19^{b} (±2.1)	3.25^{b} (±0.9)	0.64^{c} (±0.1)	0.98^{b} (±0.25)	0.30^{b} (±0.06)
T_4	29.72^{a} (±3.6)	19.92^{a} (±3.2)	11.18^{a} (±2.3)	1.84^{a} (±0.6)	2.84^{a} (±0.6)	0.67^{a} (±0.15)	27.45^{a} (±3.8)	19.67^{a} (±2.7)	12.69^{a} (±2.2)	2.84^{a} (±0.9)	3.56^{a} (±0.8)	0.96^{a} (±0.12)
CD (5%)	3.88	3.05	3.70	0.63	0.61	0.17	4.54	2.82	2.77	0.40	0.88	0.18

SL - Shoot length (cm); RL- Root length (cm); FSW-Fresh shoot weight (gm); FRW- Fresh root weight (gm); DSW-Dry shoot weight (gm); DRW-Dry root weight (gm)

Analysis of soil samples collected from all the four growth mediums after six months of seedling growth under nursery condition revealed that the soil sample from T_2 growth medium showed the highest pH values (arabica-8.3; robusta-7.6) while the soil sample from T_1 growth medium recorded the least pH values (arabica-5.6; robusta-5.7). Similar trend was seen even in case of electrical conductivity (EC) in both arabica and robusta coffee varieties. Regarding organic carbon (OC) content, the soil samples from T_2 growth medium showed the highest OC values (arabica-7.3%; robusta-6.3%). In the remaining growth mediums (T_1, T_3, T_4), the OC content ranged from 2.4% to 4.8% in arabica variety and from 2.9% to 4.2% in robusta variety (Table 2). The data on pH, EC and OC recorded in the current study matches to the results of Gopinandhan et al., (2022) and Lehmann et al., (2011) who reported that addition of biochar makes the soil alkaline, exhibits higher EC value and contains comparatively higher amount of organic carbon.

Table 2. Influence of biochar on soil properties of nursery potting mixture

Treatments	Arabica			Robusta		
	pH	EC (dS/m)	Organic carbon ((%)	pH	EC (dS/m)	Organic carbon (%)
T_1	5.6 ± 0.57	0.43 ± 0.06	2.4 ± 0.63	5.7 ± 0.60	0.38 ± 0.03	2.9 ± 0.40
T_2	8.3 ± 0.9	1.14 ± 0.1	7.3 ± 0.8	7.6 ± 0.4	0.97 ± 0.1	6.3 ± 0.5
T_3	7.7 ± 0.8	0.86 ± 0.07	4.8 ± 0.55	7.2 ± 0.4	0.71 ± 0.1	4.2 ± 0.4
T_4	6.2 ± 0.67	0.67 ± 0.09	2.9 ± 0.58	6.4 ± 0.7	0.57 ± 0.02	3.5 ± 0.20

Several authors have reported that optimal addition of biochar in the growth medium increased the overall biomass of the coffee seedlings (Samuel et al., 2019; Herviyanti et al., 2020; Jessica et al., 2022; Leta et al., 2022) and also in other crops such as soybean (Zamriyetti and Mufriah, 2020) and asparagus (Elmer and Pignatello, 2011). Coffee grows better at a pH value of between 5.5 and 6. In the present study, the poor performance of coffee seedlings in T_2 and T_3 growth mediums probably due to the presence of excess levels of biochar in the growth medium (T_2 -14%; T_3 -10%) which led to alkalinisation of the growth mediums. Barotni et al., (2010) and Samuel et al., (2019) reported that that excess addition of biochar resulted in a general reduction of biomass due to changes in the physico-chemical properties of soil.

4. CONCLUSION

The findings of current study clearly revealed that the overall growth performance of coffee seedlings was equally good in both T_1 growth medium (jungle soil: farmyard manure: sand in 6:2:1 proportion) and T_4 growth medium (jungle soil: farm yard manure: biochar in 6:2:1 proportion) when compared to T_2 growth medium (biochar: farmyard manure: sand in 6:2:1 proportion) and T_3 growth medium (jungle soil: biochar: sand in 6:2:1 proportion). The results of study suggests that jungle soil and FYM are essential ingredients for the growth of coffee seedlings and sand can be replaced with the biochar. Substitution of biochar at the rate of 2% in the coffee nursery mixture is optimal for the better performance of coffee seedlings. Previous reports along with the results generated in the current study clearly indicated that the excess addition biochar increases the pH of the growth medium and thus optimization of biochar application rate is paramount importance for the better performance of coffee seedlings. Given the increasing demand for eco-friendly and cost-effective agricultural practices, this study provides valuable insights into how biochar influences soil properties, nutrient availability, and seedling development. Further, the findings contribute to sustainable nursery management strategies, enhancing coffee cultivation while promoting soil health and resource efficiency.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that no generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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