

Coffee (*Coffea arabica* L.) Seed Emergence and Seedling Growth Rate Responses to Different Pot Size and Biochar Based Nursery Media Preparation at Awada South Ethiopia

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Abstract: Coffee production is essentially based on the production of quality seedlings with the desirable shoot and root growth at appropriate time of transplanting. Therefore, this study was conducted to evaluate the effects of pot size and biochar based rooting media composition on the coffee seedling emergence rate and relative growth rate. The experiment was laid out in a factorial experiment arranged in RCBD with three replications. The treatment combination included four levels of pot size ($P_1=7 \times 13$ cm, $P_2=10 \times 16$ cm, $P_3=13 \times 19$ cm and $P_4=16 \times 22$ cm) and five biochar to topsoil ratios (0:1, 1:1, 1:2, 1:3, and 1:4 v/v). All emergence percentage, emergence rate and also seedling relative growth rate data were collected appropriately and computed using SAS software. Treatment means separation was conducted by using LSD at 5%. Biochar application was highly ($P=0.0001$) accelerated coffee seed emergency rate. The highest value (0.33) emergence rate also recorded from one to one (1:1) biochar to topsoil ratio while the lowest for topsoil alone or 2gDAP/seedling. However, significantly ($P=0.014$) higher relative growth rate (0.83 mg/g/day) were found in the 16x22cm pot size interacted with one to four (1:4) biochar to top soil ratio followed by the seedling grow in 13x19cm and the same ratio of biochar to top soil. On the other hand, the lowest value of relative growth rate (0.64 mg/g/day) was recorded under (7x13cm) pot size without any amendments. Therefore, biochar based nursery media preparation is the best option to accelerate the coffee seedling emergence and seedling relative growth rate at a lower ratio of biochar that provides alternative enhancement media options to speed up coffee seedling growth rate.

Keywords: Biochar-Ratio, Coffee Seedling, Emergency Rate, Growth Rate, Pot Size

1. Introduction

Commercially coffee is propagated through seeds with a various factors that influence the initial development of coffee seedling and/or growing in the field, such as the seedlings production process specially, container substrate and seed quality used to raise coffee seedling [1]. Germination percentage and emergence rate of coffee seeds found to be considerable due to different containers, rooting media and with their interactions [2]. Coffee seeds are classified as intermediate seeds [3] because they require high moisture content during the storage and the shelf life of coffee seeds is relatively short, especially within the changing climate temperature [3, 4]. Seedling emergence is the appearance of normal hypocotyls after sowing [1], and

the growth of the plumule towards the soil surface and coming out from the soil, making a shoot. Thus, within our study the number of seedlings that emerged above the soil surface and attained the normal the soldier-stage of growth is considered as seed emergence as well it was also defined by Coste, R. [5]. On the other hand, the relative growth rate (RGR), or the rate of accumulation of new dry mass per unit of existing dry mass, is a major determinant of plant competitiveness to develop in to mature plant. RGR is an indirect measurement of the rate of resource acquisition, and numerous studies have found that increasing crop RGR used to increases weed suppression [3]. The faster an individual seedling accumulates biomass, the more carbon is available to increase growth of roots and shoots for greater access to light and soil nutrients.

Regardless of Ethiopia is the largest coffee producer, having favorable environmental condition, the existence of enormous genetic diversity and importance of the crop in the national economy of the country, its production potential hardly exceeds 0.85 ton ha⁻¹ clean coffee [6], which is by far lower than world average. This a low productivity of the crop stems from different factors starting from the nursery managements leads to low quality seedlings with undesirable shoot and root growth for field transplanting [7], and unable to transplant on appropriate planting time because of late seed germination and too slow seedling growth rate. Using optimized and economical pot size, and enhanced soil growth media is very important to get quality seedling at appropriate transplanting time. Maintenance of coffee seedling in nurseries is also essential for successful field establishment [8] and maintaining fertility of growth media of coffee seedling enhances the production of vigorous seedlings for transplanting [9]. Emergence rate, growth, development and performance of coffee seedlings are determined by both container size and media type available in the soil or supplied as organic or inorganic fertilizers [10].

Even though, Ethiopia is endowed with a good production environment for growing coffee with a combination of appropriate altitude, temperature, and rain fall and soil type [11] currently, climate change is the major threat to coffee production [12], seed emergence rate and seedling growth rate is a seriously problem of to get the quality seedling at appropriate planting time that leads to the late planting time should be conducted at April month. Therefore, it was hypothesized that, by speeding up emergency rate and seedling growth rate through different rooting media, it could be possible to escape up the overlapping activities of harvesting and nursery operation to attain a good quality seedling during the main planting time. Therefore, generating appropriate nursery management practice to accelerate seedling emergence rate and relative growth rate of the seedling growth rate are urgently needed for the main season planting time. Therefore, the objective of this study was to evaluate the effect of nursery soil based rooting media and pot size that speed up the seedling emergence and relative growth rate of coffee Arabica seedlings.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Awada Agricultural Research Sub-Center. The area has a semi-bimodal rainfall distribution with an average precipitation of 1354 mm per annum, while the annual average minimum and maximum air temperatures are 6°C and 28.8°C, respectively. The major soil type of the center is *nitisol* [13].

2.2. Biochar, Topsoil, and Compost Preparation

Biochar was prepared from coffee husk within minimum oxygen and/or facilitated the pyrolysis process. The resulting biochar material was grounded and sieved through a 2mm

square-mesh sieve to have the same particle sizes as the topsoil used for the experiment. Topsoil was collected from the surface of cultivable lands at 0-15cm depth, dried and crushed by pestle and mortar, and sieved with a two mm square-mesh sieve to have a smaller particle size. Compost was also prepared from locally available materials such as maize straw, ash, and farmyard manure, following the conventional compost preparation method. The nursery media adopted by farmers in the study area was prepared by mixing topsoil and compost in a three to one (3:1) ratio [7]. The media was thoroughly mixed with biochar following the adjusted ratio for each treatment.

2.3. Experimental Design and Treatment Combinations

The experiment was conducted with a factorial experiment arranged in RCBD with three replications to provide the estimates effects of treatment. Twenty four (24) treatment combinations with four levels of pot size (width by height) (P1 = 7cm x13cm, P2 = 10cm x 16cm, P3 = 13x19 cm and P4 = 16 x 22cm) and five levels of biochar to topsoil (0:1, 1:1, 1:2, 1:3, 1:4) by (v/v) ratios were used for the treatment. The conventional pot (16x22 cm) filled with topsoil with 2gDAP was used as a standard control, while topsoil alone in the same size (16x22cm) was used as local control.

2.4. Data Collection

2.4.1. Seedling Emergence

Emergence percentage, Emergence rate, days required to 50% emergence (MDE) were conducted by counting the numbers of emerged seedlings starting from (45 days after sowing) until 90 days after sowing, were the number of seedlings that emerged above the soil surface and attained the soldier stage of growth was recorded every 7 days until complete emergence.

Then percentage of emerged seedlings was determined as

$$\text{Germination \%} = \frac{\text{Total number of emerged seedling}}{\text{Number of planted seed}} \times 100, \dots [14].$$

Mean days required to 50% emergence (MDE) and rate of seedling emergence were calculated by using the formula described by [14].

$$\text{MDE} = \frac{\sum t}{n} [15]$$

$$\text{ER} = \frac{\sum t}{t} \dots \dots \text{Magurie, 1962}$$

Where, n = number of newly emerged seedlings at time t, t = days from sowing.

2.4.2. Mean Relative Growth Rate (RGR)

The mean relative growth rate (RGR) was also calculated by taking plant growth at two points (first at 7th month after sowing and second at the end of the experiments). The total dry biomass yield at the beginning (T1) which was seventh months and at the end ten (10) month (T2) after seed sowing at the nursery was used to calculate the (RGR). Four coffee

seedlings were randomly selected from each experimental unit at each occasion and dried in an oven until a constant weight. Then, the mean weight (gplant-1) was used for the determination of RGR.

$$\text{Mean RGR} = \frac{\ln W_2 - \ln W_1}{T_2 - T_1} \dots \text{Williams et al., 2011}$$

Where: W1 and W2 are the dry biomass at the beginning (T1) and end (T2) of the sampling period and ln is the natural logarithm.

2.5. Data Analysis

All the measured seed emergency percentage, emergency rate and seedling growth parameters were summarized. The derived relative growth rate were subjected to analysis of variance (ANOVA) using a factorial experiment arranged in RCBD were done using the General Linear Model (GLM) of Statistical Analysis System (SAS) software version 9.3 [16]. List Significant difference (LSD) at 5% probability level was used for mean separation when analysis of variance indicated the presence of significant differences [17].

3. Result and Discussions

3.1. Emergence Percentage and Emergence Rate

Emergence percentage was not statistically ($P=0.48$) affected due to the main effects of pot size nor by the interaction effects of ($P=0.09$) the two factors. Similarly, pot size had no significant variation ($P=0.063$) on the seed emergence rate due to the main effects of pot size nor pot size biochar interaction effects ($P=0.55$). This result is in line with the findings of [18] that reported, emergence percent, and emergence rate were not significantly affected by the main effect of pot sizes.

Addition of biochar into topsoil significantly ($P = 0.0001$) affected emergence percentage of coffee seeds (Table 1). Biochar applied at one to one (1:1) and one to three (1:3) ratio of biochar to topsoil, enhanced the emergence percentage of coffee seeds. Statically significant and higher emergence percentage was recorded from all media treated with biochar to topsoil ratios while the lowest value was recorded for topsoil alone and topsoil with 2g DAP/pot (Table 1). Biochar application was significantly ($P=0.0001$) influenced coffee seed emergency rate. The highest value of emergence rate (0.33) was recorded from one to one (1:1) biochar to topsoil ratio while the lowest for topsoil alone or 2gDAP/seedling (Table 1). This could be due to the physical characteristics of biochar like water holding capacity and aeration, which are the main requirements for seed emergence. It is well documented by different author as biochar the large surface area of biochar can improve the soil water retention and its interactions with minerals and microorganisms [18] enhance the seed emergency rate and seedling relative growth rate. Biochar soil water retention was 18% higher in terra petera soil compared to adjacent soils [19]. Lei and Zhang [20] also confirm biochar capacity

to enhanced water retention capacity to increases field capacity, resulting an increased plant growth and improved water economy. Biochar can also increase water-holding capacity (25 to 36% increases with 7% biochar by weight addition [21].

On the other hand, the seed emergence rate was totally too let due to low air temperature occurred at the study area just after sowing coffee seed (own observation). The result of the present study was in line with the study of [22] who was reported the germination percentage of soybean that biochar treatments under the rates 10 and 20 29 tons per hectare had significant effects on the germination percentage. It was also reported as biochar could enhance the emergence rate of Virginia mallow seeds [23].

Table 1. Emergence percentage and rate as affected by biochar to topsoil ratio and pot size.

Pot size (cm)	Emergence (%)	Emergence rate
7x13	90.28	0.29
10x16	89.17	0.29
13x19	90.83	0.29
16x22	90.55	0.28
LSD (0.05)	Ns	Ns
Biochar to top soil ratio		
Topsoil alone	87.65 ^b	0.24 ^c
1 BC: 1TS	93.33 ^a	0.33 ^a
1 BC: 2TS	91.66 ^a	0.31 ^b
1 BC: 3TS	91.67 ^a	0.30 ^b
1 BC: 4TS	92.59 ^a	0.30 ^b
Ts+ 2gDAP/Pot	88.33 ^b	0.25 ^c
CV (%)	3.75	6.65
LSD (0.05)	2.78	0.02

BC and TS are Biochar and Topsoil respectively. Mean values followed by the same letter(s) are not significantly different from each other at $P \leq 0.05$.

3.2. Days to 50% Emergence

The interaction between pot size and biochar to topsoil ratio was highly ($P = 0.003$) affected the mean days to 50% emergence date (Table 2). Too late days to 50% seedling emergence was recorded for topsoil alone as well as for topsoil plus 2g DAP/pot while the lowest value was recorded for (7x13cm) pot size filled with one to one ratio of biochar to topsoil (Table 2). Improvements in soil moisture content and in fertility status of the media blended with biochar could be the main reason for the less number of days to 50% emergence. The black color of biochar can contributes absorb the heat that leads to accelerate the emergence and to the avoid the inhibitory effect of white light during coffee seed germination as coffee (*Coffea arabica* L.) seeds are sensitive to white light, which delays seed germination [24]. In line with this, it has been reported that, applications of biochar could be adopted as a sustainable agronomic strategy, since it demonstrated a strong potential to improve soil nutrient status and soil water content [25]. Therefore, the fastest emergence rate most probably be related to the stored soil growth media moisture on high surface area of biochar applied could enhanced the emergence rate of coffee seeds.

Table 2. Days to 50% emergence of coffee seedlings affected by the interaction of Pot size and biochar to topsoil ratio.

Biochar Ratio						
Pot size (cm)	Top Soil	1BC: 1TS	1BC: 2TS	1BC: 3TS	1BC: 4TS	Ts+2gDAP
7x13	62.00 ^a	46.33 ^h	50.66 ^{gh}	49.66 ^{gh}	55.00 ^{cde}	61.33 ^{ab}
10x16	63.33 ^a	49.33 ^{gh}	52.66 ^{c-g}	54.33 ^{c-f}	53.00 ^{c-g}	61.66 ^{ab}
13x19	64.00 ^a	54.33 ^{c-f}	51.00 ^{d-h}	54.33 ^{c-f}	52.33 ^{c-g}	63.66 ^a
16x22	63.67 ^a	50.00 ^{gh}	57.00 ^{bc}	56.00 ^c	55.66 ^{cd}	64.00
CV (%)	5.14					
LSD (0.05)	4.74					

Mean values within a row or column followed by the same letter(s) are not significantly different from each other at $P \leq 0.05$.

3.3. Relative Growth Rate (RGR)

A significantly ($P=0.014$) higher relative growth rate (0.83 mg/g/day) were found in the (16x22 cm) pot size interacted with one to four (1:4) biochar to top soil ratio followed by the seedling grown in (13x19cm) and the same ratio biochar to top soil (Table 3). On the other hand, the lowest value of relative growth rate (0.64 mg/g/day) was observed under (7x13cm) pot size without any amendments. This result could be probably due to the larger growing media offers larger plant nutrient and increase vegetative growth at their early growth stage that increased at decreasing ratio of biochar to top soil that improved the media without any negative effects.

Relative growth rate expresses the total plant dry weight increase in a time interval in relation to the initial weight or dry matter increment per unit biomass per unit time of dry weight increase and expressed as unit dry weight per unit dry weight per unit time available from soil based rooting media. This could be due to the largest pot providing adequate space and plant nutrients required for the seedling growth over a short time. Inline result was also reported as pot size directly affects the seedling growth rate within a short time [26]. The RGR is the product of Net Assimilation Rate (NAR) and Leaf Area Ratio (LAR), where NAR is largely the net result of carbon gain (photosynthesis), and carbon losses (respiration, exudation, and volatilization) expressed per unit leaf area [26].

Table 3. Relative growth rate (mg/g/day) affected by biochar ratio and pot size interaction.

Biochar Ratio						
Pot size (cm)	Top Soil	1BC: 1TS	1BC: 2TS	1BC: 3TS	1BC: 4TS	Ts+2gDAP
7x13	0.65 ^k	0.68 ^{ij}	0.71 ^{efgh}	0.75 ^{cd}	0.76 ^c	0.71 ^{efgh}
10x16	0.67 ^j	0.69 ^{ghij}	0.72 ^{efg}	0.76 ^c	0.77 ^c	0.73 ^{def}
13x19	0.68 ^{ij}	0.68 ^{hij}	0.73 ^{de}	0.80 ^b	0.81 ^{ab}	0.78 ^c
16x22	0.68 ^j	0.70 ^{fghi}	0.74 ^{def}	0.82 ^{ab}	0.83 ^a	0.77 ^c
CV (%)						
LSD (0.05)						

Mean values followed by the same letter(s) within a row or column are not significantly different from each other at $P \leq 0.05$.

4. Summary and Conclusions

Coffee (*Coffea arabica* L.) seed emergence percentage, emergency rate and seedling relative growth rate was affected by different ratio of biochar to topsoil application ratio under nursery condition. The findings of the study showed that different pot sizes and amendment of topsoil by biochar ratio significantly affected the total seedling growth and leaf macronutrient contents.

All pot size interacted with one to three and one to four biochar to topsoil ratio were relatively enhanced the seedling growth compared to the local practice. Pot size 13x19cm and 16x22cm interacted with one to three ratio of biochar to topsoil were seen superior to improve the seed emergency rate and seedling relative growth rate. Therefore, even though the seed emergency percentage and emergency rate is higher in higher ratio of biochar, it is very important to use the biochar in lower amount of ratio in coffee seedling nursery media preparation as the seedling relative growth rate is very

aggressive in the lower (1:3 and 1:4) ratio of biochar to topsoil.

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