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Research Article

Cost of Productions and Partial Budget Analysis of Coffee (*Coffea arabica* L.) Seedling Across Various Pot Sizes and Biochar-Based Media Preparations

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Abstract

Coffee cultivation mainly lies in the production of coffee seedlings with desirable characteristics under the recommended nursery management operations. Any improper handling made at early stage would remain to cause poor field performances. Biochar is considered as a soil conditioner and a carrier for plant nutrients, which improve the different soil functions, as an amendment to improve soil fertility, soil pH, available phosphorus, organic carbon, and water retention. The experiment was conducted to provide detail information on production costs and gross net profits of reduced sizes poly bag and biochar application used for coffee seedling production under small scale farmers. Biochar to topsoil blended at 1:3 ratio was found to increase (SVI) over the local and standard practice by 66.50% and 7.50%, respectively. Hence, combined effects of reduced pot size (13x19cm) with biochar mixed topsoil 1:3 noticed to significantly improve soil chemical conditions and growth response of coffee seedlings under nursery conditions at the study area. Besides, the result of simple partial budget analysis indicated the cost effectiveness with reduced polybag sizes as compared to the conventional pot sizes, especially for production, transportation and early stage field transplanting of quality coffee seedlings in large quantities. However, it is imperative to assess the effects of the present promising pot size and pot media treatments under field performance by considering growth, yield, and quality performances and profitability to smallholder coffee farmers over locations and year in the study area and other similar agro ecological zones in the country.

Keywords

Biocha, Cost of Production, Coffee Seedling, Poly Bag, Net Benefit

1. Introduction

Ethiopia stands in respect not only as the birth place/origin of coffee (*Coffea arabica* L,) with wide genetic diversity, an important and leading coffee producer and 1st exporter from Africa and 5th world wide, but the country is also the highest coffee consumer still with a dramatical domestic market increments. In addition to that, Ethiopia has immense production potential and opportunity because of favorable agro-climatic conditions. Coffee is a major source of export revenue generating about 30-35 percent of the country's total export earnings. Currently around 1,062,034.00 hector of land is covered by coffee cultivation that yields (761,500.00MT) during 2022/2023 cropping season with very low productivity not more than (7.17Q/ha) [1]. In 2023/24

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total production is forecasted to be 8.35 million 60 kg bags (501,000 MT). The coffee industry in Ethiopia is the driving force of the country's economy, socio-cultural, life of Ethiopian people. 25 percent of the country's population is directly or indirectly dependent on the coffee value chain. The study conducted to provide detail information on production costs and gross profits of coffee production under smallholder farmers at the stage to coffee age of one-year describes gross margin, benefit-cost ratio, sensitivity, and break-even analysis showed that, seedling purchase cost is the most important cost. For the establishment of a hectare of new coffee and plant management until one year, ETB 79920.95 is needed. A single coffee seedling needs ETB 31.9 at this stage [2]. Land and nursery clearing and digging, weeding to collect forest soil, transporting soil, sand and compost to nursery, Compost preparation, mixing and sieving, Seed bed preparation, Shade construction, cutting poly-bag, Filling, and Put the filled polytene bag on the seed bed, Watering and sowing seed, removing mulch and, Re-arrange seedlings on seed bed, Fertilizer application, Guarding nursery site, are a tedious activity done within the nursery operation until to transplanting time.

Despite the fact that coffee plays a significant role in Ethiopian economy, productivity at farm level is among the lowest in the world in the last decade [3]. Coffee productivity potential hardly exceeds 0.67ton ha^{-1} [4] and 0.71ton ha^{-1} [1] that could indicate the current environmental and soil fertility status of coffee producing area both in nursery and at field as producers are using traditional management practice due to the lack of new production information. Coffee cultivation mainly lies in the production of coffee seedlings with desirable characteristics under the recommended nursery management operations. Any improper handling made at early stage would remain to cause poor field performances in the lifespan of coffee trees in the field [5]. Biochar is considered as a soil conditioner and a carrier for plant nutrients, which improve the different soil functions, as an amendment to improve soil fertility, that significantly increase soil pH, available phosphorus, organic carbon, and water retention (Jin *et al.*, 2018). Biochar applications gradually increased the contents of ammonium ($NH4^+$), nitrate ($NO3^-$), and enhanced the soil microorganism and enzymatic activities [6], to stimulate seed germinations and also the seedling growth [7]. Despite the various advantages and techniques of utilizing biochar on established coffee plants as documented by [8], there is a lack of appropriate information regarding the impacts of poly bag size and nursery media amendments on quality seedling productions and economic analysis or even the partial expenses related to the utilization of biochar during the nursery phase of coffee seedling productions in general particularly in Ethiopia. The main objective of this study was to provide detail information on production costs and gross net profits of reduced sizes poly bag and biochar application used for coffee seedling production under smallholder farmers.

2. Material and Methods

2.1. Description of the Study Area

The study was conducted at Awada Agricultural Research Sub-Center (AARSC) of the Wondogenet Agricultural Research Center. The area is situated in the moderate to cool semi-arid mid highland agro-ecology of south Ethiopia [7], with 6°3'N Latitude and 38°E Longitude at an altitude elevation of about 1740 meter above sea level. The major soil types of the center are Nitisol and chromatic-cambisols that are highly suitable for coffee production [9]. The area has a semi-bimodal rainfall distribution characterized by double wet and dry seasons with an average precipitation of 1342 mm per annum [10].

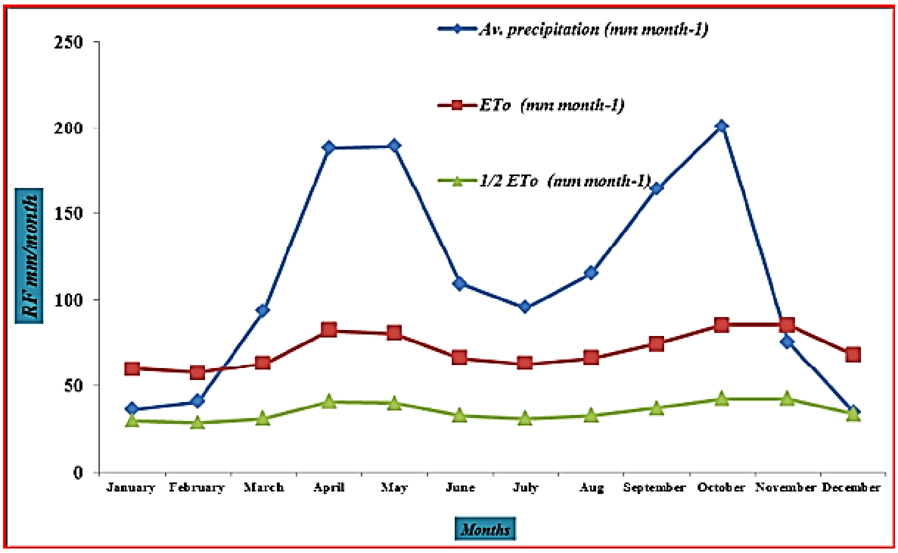

Figure 1. *Awada Agricultural Research Sub-center metrological station for the last decade rain fall data (2010-2020).*

2.2. Experimental Design and Treatment Combinations

The experiment was conducted at Awada Agricultural Research sub-center with factorial experiment arranged in a randomized complete block design (RCBD) with three replications to provide estimates of treatment effects or differences among treatment effects. Twenty-four (24) treatment combinations with four levels of pot size (width by height) (P_1 = 7cmx13cm, P_2 = 10cmx16cm, P_3= 13cmx19cm and P_4 = 16cmx22cm) and five levels of biochar to top soil ratio (0:1,1:1, 1:2, 1:3, 1:4) by(v/v) were used for the treatment. The conventional pot (16cmx22cm) filled with, Top-soil+2gDAP was used as a positive control, while topsoil alone in the same size (16cmx22cm) was used as a control.

2.3. Total Variable Cost

Total variable cost of poly-bag, biochar preparation, fertilizer cost, filling poly bags and other nursery operations were some of the variable costs considered in the experiments. The costs of other inputs like labor cost for nursery management seed sowing and weeding, harvesting sample were considered to be remain the same or would be insignificant among treatments.

2.4. Gross and Net Benefit

Gross field benefit of each treatment was computed by multiplying field or farm gate price of seedlings in the study area for one hectare field planting (2500 seedling ha^{-1}), as the variety used for the study was classified as open canopy type. Hence, net benefit was calculated by subtracting the total variable costs that vary from the gross field benefit for each treatment. The process of calculating the MRR of alternative treatments, proceeding in steps from the least costly treatment to the most costly, and deciding if they are acceptable to farmers, is called marginal analysis [11], this experimental treatment was also adjusted following this formula.

$$\text{Marginal Rate of Return (MRR)} = \frac{\text{Change of net benefit (CNB)}}{\text{Change of production cost}} \text{x100} \ldots \text{CIMMITY, 1988}$$

3. Result and Discussion

3.1. Partial Budget Analysis

The analysis of partial budgets offers valuable insights for decision-making purposes. It serves as a tool to compare the effects of technological changes on farm costs and returns by assessing both positive and negative impacts. This method is straightforward yet efficient in evaluating cost and benefit differentials among various technologies to determine profitability. Referred to as partial due to its focus on the changing costs rather than all production expenses, this analysis helps farmers understand the financial implications of altering their production practices. By concentrating on the net income impact of production changes, rather than the complete production costs, this approach provides a practical assessment [12]. According to CIMMYT (1988), a partial budget transcends mere numerical calculations to assist farmers in identifying reasons behind potential changes. An underlying assumption of this analysis is that farmers act rationally to maximize profits, adjusting seedling prices to cover production costs while deviating from their original plans. The study assumes that farmers sell seedlings to observe the technology's impact at the nursery level, without extending the analysis to post-nursery stages or field experiments for standardization. This analysis relies on the average costs and benefits of each treatment across all trials, with total variable costs. Seed and seedling prices are considered constant within each treatment. Drawing from the experience of Dale woreda, coffee seedlings are typically sold at five birr each, while Avocado seedlings fetch around Birr 15 per seedling, sometimes on credit from nursery operators [13]. Through participatory extension approaches and collaborations, the number of private nursery operators grew from six to 20 by 2009 [13]. Connections with the productive safety net program aid in expanding seedling sales to emerging commercial farmers. As reported by [13], the absence of intermediaries in coffee seedling marketing in Dale woreda ensures farmers receive the full market price.

Table 1. *Cost of input Pot, Fertilizer, Topsoil, Biochar production, and other materials.*

Treatments	Preparing Top-Soil.	Biochar preparation	Pot Cost	Fertilizer Cost	Nursery preparation	Filling Pots	Nursery Operation	Total cost of each Treatment	Converted cost to hectare
P1B0Ts	30.00	0.00	15.00	0.00	39.00	1.50	30.00	85.50	3,562.50
P1BTs4	30.00	12.00	15.00	0.00	39.00	1.50	30.00	97.50	4,062.50
P1BTs3	30.00	15.00	15.00	0.00	39.00	1.50	30.00	100.50	4,187.50

Treatments	Preparing Top-Soil.	Biochar preparation	Pot Cost	Fertilizer Cost	Nursery preparation	Filling Pots	Nursery Operation	Total cost of each Treatment	Converted cost to hectare
P1BTs2	30.00	18.00	15.00	0.00	39.00	1.50	30.00	103.50	4,312.50
P1BTs1	30.00	24.00	15.00	0.00	39.00	1.50	30.00	109.50	4,562.50
P1BTs5	30.00	0.00	15.00	24.00	39.00	1.50	30.00	109.50	4,562.50
P2B0Ts	45.00	0.00	24.00	0.00	54.00	2.25	45.00	125.25	5,218.75
P2BTs4	45.00	18.00	24.00	0.00	54.00	2.25	45.00	143.25	5,968.75
P2BTs3	45.00	21.00	24.00	0.00	54.00	2.25	45.00	146.25	6,093.75
P2BTs2	45.00	24.00	24.00	0.00	54.00	2.25	45.00	149.25	6,218.75
P2BTs1	45.00	30.00	24.00	0.00	54.00	2.25	45.00	155.25	6,468.75
P2BTs5	45.00	0.00	24.00	39.00	54.00	2.25	45.00	164.25	6,843.75
P3BoTs	60.00	0.00	36.00	0.00	78.00	3.00	60.00	177.00	7,375.00
P3BTs4	60.00	18.00	36.00	0.00	78.00	3.00	60.00	195.00	8,125.00
P3BTs3	60.00	24.00	36.00	0.00	78.00	3.00	60.00	201.00	8,375.00
P3BTs2	60.00	30.00	36.00	0.00	78.00	3.00	60.00	207.00	8,625.00
P3BTs1	60.00	36.00	36.00	0.00	78.00	3.00	60.00	213.00	8,875.00
P3BTs5	60.00	0.00	36.00	60.00	78.00	3.00	60.00	237.00	9,875.00
P4B0Ts	75.00	0.00	48.00	0.00	99.00	3.75	75.00	225.75	9,406.25
P4BTs4	75.00	30.00	48.00	0.00	99.00	3.75	75.00	255.75	10,656.25
P4BTs2	75.00	36.00	48.00	0.00	99.00	3.75	75.00	261.75	10,906.25
P4BTs3	75.00	36.00	48.00	0.00	99.00	3.75	75.00	261.75	10,906.25
P4BTs1	75.00	42.00	48.00	0.00	99.00	3.75	75.00	267.75	11,156.25
P4BTs5	75.00	0.00	48.00	81.00	99.00	3.75	75.00	306.75	12,781.25

P_1=pot size (7x13cm), P_2=pot size (10x16cm), p_3=pot size (13x19cm), p_4=pot size (16x22cm). B0TS = No Biochar or Top soil only, BTs_1 = one to one biochar to top soil ratio BTs_2 = one to two biochar to top soil ratio, BTs_3 = one to three biochar to top soil ratio, BTs_4 = one to four biochar to top soil ratio, BTS_5= Top soil with 2g DAP per Seedling.

3.2. Total Variable Cost

The total variable cost incurred in the preparation of pot, topsoil, and biochar, as well as the expenses for fertilizer, pot filling, and nursery operations conducted during the experiment are categorized as variable costs. Other expenses related to inputs and production activities like labor for nursery management, seed procurement, planting, weeding, and harvesting were assumed to either remain constant or be negligible across different treatments. The plot treated with the largest pot size and 2gDAP/pot fertilizer recorded the highest variable cost of 12,781.25 (ETB), while the lowest variable cost of 3,562.50 (ETB) was observed in the plot treated with the smallest poly bag size without biochar or artificial fertilizer.

3.3. Gross and Net Benefit of Each Treatment

The calculation of the gross field benefit for each treatment involved multiplying the field or farm gate price of seedlings produced in the study area per hectare (2500 seedlings ha^{-1}), given that the variety under examination belonged to the open type canopy category. Despite each seedling being priced equally, the gross field benefits derived from all treatments were nearly identical. The seedling prices were determined based on the average price of three Ethiopian Birr per seedling, as indicated by local seedling pricing [13]. In the partial budget analysis, the final component is the net benefits, which were computed by deducting the total costs from the gross field benefits of coffee seedlings in each treatment. Consequently, the treatment with the highest net benefit was observed in plots using the smallest poly bag size without any amendments, although this might not be advisable for farmers aiming to enhance seedling quality or growth performance as the primary objectives of this study. Thus, the optimal combination of superior seedling performance and maximum net benefit was obtained in plots treated with a 13x19cm size with a biochar to topsoil ranging from one to three ratios (Table 2).

3.4. Marginal Rate of Return

The marginal rate of return signifies the anticipated gains for farmers upon transitioning from one practice to another, according to [11]. The computation of marginal rates of return for different treatments involves a stepwise approach from the least expensive to the costliest, determining their viability for farmers, a process known as marginal analysis [11]. A method to evaluate this transition is by dividing the change in net benefits by the varying costs, emphasizing that farmers recommended minimum rate of return ranges from 50 to 100% [13]. Hence, the adoption of a (13cmx19cm) pot size with a biochar to topsoil ratio of one to three yields a rate of return of 63.15%, attributed to the reduced size compared to the local control (Table 2). The analysis of this scenario, based on a single year's experiments, would likely guide the selection of promising treatments for further field testing on seedling performance and yield potential, rather than immediate farmer recommendations. Nevertheless, determining the acceptability of treatments to farmers necessitates knowledge of the expected rate of return. [14] conducted a study assessing the influence of agronomic factors and costs associated with incorporating biochar into soil at varying rates. The advantages of biochar application include its ease of implementation for farmers, reduction in fertilizer usage, cost savings in production, mitigation of inorganic fertilizer scarcity issues, simple installation and application processes on farmland, availability of abundant raw materials in local farms, and utilization of agricultural waste that would otherwise be discarded. Labor employed is considered productive as the wages paid are lower than the labor's contribution to the farming enterprise.

Table 2. *Total cost and net benefit analysis of the seedling production with different poly-bag size and media.*

Treatments	No. Seedling/ plot	Total production cost	Prod cost / seedling	No. of seedling /hector/	Total cost per hectare (ETB)	Farm get price /seedling/(ETB)	Growth field benefit (ETB)	Net benefit (ETB)
P1B0Ts	60	78.00	1.30	2500	3250.00	5.00	12500.00	9250.00
P1BTs4	60	90.00	1.50	2500	3750.00	5.00	12500.00	8750.00
P1BTs3	60	93.00	1.60	2500	3875.00	5.00	12500.00	8625.00
P1BTs2	60	96.00	1.60	2500	4000.00	5.00	12500.00	8500.00
P1BTs1	60	102.00	1.70	2500	4250.00	5.00	12500.00	8250.00
P1BTs5	60	102.00	1.70	2500	4250.00	5.00	12500.00	8250.00
P2B0Ts	60	114.00	1.90	2500	4750.00	5.00	12500.00	7750.00
P2BTs4	60	132.00	2.20	2500	5500.00	5.00	12500.00	7000.00
P2BTs3	60	135.00	2.30	2500	5625.00	5.00	12500.00	6875.00
P2BTs2	60	138.00	2.30	2500	5750.00	5.00	12500.00	6750.00
P2BTs1	60	144.00	2.40	2500	6000.00	5.00	12500.00	6500.00
P2BTs5	60	153.00	2.60	2500	6375.00	5.00	12500.00	6125.00
P3BoTs	60	162.00	2.70	2500	6750.00	5.00	12500.00	5750.00
P3BTs4	60	180.00	3.00	2500	7500.00	5.00	12500.00	5000.00
P3BTs3	60	186.00	3.10	2500	7750.00	5.00	12500.00	4750.00
P3BTs2	60	192.00	3.20	2500	8000.00	5.00	12500.00	4500.00
P3BTs1	60	198.00	3.30	2500	8250.00	5.00	12500.00	4250.00
P4B0Ts	60	207.00	3.50	2500	8625.00	5.00	12500.00	3875.00
P3BTs5	60	222.00	3.70	2500	9250.00	5.00	12500.00	3250.00
P4BTs4	60	237.00	4.00	2500	9875.00	5.00	12500.00	2625.00

Treatments	No. Seed-ling/ plot	Total pro-duction cost	Prod cost / seedling	No. of seed-ling /hector/	Total cost per hectare (ETB)	Farm get price /seedling/(ETB)	Growth field benefit (ETB)	Net bene-fit (ETB)
P4BTs2	60	243.00	4.10	2500	10125.00	5.00	12500.00	2375.00
P4BTs3	60	243.00	4.10	2500	10125.00	5.00	12500.00	2375.00
P4BTs1	60	249.00	4.20	2500	10375.00	5.00	12500.00	2125.00
P4BTs5	60	288.00	4.80	2500	12000.00	5.00	12500.00	500.00

P_1= pot size (7x13cm), P_2=pot size (10x16cm), p_3=pot size (13x19cm), p_4=pot size (16x22cm). B0TS = No Biochar or Top soil only, BTs_1 = one to one biochar to top soil ratio BTs_2 = one to two biochar to top soil ratio, BTs_3 = one to three biochar to top soil ratio, BTs_4 = one to four biochar to top soil ratio, BTS_5= Top soil with 2g DAP per Seedling.

4. Summary and Conclusions

The improved nutrient uptake and growth of coffee seedlings through the use of biochar as a fertilizer provides alternative fertilizer and/or enhancement options to promote coffee seedling growth. Therefore, biochar-based media preparation was significantly promising to better growth of coffee seedlings than the topsoil only and even more efficient than using inorganic fertilizer. This one-year study showed that, a promising potential of even the smallest polybag size to produce good quality seedling when the topsoil amended with biochar as a fertilizer for the nursery media to coffee seedling growth at the lower rate of applications. Even though, the highest net benefit was recorded from the smallest pot without amendments, using biochar from locally available biomass such as coffee husk would also reduce the dependence on the external cost of production like fertilizer cost. The seedling raised in 7x13cm and 10x16cm pot filled with one to three ratios of biochar to topsoil were able to produce a good quality seedling. However, as the seedlings, roots raised in the smaller volume were twisted due to narrow space and the taproot were passing through the size; waiting up to transplanting time might result to damage the root system of the seedling. Therefore, transplanting these seedlings before the first four pair of a leaves would be advantageous especially for those produce is large number of seedlings. As coffee is a perennial crop, and can be used from the long-lasting effects of biochar, further investigation is very important to identify the effects of these treatments on soil acidity, water holding capacity, and general fertility status of coffee farm. However, it is imperative to assess the effects of the reduced poly bag size and optimum ratio of biochar to topsoil well performed at nursery level by considering growth, yield, and quality performances and profitability to smallholder coffee farmers over locations and year in the study area and other similar agro-ecological zones in the country. The adoption of a (13cmx19cm) pot size with a biochar to topsoil ratio of one to three yields a rate of return of 63.15%, attributed to the reduced size compared to the local control. The analysis of this scenario, based on a single year's experiments, would likely guide the selection of promising treatments for further field testing on seedling performance and yield potential, rather than immediate farmer recommendations.

Abbreviations

BC	Biochar
MRR	Marginal Rate of Return

Author Contributions

Leta Ajema Gebisa is the sole author. The author read and approved the final manuscript.

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Conflicts of Interest

The author declares no conflicts of interest.

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