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Effect of Different Rates of Vermicompost on Growth Performance of Coffee *(Coffea arabica* L.) Seedlings in Buno Bedele Zone

Habtamu Girma*, Samuel Rabuma and Tamiru Tolasa

Oromia Agricultural Research Institute (OARI), Bedele Agricultural Research Center (BeARC), P.O.Box 167, Bedele, Ethiopia

**Corresponding author*

Abstract

Coffee (*Coffea arabica* L.) is one of the most important cash crops in Ethiopia, contributing significantly to the national economy and rural livelihoods. However, the production of vigorous and healthy coffee seedlings is often constrained by declining soil fertility and inadequate nutrient management practices in nursery systems. Vermicompost is an environmentally friendly organic fertilizer that enhances soil fertility and plant growth through the supply of essential nutrients and improvement of soil physical, chemical, and biological properties. This study aimed to evaluate the effect of different rates of vermicompost on the growth performance of coffee seedlings. The experiment was conducted during 2022-2024 cropping season at Bedele Agricultural Research Center, Seko nursery site Gachi District, Southwestern Ethiopia, using a Randomized Complete Block Design and replicated three times. The experiment consisted of six treatments: vermicompost application rates equivalent to 0.25, 0.50, 0.75, 1.00, and 1.25 t ha^{-1}, along with a control treatment comprising a conventional potting mixture of topsoil, compost, and sand in a ratio of (2:1:1). The results revealed that vermicompost application significantly ($P < 0.01$) improved key growth parameters, including seedling height, stem girth, leaf number, leaf area, number of nodes, root volume, and both shoot fresh and dry biomass. In contrast, taproot length, root fresh weight, and root dry weight were not significantly affected by vermicompost application. Among the tested treatments, the application of 0.75 t ha^{-1} vermicompost produced the most vigorous seedlings and resulted in the highest benefit–cost ratio (2.19). Therefore, the application of 0.75 t ha^{-1} vermicompost is recommended for coffee seedling production in the study area and similar agro ecological conditions, as it enhances seedling growth and offers superior economic returns.

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Buno Bedele Zone, *Coffea arabica* L., Coffee seedlings, Growt performance and Vermicompost

Introduction

Coffee (*Coffea arabica* L.) belongs to the genus *Coffea*, which is part of the *Rubiaceae* family, one of the largest families of flowering plants, consisting 500 genera and 6,000 species (Ferreira *et al*., 2019). Currently, around 139 species are classified under the *Coffea* genus (Guyot *et al*., 2020). However, only two species dominate coffee production worldwide: *Coffea arabica* L. and *Coffea canephora* P. (Robusta). *Coffea arabica* L. accounts for over 60% of global coffee production, while *Coffee canephora* P. contributes less than 40% (Farah and Dos Santos, 2015). The highlands of southwestern Ethiopia are recognized as the primary center of origin and genetic diversity of Arabica coffee (Lashermes *et al.,* 1996; Tesfaye *et al.,* 2014). In Ethiopia, *Coffea arabica* L. is distributed across diverse agro-ecological zones, occurring at elevations ranging from 560 to 2,600m above sea level and under annual precipitation regimes of approximately 800–2,000mm (Tesfaye *et al.,* 2014; Moat *et al.,* 2017). Ethiopia stands as Africa's largest coffee producer and the fifth-largest exporter of Arabica coffee in the world.Ethiopia currently accounts for approximately 6.5% of global coffee production (USDA, 2025/26). The crop is crucial to the livelihoods of over 15 million smallholder farmers and other actors in the coffee sector and contributing 30% of the nation's total export revenue (ECTA 2025). Coffee is deeply embedded in Ethiopian culture, politics, economy, social life, and national identity. Approximately 55% of Ethiopia's coffee production is consumed domestically (USDA, 2021). In Ethiopia, the Oromia Region accounts for approximately 59.5% of national coffee production, according to ECTA (2026), making it the country's leading coffee-producing region.

Coffee is an important agricultural commodity and a major source of income for smallholder farmers in Buno Bedele Zone, Southwestern Oromia, Ethiopia. Despite the region's favorable agroecological conditions and long-standing tradition of coffee production, productivity in many coffee-growing areas remains below its potential. This low productivity is associated with several factors, including declining soil fertility, inadequate nutrient management, and inappropriate nursery management practices (Mekonen *et al.,* 2020). Successful coffee production largely depends on the establishment of vigorous, healthy, and high-quality seedlings with desirable agronomic characteristics through the application of appropriate nursery management practices. Management practices during the nursery stage are particularly critical because improper handling at this early stage can adversely affect subsequent field establishment, growth, productivity, and ultimately the productive lifespan of coffee trees (Anteneh *et al.,* 2015). Therefore, the use of suitable growing media is an essential component of quality coffee seedling production.

Previous studies and recommendations have emphasized the use of appropriate potting media, particularly forest soil, to promote the production of vigorous and healthy coffee seedlings (IAR, 1996; Yacob *et al.,* 1996). The application of compost and animal manures to agricultural soils generally has beneficial effects because these organic amendments contain substantial amounts of both macro- and micronutrients. Moreover, the growing need for renewable, locally available, and cost-effective nutrient sources has increased interest in organic amendments as an integral component of sustainable agricultural production systems (Tigist *et al.,* 2019). In response to increasing demand for sustainably produced agricultural commodities driven by environmental, social, and food-safety considerations, the utilization and recycling of organic materials have become increasingly important. This is particularly relevant to export-oriented crops such as coffee, for which sustainable production practices are becoming an important consideration in international markets (Chemura, 2014).

Among organic soil amendments, vermicompost (VC) has gained considerable recognition because of its potential to improve soil fertility, enhance nutrient availability, and stimulate plant growth (Ayilara *et al.,* 2020). Compared with conventional compost, vermicompost has been reported to increase plant growth by 50–100%, while improvements of 30–40% have been observed relative to the use of chemical fertilizers (Sinha *et al.,* 2010). These effects are attributed to the relatively high availability of essential nutrients and the presence of biologically active compounds that can promote plant development. In coffee nurseries, the incorporation of vermicompost into growth media can improve important physical and chemical properties, including water-holding capacity, aeration, and cation exchange capacity.

These improvements create a more favorable rhizosphere environment for root establishment, nutrient uptake, and seedling development. Such benefits are particularly important during the early stages of coffee growth, when adequate nutrient supply and rapid root development are critical for producing vigorous seedlings capable of successful establishment and sustained growth after field transplantation (Berhe, 2024). Consequently, the use of vermicompost represents a promising and environmentally sustainable approach for improving the quality of coffee seedlings while reducing dependence on externally sourced and potentially costly inorganic fertilizers.

Although several studies have reported the beneficial effects of organic amendments on coffee production, information regarding the optimum rate of vermicompost application for coffee seedling growth under nursery conditions remains limited, particularly in the coffee-growing areas of Buno Bedele Zone. Determining an appropriate vermicompost application rate is essential for improving nursery management practices and enhancing sustainable coffee production. Therefore, this study was conducted to evaluate the effects of different vermicompost application rates on the growth performance of coffee seedlings and to identify the optimum rate that promotes vigorous growth and produces high-quality seedlings in the study areas and similar agro-ecological conditions.

Materials and Methods

Description of the Study Areas

The experiment was carried out at Bedele Agricultural Research Center (BeARC) Seko Coffee nursery site Gechi district, Buno Bedele Zone during 2022-2024 cropping season. The district is bordered on the south by Didessa, on the west by Didessa River, on the north by Bedele, and on the east by Jimma Zone. The district is located 465 km from Addis Ababa and 18 km from Bedele town. It is located at an average elevation 1277 - 2467 m.a.s.l and located at $8^0$16'60''N Latitude and $36^0$34'00''E Longitude. The annual rainfall ranges from 1500-2100 mm. and the minimum and maximum daily temperatures are 11°C and 28°C respectively.

Experimental Materials and Design

One improved (74110) coffee variety was used for this experiment. The experiment was arranged in randomized block design (RCBD) with three replications and Six (6) treatments. The rates of vermcompost in pots were used: 0.25 t/ha, 0.5 t/ha, 0.75 t/ha, 1 t/ha, 1.25 t/ha and Control, (2: Topsoil, 1: Compost and 1: Sand). Twenty (20) pots per treatments were used. All the necessary management practice has been done uniformly for all treatments.

Data Collected

Growth parameters of coffee seedlings were recorded using standard measurement procedures and appropriate instruments. The parameters assessed included plant height, stem diameter, number of primary branches, number of leaves, and number of nodes, taproot length, leaf area, and root volume. Fresh biomass measurements comprised leaf, stem, and root fresh weights, while dry biomass measurements included leaf, stem, and root dry weights. Total dry matter accumulation was subsequently determined from the combined dry biomass of the plant components.

Data Analysis

The data were analyzed using analysis of variance (ANOVA) in SAS version 9.3 (SAS, 2011). Treatment means were compared and separated using Duncan's Multiple Range Test (DMRT) at the 5% level of significance (Steel and Torrie, 1980).

Cost Benefit Ratio Analysis

Potentially profitable treatments were selected from among the tested treatments following the procedure outlined by CIMMYT (1988). Economic analysis was performed using the following indicators: Total Variable Cost (TVC), Total Benefit (TB), and the Cost–Benefit Ratio (CBR), calculated as the ratio of Total Benefit to Total Variable Cost.

Results and Discussion

Pre-Sowing Physico-Chemical Properties of the Soil and Vermcompost

The selected physicochemical properties of the soil at the experimental site prior to planting are presented in (Table 1).The particle size analysis revealed that the soil comprised 63.6% clay, 18.0% silt, and 18.4% sand. Based on the textural classification system of Bouyoucos (1962), the soil was classified as clay. This finding is in close agreement with the results reported by Teshome B. and Sofiya A. (2021), who documented a clay soil containing 64.67% clay, 25.95% silt, and 9.38% sand. The soil pH recorded in the present study was 5.18, indicating a strongly acidic soil condition according to the classification of Tekalign (1991). This finding is consistent with the results reported by Brady and Weil (2017), who also documented strongly acidic soil conditions within a similar pH range.

The cation exchange capacity (CEC) of the soil was 36.4 meq 100 g^{-1} soil, indicating a high capacity of the soil to retain and exchange essential nutrient cations. According to Murphy (2007), soils with high CEC values generally possess greater nutrient-holding capacity, enhanced buffering against changes in soil chemistry, and improved fertility status. The observed CEC value of 36.4 meq 100 g^{-1} suggests that the soil has a strong ability to adsorb and supply plant nutrients such as calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), and ammonium (NH_4^+), thereby reducing nutrient losses through leaching. The organic carbon (OC) content of the experimental soil was 1.6%, which is classified as low according to the rating established by Tekalign (1991). This level of organic carbon suggests a moderate capacity of the soil to supply nitrogen through the mineralization of organic matter. Similarly, the organic matter (OM) content of the experimental site was 2.7%, which also falls within the low category based on the classification of Tekalign (1991). The low OC and OM contents indicate limited soil fertility and may constrain nutrient availability for optimal crop growth.

The result of the analysis revealed that the available phosphorus (P) content of the soil was 6.2 mg kg^{-1}.This finding is consistent with the results reported by Bray and Kurtz (1945), who indicated that soils with available P values below 10 mg kg^{-1} are generally considered low in phosphorus status. Similarly, Havlin *et al.,* (2014) reported that available phosphorus levels below 7 mg kg^{-1} often indicate phosphorus deficiency for optimum crop growth. Coffee seedlings needs a good supply of readily available phosphorus, since the root system is not extensive and does not readily utilize less available P forms. According to Tekalign (1991) classification the result of the analysis showed that the available nitrogen content of the soil was 0.14% (Table 1). This finding is in agreement with the results reported by Brady and Weil (2017), who stated that soils containing total nitrogen values between 0.1% and 0.2% are generally classified as having a medium nitrogen status. Similarly, Havlin *et al.,* (2014) reported that agricultural soils with nitrogen content around 0.14% exhibit moderate fertility levels and may require supplementary nitrogen fertilization to achieve optimum crop growth.

The Vermcompost analysis results showed that in (Table 2.) pH (7.5), organic Carbon (23.21) and/or organic matter (40.01), Nitrogen (2) and Available Phosphorus (38.53) are high.These values indicate that the vermicompost is rich in essential plant nutrients and can serve as an effective organic fertilizer. Similar findings were reported by Derib Kifle (2017), who found that vermicomposts contained nutrient levels and pH values suitable for plant growth and soil fertility improvement. Likewise, Tadele Geremu *et al.,* (2020) reported that vermicompost prepared from different organic substrates had high concentrations of organic carbon, nitrogen, and phosphorus, demonstrating its potential as a valuable source of plant nutrients. Furthermore, Bati Dube *et al.,* (2025) also observed that vermicompost produced from various organic materials exhibited favorable pH and high nutrient contents, confirming its effectiveness in enhancing soil fertility and crop productivity.

The Growth Response of Coffee Seedlings to Different Vermcompost Application

The application of vermicompost significantly enhanced the growth performance of *Coffee arabica* seedlings. Plant height, stem diameter, root volume, number of leaves, and leaf area showed highly significant differences ($P \leq 0.01$) among the different vermicompost rates in (Table 3). Seedlings receiving higher rates of vermicompost exhibited superior vegetative growth compared with the control treatment, indicating the beneficial effect of vermicompost on nutrient availability, soil structure, and root development. Similar findings were reported by Senthil Raj R *et al.,* (2022), who found that Arabica coffee seedlings grown in a medium containing soil, sand, and vermicompost recorded significantly greater seedling height, stem diameter, number of leaves, and leaf area compared with other growing media. The authors attributed these improvements to the enhanced supply of essential nutrients and improved physical properties of the growing medium provided by vermicompost. Similarly, Ruba A.V. (2015) observed that vermicompost application stimulated root development, further contributing to improved plant growth and performance.

The Dry and Fresh weight Response of Coffee Seedlings to Different Vermcompost Application

The results showed that different vermicompost application rates significantly affected the fresh and dry weights of coffee seedlings (Tables 4 and 5). Increases in fresh weight were accompanied by corresponding increases in dry weight, indicating enhanced biomass accumulation. This response may be attributed to improved nutrient availability, particularly nitrogen (N), phosphorus (P), and potassium (K), which are essential for plant metabolic processes and vegetative growth.

Vermicompost also enhances soil biological activity and microbial-mediated nutrient mineralization, thereby improving nutrient uptake and plant growth (Kashem *et al.,* 2015). Similar findings were reported by Huang *et al.,* (2019), who observed that increased dry matter production reflects greater protoplasm accumulation and cell development.

Enhanced chlorophyll content may further stimulate photosynthetic activity, leading to higher assimilate production and increased plant dry weight. Overall, across recent findings (Abawari *et al.,* 2021; Soumya *et al.,* 2023; Zergaw *et al.,* 2023; Berhe, 2024), vermicompost application consistently increases both fresh and dry weight of coffee seedlings, with moderate application rates generally producing the most pronounced growth responses due to balanced nutrient release and improved soil physical–biological properties.

Table.1 Physico-Chemical Properties of the Top Soil of Seko nursery site

Soil properties	Values	Ratings
Physical properties		
Clay (%)	63.6	
Silt (%)	18	
Sand (%)	18.4	
Textural class	Clay	
Chemical Properties		
PH (1:2.5 HO)	5.18	Strongly acid
Organic carbon (%)	1.6	Low
Total nitrogen (%)	0.14	Medium
Available P (ppm)	6.2	Low
CEC (meq/100 g soil)	36.4	High

Table.2 Chemical Properties of Vermcompost

Chemical Properties	Values
PH (1:2.5 H2O)	7.5
Organic carbon (%)	23.21
Total nitrogen (%)	2
Available P (ppm)	38.53
Organic matter (%)	40.01

Table.3 Mean Growth parameters of Coffee seedlings at Seko on station

Treatments	PH (cm)	SD (mm)	NL (Single No)	NN (No)	LA (cm2)	TRL (mm)	RV (mm)
Control	24.33^{b}	5.13^{b}	17.56^{b}	9.36^{b}	40.23^{b}	16.13	4.23^{b}
0.25 t/ha VC	27.70^{ab}	6.70^{a}	19.26^{ab}	9.76^{ab}	45.56^{ab}	17.03	6.36^{ab}
0.5 t/ha VC	30.46^{ab}	6.50^{a}	19.33^{ab}	10.23^{ab}	45.80^{ab}	18.96	6.00^{ab}
0.75 t/ha VC	32.56^{a}	6.96^{a}	20.56^{a}	10.13^{a}	54.46^{a}	17.43	8.00^{a}
1 t/ha VC	33.36^{a}	6.73^{a}	20.43^{a}	10.33^{a}	54.13^{a}	16.76	8.00^{a}
1.25 t/ha VC	33.43^{a}	6.93^{a}	21.00^{a}	11.23^{a}	54.36^{a}	17.06	8.56^{a}
Mean	30.31	6.49	19.69	10.17	47.26	17.23	6.52
CV	10.25	8.77	9.78	5.23	14.75	16.93	28.95
LSD(0.05)	7.48	1.03	1.42	1.33	19.13	NS	3.43

PH-Plant height, SD-Stem diameter, NL-Number of leaf, NN-Number of nodes, LA- Leaf area, TRL-Tap root length and RV-Root volume

Table.4 Mean Fresh weight parameters of Coffee seedlings at Seko on station

Treatments	LFW(g)	SFW(g)	RFW(g)
Control	13.43[b]	6.53[b]	5.23
0.25 t/ha VC	16.60[ab]	8.46[ab]	6.43
0.5 t/ha VC	19.60[ab]	9.53[ab]	6.33
0.75 t/ha VC	21.60[a]	11.43[a]	8.00
1 t/ha VC	21.26[a]	11.06[a]	7.33
1.25 t/ha VC	21.70[a]	11.53[a]	7.30
Mean	19.03	9.75	6.77
CV	19.56	23.87	23.69
LSD(0.05)	6.65	4.16	NS

LFW-Leaf fresh weight, SFW-Stem fresh weight, and RFW-Root fresh weight

Table.5 Mean Dry weight parameters of Coffee seedlings at Seko on station

Treatments	LDW(g)	SDW(g)	RDW(g)	TDM(g)
Control	3.23[b]	2.03[b]	1.63	6.56[b]
0.25 t/ha VC	4.86[ab]	3.06[ab]	1.66	10.03[ab]
0.5 t/ha VC	4.16[ab]	3.73[a]	1.60	10.16[ab]
0.75 t/ha VC	5.43[a]	3.86[a]	1.80	11.73[a]
1 t/ha VC	5.50[a]	3.83[a]	1.86	11.63[a]
1.25 t/ha VC	5.10[a]	3.83[a]	1.88	11.13[a]
Mean	4.71	3.39	1.74	10.21
CV	20.06	32.17	23.35	21.84
LSD(0.05)	1.72	1.53	NS	4.05

LDW-Leaf dried weight, SDW-Stem dried weight, RDW-Root dried weight, and TDM-Total dried matter

Table.6 Cost–Benefit Ratio Analysis of Vermicompost Treatments on Coffee seedling growth

Treatments	LC	L/ULC	Fe C	FC	TVC	TB	CBR %
Control	2500	1250	12500	10000	26250	25000	0.95
0.25 t/ha VC	400	125	3750	10000	14275	25000	1.75
0.5 t/ha VC	800	250	7500	10000	18550	31250	1.68
0.75 t/ha VC	1200	375	11250	10000	22825	50000	2.19
1 t/ha VC	1600	500	15000	10000	27100	50000	1.85
1.25 t/ha VC	2000	625	18750	10000	31375	50000	1.59

LC-Labor cost, L/ULC-Loaded, unloaded cost, Fe C-Fertilizer cost, F-Fixed cost, TVC-Total variable cost, TB-Total Benefit and CBR-Cost benefited ratio

Cost Benefit Ratio Analysis

The result revealed that marginal rate of return (MRR %) analysis for seedlings indicated that the highest cost benefit ratio (2.19) was recorded from the application of 7.5 Qt VC ha-1 over the control treatment (Table 6). From this result, the treatments receiving 7.5 VC Qt ha-1 was more profitable than the rest of treatment combinations.

In conclusion, the experiment demonstrated that vermicompost application significantly improved the growth performance of *Coffea arabica* L. seedlings in the Buno Bedele Zone. Among the evaluated application rates, 0.75 t ha^{-1} consistently produced the highest values for measured growth parameters, including plant height, stem diameter, leaf area, and root volume.This treatment also resulted in the greatest leaf and stem fresh biomass and the highest cost–benefit ratio (2.19), indicating superior economic viability and supporting its approval for coffee seedling production under the studied conditions. In contrast, the lowest growth performance and economic return were recorded in the control treatment.

The observed improvements are likely attributable to enhanced soil physical properties, increased nutrient availability, and stimulated microbial activity associated with vermicompost application. Nevertheless, the results indicate a clear rate-dependent response, whereby both suboptimal and excessive application rates may constrain seedling performance.Overall, an intermediate vermicompost application rate provided the most balanced and efficient growth response in *Coffea arabica* L. seedlings.

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