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The Response of Coffee (*Coffea Arabica L*) Seedling Growth and Performance to Different Ratio of Organic Matter Combinations at Bako, Western Oromia, Ethiopia

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ABSTRACT

This study was carried out to explore the effect of different growing media on seed germination and seedling growth of Coffee (Coffea arabica L). The research was conducted at Bako Agriculture research center coffee nursery site during three successive seasons from November to November, 2021-July 2021, November, 2022-July 2022and November, 2023-July 2023. This research was arranged in a complete randomized design with thirteen treatment combinations and three replications. The treatments were combination between types of media shoat, dairy manure, compost, vermicompost and sandy soil. The result describes different ratio of organic matter combinations affect all the growth parameters of coffee seedlings. In interaction of year by treatments highly significant difference was recorded for days to emergence, root length, Internode length and girth. Based on cost of organic maters the highest cost was incurred for combination of 20% top soil+40% sand+ 40% vermin compost (10950ETB) while the lowest cost was incurred for treatment 40% top soil + 20% sand +40% dairy manure (5400ETB). In general, a growth media combination of 40% top soil plus 20% sand plus 40% vermin compost (2:1:2) works better than treatments. We recommend 40% top soil + 20% sand + 40% dairy manure (2:1:2) for coffee growers and private sectors located in Bako areas and areas with similar agroecology, taking into consideration the financial issue, health and performance of the seedlings.

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Introduction

Coffee is a commodity that is widely traded and is one of the most popular drinks consumed worldwide. Brazil, Vietnam, Colombia, and Ethiopia are the primary coffee-producing countries, and the European Union and the United States of America are the world's two largest consumer and import markets (FAO 2022). Because of its low bitterness, aromatic qualities, and low caffeine content, consumers prefer C. arabica over other coffee varieties. It is grown primarily in the midlands and highlands. Coffee is the Ethiopian economy's backbone and is essential to the country's cultural and socioeconomic life. One reason for this is that it employs over 15 million Ethiopians. Casual labor provides a good living for many poor rural people. Furthermore, coffee generates more than one-quarter of the country's foreign exchange earnings. In most parts of Ethiopia, coffee is consumed from coffee beans, but in Kaffa, sheka, and Bench-Maji it is prepared and consumed from coffee leaf and spices and known as "Chemo" [1].

Quality seedling production is very important for any plantation programme. One of the main characteristics of sustainable agriculture is the use of organic soil fertility options. In principle, a variety of factors, including the kind of substrate utilized and environmental elements like oxygen, water, temperature, and light for certain plant species, can influence the germination of seeds [2]. It is crucial to use the right growing medium in order to produce healthy and high-quality seedlings [3]. The ideal mixture of organic matter would give seedlings enough anchorage or support and it can also have a direct impact on the development and continual maintenance of a complex, functional rooting system [4].

The development of a healthy root system depends on physical and chemical properties of the substrate used rather than, genetic properties of the plant [5-8]. Growing media having higher organic matter concentrations have been proved to enhance the growth as well as soil aeration, soil density and maximizing water holding capacity of soil for seed germination and plant root development [9-11].

The survival rate of seedling is depended on the development of root system. Generally, media for coffee seedling are composed of topsoil, organic matter, forest soil and sand. Supplementing of the sand is aimed to make media more porous while the organic matter (FYM and vermicompost) is added so as to enrich adequate nutrients for the seedling. Cattle manure has potential to be used as an organic nutrient source in coffee production [12]. Several studies on growth media had been conducted on the various fruit crops and coffee by previous researchers. According to application

of vermicompost in the media increased plant height, leaf area and dry weight of peppers, tomatoes and marigold [13]. For coffee seedling growth, the optimum media combination was 2:2:1 for top soil, sand soil and farm yard manure, respectively revealed that a mixture of locally available organic manure and in different ratio had promoted both shoot and root growth of coffee seedlings. But, because of climate change, the structure of soil has entirely changed in all respects, including its nutrient composition, texture, porosity, ability to hold water, and other characteristics. Thus, reconsider some of the nursery-level coffee seedling management practices in order to generate robust, healthy seedlings for field planting by supplementing the media with organic matter. Based on these findings, the current study is designed to assess various combinations of organic matter for the germination and early growth of coffee seedlings at the nursery level in various locations. Therefore, the following activity is objected to

- To identify and recommend appropriate pot size and growth media combinations for coffee seedling growth and development

Materials and Methods

Study Area

The experiment was carried out at the Bako Agriculture Research Center's coffee trial site. The experimental site is located 254 kilometers west of Ethiopia's capital, Finfinne (Addis Abeba), and lies between 906'N latitude and 3709'E longitude at an altitude of 1650masl. Mid-altitude agro-ecology with high rainfall of 1238 mm year-1 and hot humid weather of 13.3 0C minimum and 280C maximum annum. The main crops grown in the surrounding area are maize and pepper. Coffee is grown as a garden crop and may be spreading at an alarming rate in the area.

Experimental Materials and Arrangement

The experiment was carried out by irrigation three times between the off-seasons of 2021 and 2023. To set up the experiment, a completely randomized design with three replications and twelve treatments was used. The 74110-coffee variety was chosen for testing, and because this ratio was recommended nationally, a 40% top soil + 40% sand + 20% dairy manure treatment was used as a control. Black polyethene tube, 16 cm wide and 22 cm tall. The field trial was set up with shade from south to north. Chemical properties of each sowing media were determined through laboratory analyses before sowing the seeds. All treatments were watered in two days interval with a water cane. Except for the treatments, agronomic techniques such as watering, shading, spacing out pots, and weeding were applied uniformly to each. Sudan grass was used as an overhead shade as well as a cover shade. All treatments were watered twice a day, using a water cane.

Collected Data and Collection Methods

- **Days to Emergence:** counted from the time of planting until 50% of the seedlings have emerged.
- **Number of Leaves:** the average count of number of opposite true leaf
- **Number of Nodes:** the average count of number of nods
- **Plant Height (cm):** the average of five randomly selected plants were measured from the base of the stem to the plant apex using graduated ruler.
- **Stem Girth (mm):** the average of five randomly taken plants was measured at the surface of the potting soil by using a caliper.
- **Root Length (cm):** The polythene bag containing the roots of the seedlings was immersed in a bucket filled with water and roots were allowed to separate carefully from the soil still being in water and the average length of the seedling's tap root in the soil, as measured in graduated ruler
- **Inter Node Length (cm):** the average length of the between two nods, measured in stick meter
- **Total Fresh Weight:** the average weight of five randomly selected plants shoot and root were measured using sensitive balance as soon as destructed from the pot.
- **Total Dry Weight:** the average weight of five randomly selected plants shoots and roots dry matters were measured using sensitive balance after oven drying at 70oC for 24 hours.

Data Analysis

The collected data has been run through the R- computer program. For over year analysis, the 'Agricola'e, 'lme4', 'emmeans','reshape','reshape2', and 'car' packages were used. For R programming, Rstudio was used as an integrated development environment (IDE). Duncan's Multiple Range Test (DMRT) at $p = 0.05$ was used to separate means for significantly different treatments.

Results and Discussions

The results revealed a significant variation among the different ratios of organic manure combinations ($p<0.05$) used in the current study (Table 2).

Table 1: Fertility Status of Organic Matter Used for The Study in Different Ratio Collected from Gobu Sayo District of East Wollega

Media type	pH (H_2O)	% OC	% OM	% TN	Ava P
FYM	6.53	2.72	4.69	0.24	8.30
Top soil	5.63	2.13	3.67	0.19	5.93
Shoat manure	7.94	2.82	4.87	0.25	9.74
Vermin compost	8.48	2.93	5.05	0.25	9.92
Compost	7.09	2.85	4.90	0.25	7.80
Sand	6.80	0.42	0.72	0.04	2.64

FYM=farm yard manure, pH= power of hydrogen, OC=Organic carbon, TN=total Nitrogen, Ava P=average Phosphorus Interims of fertility statues of the materials used in the study, vermicompost is relatively better than all organic matters used for the current study while sandy soil was the lowest. In pH vermicompost (8.48) and shoat manure (7.94) were lied in base sandy (6.80); FYM (6.53) and compost (7.09) were neutral. Top soil was in the range of weak acid. The highest percentage of organic caron (2.93) was found in vermicompost while the lowest was obtained from Sandy soil (0.42). In case of organic matter, the highest percentage of organic matter (5.05) was obtained from while the lowest was obtained from sandy soil (0.72) (Table 1).

Days to Emergence (DE): Significant variation in days to emergence was observed when different ratios of organic matter were combined (Table 2). The combination of 40% top soil + 20% sand + 40% shoat had the longest days to emergence (66 days), followed by 40% top soil + 20% sand + 40% dairy manure (64.56), and the combination of 40% forest soil + 20% sandy soil + 40% vermicompost had the shortest days to emergence (59 days) (Table 3).

Plant Height (PH): Plant height showed a highly significant variation in different ratios of organic matter combination (Table 2). The combination of 40% top soil+20% sand+ 40% vermin compost produced the highest plant height (11.05cm), followed by 40% top soil + 20% sand + 40% shoat (10.68cm), and the combination of 40% top soil+40% sand + 20% shoat (8.69cm) (Table 3).

Leaf Number (no): The variation in leaf number was highly significant in different ratios of organic matter combination (Table 2). The combination of 40% top soil+20% sand+40% vermin compost produced the longest root length (10.40cm), followed by 40% top soil +20% sand +40% compost (10.02cm), and the organic matter combination of 20% top soil + 40% sand +40% shoat produced the shortest plant height (8.02cm) (Table 3).

Root Length (cm): root length varied significantly in different ratios of organic matter combination (Table 2). The highest leaf number was recorded for the treatment combination of 40% top soil+20% sand+ 40% vermin compost (17.37), followed by 40% top soil + 20% sand + 40% shoat (17.06), and the lowest leaf number was recorded for the treatment combination of 40% top soil+40% sand + 20% shoat (14.18) (Table 3).

Internode Length (INL): Internode length showed a highly significant variation in different ratios of organic matter combination (Table 2). The highest internode length was found in 40% top soil+40% sand + 20% shoat (2.47cm), followed by 20% top soil + 40% sand + 40% shoat (2.41cm), and the lowest internode length was found in 40% top soil+20% sand+ 40% vermin compost (1.43cm). (Table 3).

Node Number (NN): Node number showed a highly significant variation in different ratios of organic matter combination (Table 2). The effect of different organic matter ratio combinations caused a highly significant variation in node number (Table 2). The treatment with the highest node number was 40% top soil+20% sand+ 40% vermin compost (4.90), followed by 40% top soil + 20% sand + 40% dairy manure (4.86) and the treatment with the lowest node number was 40% top soil+40% sand + 20% shoat (3.94) (Table 3).

Stem Girth (mm): A highly significant difference in stem girth was observed between treatment effects (Table 2). The highest stem girth was measured for 40% top soil + 20% sand + 40% shoat (2.33mm), followed by 40% top soil + 20% sand + 40% vermin compost (2.30mm), and the lowest stem girth was measured for 40% top soil + 40% sand + 20% shoat (1.88mm) (Table 3).

Total Fresh Weight (g): Highly significant difference was recorded for total fresh weight of coffee seedling due to combined effect of different ratio of organic matter combinations (Table 2). The highest total fresh weight was recorded for 40% top soil+20% sand+ 40% vermin compost (11.24g) followed by 40% top soil + 20% sand +40% dairy manure (11.11g) while the lowest total fresh weight was recorded for 40% top soil+40% sand + 20% shoat (9.86g) (Table 3).

Total Dry Weight (g): Highly significant difference was recorded for total fresh weight of coffee seedling due to combined effect of different ratio of organic matter combinations (Table 2). The highest total dry weight was recorded for 40% top soil+20% sand+ 40% vermin compost (8.33g) followed by 40% top soil +20% sand +40% compost (8.19g) while the lowest total dry weight was recorded for 40% top soil+40% sand + 20% shoat (7.45g) (Table 3).

Table 2: Combined ANOVA Table for Different Coffee Seedling Parameters under Different Ratio of Growing Media 2021-2023

Source of variation	DF	DE (days)	PH (cm)	RL (cm)	LN (no)	INL (no)	NN (no)	G (mm)	TFW (g)	TDW (g)
Treatment	11	31.95***	4.59***	16.27***	4.51***	0.84***	1.01***	0.17***	8.52***	0.78***
Year	2	214.78***	0.69	1.73	0.11	5.61***	0.09	1.62***	0.01	1.81***
Replication	2	0.56	2.09	8.18	0.12	0.16*	0.29	0.01	0.12	0.44
Year*Treatment	22	14.18***	0.25	0.49***	0.24	0.49***	0.04	0.24**	0.03	0.24
Error	70	0.42	0.92	1.07	0.98	0.04	0.18	0.04	1.21	0.22

ED=days to emergence, PH=plant height, RL=root length, LN=leaf number, NN=node number, NL=lode length, G=girth, TFW=total fresh weight, TDW=Total dry weight. Duncans multiple range test at P<0 '***' 0.001 '**' 0.01 '*' 0.05.

Table 3: The Combined Effect of Different Organic Matter Combination on Coffee Seedling Growth Parameters

Treatment combinations	Ratio	DE (days)	PH (cm)	RL (cm)	LN (no)	INL (cm)	NN (no)	G (mm)	TFW (g)	TDW (g)
40% top soil + 40% sand +20% compost	2:2:1	61.56f	9.48ce	9.44ac	13.30g	2.29ab	4.01c	2.14ac	10.34ce	7.59bc
40% top soil +20% sand +40% compost	2:1:2	63.00e	10.17ad	10.02a	16.11bd	1.99cd	4.84a	2.22ab	10.59bd	8.19a
20% top soil+ 40% sand + 40% compost	1:2:2	62.11f	9.94bd	9.37ac	13.66fg	2.02cd	4.57ab	2.05bd	10.05de	8.00ab
40% top soil+40% sand + 20% dairy manure	2:2:1	63.67cd	9.34de	8.89bd	15.37de	2.37ab	4.53ab	2.18ab	10.39ce	7.56bc
40% top soil + 20% sand +40% dairy manure	2:1:2	64.56b	10.67ab	9.44ac	16.64ac	2.01cd	4.86a	2.27ab	11.11ab	8.15a
20% top soil + 40% sand + 40% dairy manure	1:2:2	63.56de	9.97bd	8.85cd	15.68cd	2.02cd	4.82a	2.07bd	10.39ce	7.88ac
40% top soil+40% sand+ 20% vermin compost	2:2:1	64.11bd	9.44ce	9.79ac	16.58ac	1.84de	4.68a	2.05bd	10.32ce	7.56bc
40% top soil+20% sand+ 40% vermin compost	2:1:2	59.33h	11.05a	10.40a	17.37a	1.43f	4.90a	2.30a	11.24a	8.33a
20% top soil+40% sand+ 40% vermin compost	1:2:2	60.67g	10.46ac	9.44ac	15.97cd	2.19bc	4.63ab	1.95cd	10.22ce	7.63bc
40% top soil+40% sand + 20% shoat	2:2:1	63.56de	8.69e	8.25d	14.18fg	2.47a	3.94c	1.88d	9.86e	7.45c
40% top soil + 20% sand + 40% shoat	2:1:2	66.33a	10.68ab	9.94ab	17.06ab	1.71e	4.83a	2.33a	10.82ac	8.05ab
20% top soil + 40% sand +40% shoat	1:2:2	64.22bc	9.16de	8.04d	14.54ef	2.41a	4.23bc	2.20ab	10.03 de	8.02ab
mean		63.06	9.92	9.32	2.14	15.54	4.57	2.06	10.45	7.87
CV		10.3	9.15	10.62	6.66	9.96	9.22	9.36	5.39	5.89
Significance level at P<0.001		***	***	***	***	***	***	***	***	***

ED=days to emergence, PH=plant height, RL=root length, LN=leaf number, NN=node number, NL=lode length, G=girth, TFW=total fresh weight, TDW=Total dry weight. Means with the same letter are not significantly different. Duncans multiple range test at P<0.001, P<0.05

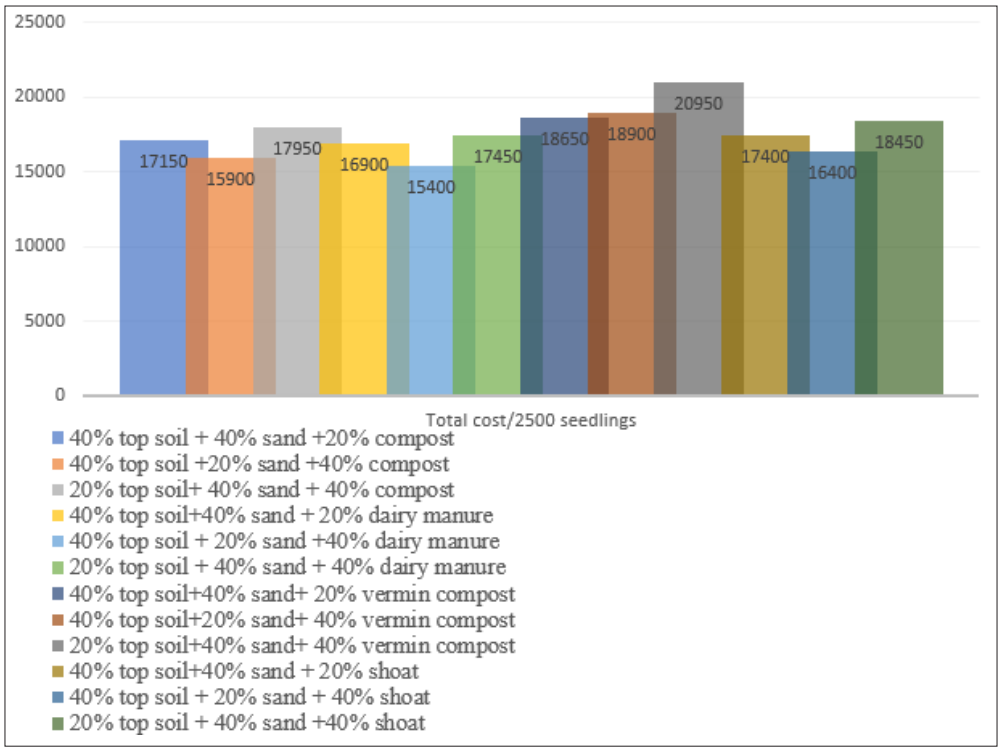

Figure 1: Total cost of organic manure required to prepare for one hectare of coffee land (2500pots)

Based on the cost of organic maters, the highest cost was incurred when purchasing the combination of 20% top soil+40% sand+ 40% vermin compost (10950ETB), followed by 40% top soil+20% sand+ 40% vermin compost (8900ETB), and the lowest cost was incurred when purchasing the treatment 40% top soil + 20% sand + 40% dairy manure (5400ETB), which is half the cost of the combination 20% top soil+40% sand+ 40% vermin compost (10950) (Figure 1)

Discussions

The result describes how various organic matter ratio combinations affect all of the growth parameters of coffee seedlings. Days to emergence, root length, internode length, and girth of coffee seedlings are all affected by the interaction of the year and different organic matter ratio combinations. The seedling growth performance and emergence improved by using appropriate growing media [14]. Different authors reported similar results in different perennial crops including coffee. According to the combination of different rate of topsoil, compost and sand significantly affect the growth parameters of coffee seedlings. In the same line, found significant difference among different Papaya seedling parameters in different rate of organic manure combinations. The seeds sown on a high ratio of vermicompost and compost germinate significantly faster than the other growth media,

which could be because the physical properties of vermicompost and compost allow for water retention and aeration, both of which are required for seed emergence, and vermicompost has the ability to facilitate seed emergence [15]. The result is in line with the finding of addition of other organic matter to top soil with different ratio had significant effect on emergence of coffee seed. The highest plant height recorded from the media contains high ratio of vermicompost. This could be due to its high fertility level. On the same line, found the highest stem height from the composition of growing media in moringa oleifera seedling growth. Similarly, reported that significant variation of seedlings among different organic fertilizers plant height. The media contains high ratio of vermicompost and compost perform better [16-18]. Vermicompost is bioactive and facilitate root growth and greater root initiation capacity [15]. This could be due to the high ratio and low nutrient content of sandy soil. According to the result, a high ratio of sandy soil and shoat manure is incompatible with coffee seedling growth. Different scholars reported similar result [16, 18-20]. High fresh weight and dry weight was obtained from media contains better soil fertility continent. Similarly, found highly significant variation in dry weight and fresh weight for tomato seedling [10, 21-28].

Conclusion and Recommendation

Growing media influences seed germination, plant height, root length, node length, and stem girth. In coffee seedling parameters, a high rate of compost, vermicompost, and dairy manure combined with a high rate of top soil results in improved performance. When Vermicompost, dairy manure, and compost are combined with a high rate of top soil, coffee seedling performance improves. Growing media combinations with a high shoat dang ratio were not as suitable as the others. The ratio of sandy soil in the top soil was high in the study area, so the addition of a high rate of sandy soil can affect seedling growth and require more water to perform. Organic matter (dairy manure, compost, and vermicompost) is added to enrich adequate nutrients for the seedling and the most important source of important nutrients required for seedling growth, including trace elements, albeit in small quantities. It is safe to use as a nutrient source in organic farming. Vermicompost is an excellent source of all essential plant nutrients. In general, based on seedling performance and health, 40% top soil+20% sand+ 40% vermin compost (2:1:2) outperforms other organic matter combinations followed by 40% top soil + 20% sand + 40% dairy manure (2:1:2). Therefore, considering the cost and availability of the materials 2:1:2 ratio was recommended for coffee seedling growth in Bako areas and areas with similar agroecology based on the availability of the materials.

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