INFULENCE OF AVOCADO WASTE AND COFFEE HUSK VERMICOMPOST AND VERMIWASH ON SEEDLING GROWTH PERFORMANCE OF COFFEE (*Coffe arabica L.*)

MSc Thesis

By

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SCHOOL OF PLANT AND HORTICULTURAL SCIENCE ADVISOR APPRVAL SHEET

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As members of the Examining Board of the Final MSc Open Defense, we certify that we have read and evaluated the thesis prepared by **Rahel Mengistu** entitled **Influence of avocado waste and coffee husk vermicompost and vermiwash on seedling growth performance of coffee** (*Coffea arabica L.*) and recommend that it be accepted as fulfilling the thesis requirement for the degree of **Master of Science in Horticulture** specialization.

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DEDICATION

I dedicate this work to the all-powerful God, who receives all glory for all eternity form him, through him, and in him and also for my beloved mother and all my family members and also my husband.

STATEMENT OF THE AUTHOR

I hereby declare that this MSc thesis is an authentic account of my work and has not been submitted to any other organizations for the purpose of receiving any academic degree, diploma, or certificate from any location. I confirm that when references to the work of others have been made in this thesis, providing adequate credit has been given. This thesis is deposited in the Hawassa University library and made available to users in accordance with the library's policies as part of the requirements for the MSc degree at that institution.

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LIST OF ABBREVIATION

AARSC	Awada agricultural research sub center
ANOA	Analysis of variance
CEC	Cation exchange capacity
CRD	completely randomized design
CV	Coefficient of variance
EAIR	Ethiopia institute of agricultural research
EC	Electric conductivity
GDP	Gross domestic product
GAIN	Global agricultural information network
IOC	International coffee organization
ISFM	Integrated soil Fertility management
LSD	Least significant difference
m.a.s.a.l	Metres above sea level
OM	Organic matter
SAS	Statistical Analysis System
VC	Vermicompost
VW	Vermiwash

Table of Contents

LIST OF TABLES

TABLE IN APPENDIX

FIGURE IN APPENDIX

INFULENCE OF AVOCADO WASTE AND COFFEE HUSK VERMICOMPOST AND VERMIWASH ON SEEDLING GROWTH PERFORMANCE OF COFFEE (*Coffea arabica L.)*

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ABSTRACT

Coffee is an important cash crop grown all over the world including Ethiopia. But in Ethiopia its production is low due to poor seedling quality and agronomic management. The experiment was conducted to evaluate the effect of avocado waste and coffee husk vermicompost and vermiwash on seedling growth performance of coffee (Coffea arabica L.) *at nursery condition, Hawassa, Ethiopia. A factorial combination of two level of vermiwash (with and without) and three types of vermicompost (coffee husk, avocado waste, 50% Coffee husk+50% avocado waste) and recommended rate of coffee growing media(3:1 top soil with compost) as positive control and soil alone as (negative control), these were laid out in CRD with three replications. Vermiwash was prepared by 50% of avocado waste plus 50% coffee husk. Whereas vermicompost were prepared by avocado waste, coffee husk and combined of avocado waste and coffee husk) and animal manure and grass were added uniformly for all wastes as starter and bedding material. 200g of VC produced from d/f wastes (avocado, coffee husk and combined of avocado and coffee husk were applied for all experimental units (polyethylene bags) except negative control and positive control. While 100ml of VW was applied for half of the experimental units. All agronomic practice were done as per required until the final growth stage of coffee seedlings. The initial soil, vermicompost and vermiwash sample were well prepared and analyzed for their chemical composition. All coffee seedling growth parameters data were collected properly and analyzed by SAS software and the treatment mean was compared using LSD at 5% probability level. The results showed that all growth parameters (plant height, leaf number, leaf area, number of node, root length, shoot fresh weight, root fresh weight, shoot dry weight and root dry weight) except internode length were significantly(<0.001) influenced by the interaction effect of vermicompost and vermiwash. The result indicated, the highest plant height(21.3cm), leaf number(12), leaf area(75cm^2), number node(6), root length (21.3cm),shoot fresh weight(9.09g), root fresh weight (5.1g), shoot dry weight(2.86g) and root dry weight (0.67g) per plant were obtained from the interaction of coffee husk vermicompost with vermiwash. While the lowest plant height(9.8cm), leaf number(4.2), leaf area (23.94cm^2), number of node(2.17), root length(9.67cm), shoot fresh weight(2.55g), root fresh weight (2.57g), shoot dry weight(0.39g) and root dry weight (0.25g) per plant were obtained from soil without vermiwash (negative control). Therefore the interaction application of coffee husk vermicompost along with vermiwash is the best treatment to improving coffee seedling growth performance.*

Key words: ***Vermicompost, vermiwash, Arabica coffee, growth parameters***

1. INTRODUCTION

Coffee is an important nonalcoholic stimulant beverage consumed highly next to water and tea in the world (Angeloni *et al.*, 2019). It belongs to the genus *Coffea*, and Rubiaceae family (Davis *et al.*, 2011). Coffea species are grouped into four sections (*Agrocoffea*, *Paracoffea*, *Mascarocoffea, Eucoffea*) and there are about 124 species in the genus Coffea, from which only arabica and robusta coffee are economically important, by accounting 99% of world coffee production (Bote *et al.*, 2018). All Coffea species are diploid with 2n=2x=22 chromosomes except arabica coffee which is tatraploid with 2n=4x=44 (Adepoju *et al.*, 2017). Arabica coffee is produced about 70% in the world, depending on its quality character (Anthony *et al.*, 2002). It is mainly grown in tropical and subtropical agro- ecological zones (Berthaud and Charrier, 1988). Among the various coffee species, Arabica coffee is the most produced because of its high quality, potent scent, and low caffeine concentration (Santos *et al.*, 2016).

More than 100 countries cultivate arabica coffee as a commercial crop in the world (Waller *et al.*, 2007). About 125 million people in Africa, Latin America, and Asia rely on coffee for their livelihoods and nine million tons of clean coffees are produced annually in the world (Bozzola *et al.*, 2021). The top arabica coffee producing countries in the world are Brazil (30%), Vetinam (19%), Colombia (9.42%), Indonesia (8.6%), Ethiopia (5%), India (4.07%), Honduras (4%), Uganda (3.32%), Guatimala (2.37%) and Peru (2.3%) (Krishnan, 2017).

Arabica coffee is a crucial cash crop in the national economy of Ethiopia and it is the most popular export item in Ethiopia and the second export goods in the world next to petroleum (Ayalew, 2014). Coffee in Ethiopia accounts for 4–5% of GDP, 10% of total agriculture production, 40% of total exports, 10% of total government revenue (Worku, 2019). And also about 25 million people in Ethiopia either directly or indirectly depend on the coffee industry for their livelihoods. Ethiopia is Africa's largest coffee producer and the world's fifth largest exporter of Arabica coffee. According to GAIN, (2023) reports Coffee is Ethiopia's number one source of export revenue generating about 30-35 percent of the country's total export earnings and in 2023/24 total production is forecasted to 501,000 million ton and 0.83 ton/ ha). While the world annual coffee production are 106,978,000 million tone (ICO, 2023). Despite the fact that Ethiopia is birth place of arabica coffee, many coffee growing areas in the country cannot benefited from this huge potential as the other producing countries and the country's coffee production is characterized by low productivity of about 830 kg per ha (GAIN, 2023) which is below the global productivity of 17,800 kg per ha (ICO, 2023).

This is due to different factors starting from germination stage to its seedling growth and the eventual development of coffee, since healthy and vigorous seeding growth performance is crucial to coffees overall growth and production (Musagomba, 2019). Kramer and Boyer (1995) also suggest that coffee is a perennial, the establishment of adequate root system is essential to its overall health and productivity over its life. This could be manipulated by using good agronomic management practice in the main nursery. Among agronomic practices, a sufficient nutrient supply to coffee seedlings in growing media is one of the best Practices (Vallone *et al*, 2009). According to Handayani, (2019) an appropriate growing medium might give a plant enough anchoring, act as a reservoir for various vital nutrients and water and diffuse oxygen to the roots. The best substrate for growing coffee is forest soil, but it is becoming harder to find due to deforestation, instead of it other growing media like vermicompost and compost could be used because these are rich in nutrients (N, P, and K) that improved crop productivity (Srigandha *et al.*, 2017). The nutrient uptakes by coffee root vary based on genotype, fertility level of soil and management condition of the farm (Nguyen *et al*, 2013).

Balanced organic fertilizer plays a crucial role in crop production and environmental concerns and integrated nutrient management strategies offer a strong opportunity to increase crop yield and agricultural sustainability (Jat *et al.*, 2015). Organic fertilizers provide right amount of nutrients to the plant, which enhance crop development and productivity and gives vital growth hormone to plant (Negeri, 2020). Vermicompost and vermiwash are the most popular organic fertilizers used on farm due to their high nutrient content, ability to minimize environmental contamination and affordability by small-scale farmers (Kishor and Praveen, 2020).

Vermicomposting is a mesophilic bioconversion process used to convert organic waste into high-value, humus- like product vermicompost (Benitez *et al*, 2000) through the joint action of earthworms and microorganisms (Suthar, 2009). Its product (i.e. vermicompost) is rich in macronutrients, micronutrients, beneficial soil microorganisms, and plant growth regulators (Adhikary, 2012).Vermicomposting process is worked by using various species of worms, usually red wigglers and white earthworms to create a mixture of decomposing organic wastes (Sinha, 2019). In addition to breaking down a significant quantity of organic wastes, vermicomposting process helps to retain a higher nutrient status of composted materials (Hema and Rajkumar, 2012). According to Gandhi *et al* (1997) vermicompost is differs from conventional compost in a various of ways, like ,the process is faster because the material passes through the gut of the earthworms, which is home to a variety of biological processes involved in the recycling and recovery of waste components. Additionally, earthworms are active in vermicomposting process at temperatures between 10°C and 32°C. According to Parthasarathi *et al* (2016) vermicompost is an excellent soil additive made up of digested feedstock and worm castings and ,it contains more nutrients and microbial life than normal compost, and it is higher-value product with five times available nutrients than conventional compost. Wako, (2021) vermicompost contains 5 times the available nitrogen, 7 times available potash and 1.5 times more calcium than that found in 15 cm of good top soil and the nutrient life is up to 6 times more in comparison to the other types of compost. Vermicompost application reduced bulk density of soil in comparison to farm yard manure and chemical fertilizer due to increasing concentration of organic matter which in turn decreases bulk density (Sonme, *et al.*, 2016).

The initial organic matter composition and the activity of earth worm extent to decomposing wastes determine the mineral composition of the feedstock. Currently, different solid waste materials of municipal or agro -industrial wastes can be used as a feedstock for worms. But these different waste materials may require different earthworm species and different environmental conditions for efficient decomposition and efficiently converting to more usable organic fertilizer (Gheisari *et al.*, 2010). The entire vermicomposting process and the quality composition of the vermicompost produced depend primarily on the quality of the source materials (Martin and Eudoxie, 2018) as well as on earthworm species and the type of substrate ingested (source materials) (Gebrehana et al., 2023).

Currently different raw materials used for vermicompost production (Paper, Kichen waste,yard waste, animal manure, soybean waste, corm waste, coffee husk etc (Warman and Anglopez, 2010; Raphael and Velmourougane, 2011). Orozco *et al*. (1996) reported that coffee husk is rich in various nutrients such as phosphorus, calcium, and magnesium. Coffee Husk had the potential for vermicomposting and composting due to having a higher quantity of cellulose apart from potash and lignin and it has magnificent moisture retaining capacity but decomposes slowly (Oliveira and Franca, 2015). According to Raphael and Velmourougane, (2011) chemical and microbiological properties of vermicompost obtained from coffee husk clearly indicates the enhancement in nutrient value and microbiological quality of vermicompost and its utility as a good source for plant nutrients and soil fertility and also an enhancement in coffee productions. However vermicompost prepared from avocado waste are not yet studied.

Vermiwash is a liquid extract produced from vermicompost in a medium where earthworms are highly populated (Gudeta *et al.*, 2021). It is one of the byproducts of vermicompost that combines earth worm secretion and washing (Das *et a*l., 2014). It can be made using the secretions of earthworms, siphoned off as seepage drains from the worm bed, and stored in Pots (Makkar, 2017). It contains a large number of decomposer bacteria, mucus, vitamins, various accessible minerals, hormones, enzymes, and various antimicrobial peptides, depending on the kind of raw materials and bedding materials. Vermiwash is more bioavailable and easily up taken by plants than solid vermicompost because the liquid fertilizer can reach quickly to the root (Sulaiman and Mohamad, 2020). It became more bioavailable and easily absorbed by plants as it liquefied (Gudeta *et al*., 2021). Therefor the physicochemical and microbiological status of the growing media is modified by the high nutritional composition of vermicompost and vermiwash, which promotes the vegetative and reproductive growth of plants (Gutierrez *et al.*, 2007).

Crop performance is the product of genetic, environmental, agronomic management and nutrient status (Shah and Wu, 2019). Due to the perennial nature of coffee, it needs a high nutrient application for optimum growth and development. Organic fertilizers like vermicompost and vermiwash are the most important fertilizer for improving crop productivity and quality. As Dwipa *et al*., (2020) reports 20 tons per ha dose of vermicompost affect the root and vegetative growth of arabica coffee seedlings in Indonesia. However, to the best of our knowledge, there are no previous studies on the effects of vermicompost and vermiwash on the growth of coffee seedlings in Ethiopia. In Ethiopia, coffee cultivation is considered organic, which is why most coffee farmers use organic fertilizers such as animal manure, ash and compost instead of chemical fertilizers. As they are certified organic coffee producers, they are also unable to buy chemical fertilizers which have high cost. This commitment to organic practices aligns with the nation's emphasis on sustainable agriculture, contributing to the preservation of soil health and environmental well-being in coffee-producing regions. However, it is noteworthy that despite their commitment to organic farming, coffee farmers in Ethiopia have not yet adopted the use of vermicompost and vermiwash as organic fertilizers for coffee plants. This reluctance is attributed to lack of awareness, limited experience on preparation techniques and a lack of research on these alternative organic fertilizers. Various studies have shown that vermicompost quality is influenced by the supplied waste materials and their chemical composition. The bioconversion of agro-industrial waste, such as avocado residue and coffee husk mixed with cow manure and grass through vermicomposting, would help in the production of high-quality vermicompost that could increase the growth of coffee seedlings. The reason for focusing on vermicompost from coffee husk and avocado waste in the present study is that coffee and avocados are mainly produced in the study region and that there is a large agro-industry mainly involved in the processing of coffee and avocados. Therefore, this study was designed to minimize the pollution caused by agro-industry wastes through the use of the vermicomposting process for the production of value-added products such as vermicompost and vermiwash.

1.1. OBJECTIVE

1.1.1. General Objective

To minimize environmental pollution through vermicomposting by using solid waste from agroindustry such as avocado and coffee husk to produce vermicompost and vermiwash, used as growing media for coffee seedlings to improve its growth performance

1.1.2. Specific objective

- To study the effect of avocado waste and coffee husk vermicompost on germination and seedling growth performance of arabica coffee
- To evaluate the effect of vermiwash application on seedling growth performance of arabica coffee
- To identify the solid waste type used for vermicompost and vermiwash that improves coffee seed germination and seedling growth performance

2. LITERATU RE REVIEW

2.1. Origin, distribution and biology of coffee

The history of coffee was started between 150000 and 350 000 years ago in the African continent (Anthony *et al.*, 2011). Around 575 years after Christ, wild coffee was brought from Ethiopia to Yemen, where it was first cultivated. All commercial coffee species are originated in Africa particularly arabica coffee is originated in southwestern parts of Ethiopia in which there are a great genetic diversity in the region (Teressa *et al.*, 2010). Arabica coffee was first introduced from Ethiopia to Yemen as early and next coffee plant distribution to Réunion islands and taken from India to Java or Indonesia (Söndahl *et al*., 2005). Then From Java, coffee was introduced to Europe (Amsterdam) in 1710 (Anthony *et al.*, 2002). Coffee was introduced to South America (Suriname) in 1718 from Europe (Lécolier *et al*., 2009). Then it was introduced in Martinique island (1720 or 1723) and Brazil via French Guiana 1727 (Pendergrast, 2010).

Based on Scientific study arabica coffee is classified into two genetic bases, namely Typica and Bourbon varieties (Charrier *et a*l., 1985). Arabica coffee are evergreen plant, woody, elliptical and waxed leaves and white flower, trees that reach heights of 10 m. Kramer and Boyer (1995) states coffee trees are perennial, the development of a sufficient root system is essential to the tree's health and future yield over its lifetime. Root plays several roles for the plants like it serves fixing the plant in the soil or substrate and providing water from soil (Eshel and Beeckman, 2013). Coffee has five types of root systems such as tap roots, axial roots, lateral roots, feeder roots and root hairs these provides nutrients and water to the plant (Gregory, 2006).Two branching patterns are found in coffee plants: plagiotropic (horizontal) branches and orthotropic (vertical) branches. Plagiotropic branches are produced by lateral stems that also produce secondary and tertiary branches and fruit while orthotropic branches are the main stem that gives rise to plagiotropic branches (Cannell, 1985).

2.2. Importance of coffee

Coffee drinking is preferred due to its taste, aroma, and stimulating properties. Coffee is a source of antioxidants that can be utilized in medications, cosmetics, and nutritional supplements (Castro *et al.,* 2018**)**. It is important for improving blood pressure, plasma lipids, and body weight, all of which lower the risk factors of metabolic syndrome are significant for human health (Bosso *et al.*, 2021). Some biologically active fatty acids found in coffee have anti-bacterial, anti-inflammatory, anti-cancerous, anti-diabetic, and anti-atherosclerotic properties (Asmari *et al.*, 2020).

Beyond the medicinal benefit coffee plays a significant economic role and serves as a major source of foreign earnings in many producing countries in the world (Krishnan et al., 2016). It serves 125 millions of people for their livelihood all over the world. It is an important source of cash income and responsible for significant employment (Petit, 2007). In Ethiopia it accounts for 25 to 30 percent of total export earnings, 4.7 million small holders directly involved in producing coffee, it contributes about 4–5% to the country's GDP and about 25 million people directly or indirectly depends on the coffee sector for their livelihoods (Endeshaw, 2017). On the other hand coffee is an important crop for the attraction of social life by growing cultures within different groups when they enjoy together in coffee (Tadesse *et al.*, 2013).

2.3. Agro ecological requirements of coffee plant and coffee seedlings

Like other crops coffee requires ideal conditions for its germination, vegetative growth and over all development of its reproductive stages. Coffee grows best at altitudes between l000 and 2000 meters. Actually, the highlands of Ethiopia are where arabica coffee originated and it is still naturally found there today at altitude of 1600–2800 m.a.s.l under shade trees (DaMatta, 2004). From their place of origin, the coffee species have spread worldwide to most regions of the tropics and subtropics that are appropriate for their production (Waller *et al.*, 2007). For the highest quality, arabica coffee is ideally suited to higher elevations in the 18–22°C temperature range with evenly distributed 1400–2400 mm of yearly rainfall over a period of seven to eight months.(Pohlan and Janssens, 2010). Optimum altitude is crucial for growth and production of coffee to achieve a quality beverage based on growing region. Coffee growing in higher altitude has best quality beverage and exhibit optimum growth.

Good physical and chemical soil conditions are ideal for coffee growth (Willson, 1985). The most crucial of the physical characteristics is the soil structure, which permits correct drainage, as water logging lowers yield and can even cause coffee to die. Arabica coffee is able to thrive in a variety of soil types and conditions, including deep, slightly acidic, well- drained, fertile loams with a high humus content that are lateric or volcanic in origin (Purseglove, 1968). The bulk of coffee soils in the southwestern and southern region of Ethiopia are classified as Nito sols, which are highly weathered and originate from volcanic rock. These soils have a pH of 5–6, are deep, well-drained, and contain medium to high levels of most important elements with the exception of nitrogen and phosphorus (Paulos, 1986).

Nitrogen, phosphorus, and potassium are essential nutrients for coffee plant (Lima and Malavolta, 2003). One of the most crucial macronutrients is nitrogen, which is needed for processes like photosynthesis and the development of new tissues (Canelli *et al.,* 2006) and adequate tissue nitrogen levels are favorable for starch and other carbohydrate production needed for fruit formation and growth. Additionally, potassium is an important for the physiology of coffee plants, particularly during the development and maturation of the fruit.

The regulation of moisture loss by evapotranspiration is influenced by the state of optimum humidity. Increased humidity reduces stress on coffee trees, lengthening the period of rainless weather during which the plants can live without harm. This makes it especially crucial during the dry season. The use of shade, mulch and wind break are the fundamental requirement of coffee plantation regulated by growers. In many coffee growing countries coffee is grown well without shade. Without shade, coffee yields are higher when produced in ideal soil and climate conditions with good cultural practices and sufficient inputs (Purseglove, 1968). However, it is advised to use shade to maintain regular yield and prevent overbearing when coffee grown in unfavorable situations like inadequate fertile soil, excessive rains, and too hot or too low temperatures. Coffee trees established without shade give higher early yields than shaded coffee. Nevertheless, they have tendency to over-bearing, die-back, biennial bearing, erosion, disease and short productive life. Whereas in Ethiopia Arabica coffee grows naturally as an understory tree under the shade of several trees.

Coffee seedlings at the nursery also need optimum agronomic management conditions for germination and proper seedling growth. Coffee production starts with the selection and raising of seedlings in the nursery. The initial establishment of seedlings is critical to the proper growth and development of coffee trees as well as their eventual yield (Musagomba, 2019). At the early stage, proper root development is important to healthy seedling growth by implementing adequate supply of water and nutrients in the soil medium. According to Taye *et al.*, (2002) coffee seedlings can be cultivated in polythene bags (12–16 cm in diameter and 22–25 cm in height) filled with forest soil taken from the top 5–10 cm of depth, or they can be grown on raised beds (15 cm in height). However, in the absence of forest soil, the following combinations of top soil and compost, or top soil alone (TS), compost (C), and sand (S), should be used: 3TS: 1C: 0S > 2TS:1C: 1S > 2TS: 1C: 0S > 6TS: 2S: 3C. Likewise, Taye (1998) found that coffee seedlings' root and shoot growth was encouraged by a combination of readily available organic manure and TS in the ratios of 1:4, 2:4, and 3: 4. In case the media blend appears to be deficient in plant nutrients, the growth of seedlings can be enhanced by adding 2 g of DAP per seedling after it has two pairs of true leaves (Taye *et al*., 1999). Coffee seeds should be sown with the grooved side down and the embryo tip up at a depth of 1 cm for optimal germination and seedling growth. But as sowing depth increases beyond 1 cm, seed germination quickly decreases (Yacob, 1996). Also he reports seedbeds covered with 3 - 5 cm thick mulching by different mulching materials immediately after sowing results in higher germination percentage. Relatively higher germination response to mulch could be ascribed to regulation of the diurnal temperature in the nursery beds; the mulch should be removed and replaced by moderate (50 - 75%) overhead shade. When the seedlings start to emerge 50% over shade is the best option after emergence and vigorous seedling growth with the highest total dry matter and relative water content and improves moisture content of the rooting medium (Yacob *et al.* 1996*)*. Watering seedbeds within two days interval until seed emergence and twice a week until seedlings attain 2 to 4 pairs of true leaves and then after at a week interval produced vigorous seedlings for field planting and it is recommended that the watering frequency and the overhead shade level should gradually be reduced one month left for transplanting to the field at a stage of six to eight pairs of true leaves (Tesfaye *et al*, 2005).

2.4. Coffee production status in Ethiopia

Ethiopian coffee is known as having superior quality coffee and is mostly produced by small-scale farmers utilizing traditional farming methods and it is regarded as organic coffee production (Ayalew, 2014). Despite of the maximum biodiversity of coffee in Ethiopia the national coffee production by small scale farmers are very low as compare to other coffee producing countries (Taye, 2010). However coffee production is higher in state farms, private investors, model farms, and medium-to large-scale farms operated by research institutions than small-scale farming. This is because, they use improved coffee agronomic practices, such as fertilizer application, and improved coffee varieties.

Ethiopian coffee production systems fall into four categories: plantations, semi-forest, gardens, and forests by accounting (5, 35, 50 and 10%) of the total production respectively (Workafes and Kasu, 1999). The major coffee growing regions in Ethiopia are southern, south western and eastern parts of the country like; Sidama, Gedeo, Kefa, Ilubabor, Jimma ,Gamo Gofa, west Harerge and west Wellega Zones (Tadesse, 2015). In southern region like Sidama and Gedeo about 98% of the farmers produce coffee as a major cash crop. Specially in Sidama region coffee accounts 80% of income source than chat (17.5%) and maize (2.5%) but the farmers use traditional farming system, which results low production of coffee (Tadesse *et al.*, 2020).

2.5. Constraints of coffee production

The main obstacles to Ethiopia's coffee production are degraded soil, climate change, dense population, traditional production methods, inadequate use of coffee technologies, and inadequate nutrient management. (Degaga, 2020). There are different biotic and abiotic factors that affect the production of coffee in Ethiopia. Among abiotic factors impacting coffee production include drought, frost, erratic rainfall patterns, high humidity, high temperature, low moisture, hail, storms, wind, and inadequate fertilizer management. These elements have the potential to produce a yield loss of up to 70% (Tesfaye *et al.*, 2020). Climate change could result in the loss of 39% to 59% of Ethiopia's current coffee-growing regions by the end of the century (NPR, 2017). Temperature will rise by 4-6°C, this risk will more vulnerable to developing countries (Etana and Merga , 2020). Coffee species have been highly sensitive to climate change, such as rising temperatures and changing rainfall pattern. Pest and disease are also the major constraints of coffee production due to climate fluctuations (Jaramillo *et al*., 2011). Low amount and erratic distribution of the seasonal precipitation and recurrent droughts are also threats to coffee production in Ethiopia. The other constraints of coffee production in Ethiopia are lack of recommend genotypes that are acceptable for each agro- ecological zone that affect coffee productivity and quality (Yonas and Bayetta, 2008; Tolera and Gebremedine, 2015).

Soil degradation and nutrient loss are the most serious environmental problems in Ethiopia, particularly in the highlands (Tizale, 2007). Duicela, (2002) has shown that understanding the physical and chemical properties of the soil used to grow coffee makes, it easier to assess the crop's nutritional state and to provide targeted advice for coffee nutrition management. It can be used to discover possible production sites. Coffee trees' nutrient requirements can vary based on a number of variables, including soil type, quantity and distribution of rainfall, variety, population of other plants cultivated alongside the coffee trees, seasonal change, and prevalent cultural practices (Melke and Ittan , 2015).

Proper coffee nutrition requires special attention of the grower because it affects bean size (grade), bean quality and the overall productivity of the crop that determines marketability. Organic amendments have beneficial effects on the soil, including increased water availability and nutrient utilization efficiency (Diacono, and Montemurro, 2011). Soil fertility depends on many factors, among them the soil organic matter, because it contributes to an increase in soil CEC which can serve to retain and increase the reserve of soil cations, improves soil structure physics and soil water relations (Murphy, 2015). By using integrated soil fertility management (ISFM), which uses nutrients from the soil through the use of organic fertilizer, recycled crop leftovers, and mulching, poor soil fertility can be improved (Sanginga and Woomer, 2009). The majority of the soils in the main coffee-growing regions are subjected to prolonged nutrient leaching, which lowers their organic matter content and it needs careful treatment to maintain high crop yields (Melke and Ittana, 2015).

On the other hand coffee productions are also declined by different problems starting from nursery conditions. These emanate from using growing media that isn't ideal for seed germination and seedling growth, planting seeds at the wrong depth, and providing too much or too little shade and moisture during the nursery stage are factors affecting seed germination and seedling growth (Tesfaye *et al.*, 2005; Anteneh *et al.*, 2008). Availability of essential nutrient in growing media influences seed germination, seedling growth performance and quality in a nursery (Kaur, 2017; Santosa *et al.*, 2021). Because it affect gas diffusion, nutrient absorption, water availability and absorption, root growth and penetration finally this highly influence the seed germination process and subsequent seedling growth and performance (Santosa *et al*., 2021).

2.6. Role of vermicompost and vermiwash on seed germination

Different plants have varied response to the effect of vermicompost and vermiwash to their germination and many plant species are sensitive to higher concentration of vermicompost and vermiwash to seed germination. Hypocotyl growths are stimulated by low and moderate vermicompost concentrations but radicle growths are more sensitive to negative effect of vermicompost and the germination of different crops (okra, brinjal, chilli, swedish turnip and radish) are improved by moderate concentration of vermicompost (Ievinsh, 2011). In contrast to this germination rate of Linum varieties (Flax seed) are not negatively affected by higher concentration of vermicompost (Makkar *et al.*, 2017). Zambare *et al*, (2008) and Prabhu, (2006) reported that vermiwash contained nitrogen and phosphate solubilizing bacteria that improved the germination percentage of the seeds and seedling vigour of various crops. Effect of lower to moderate application of vermiwash on germination of various crops like cow pea , rice ,green mung and okra were high as reported by the following authors (Rajan and Murugesan, 2012; Chattopadhyay, 2015 ;Senthilmurugan *et al.*., 2018**).** The application of vermiwash diluted 1: 5 with water respectively had a positive effect on the germination percentage (100%) of green mung (Chattopadhyay, 2015). The moderate concentration of vermiwash diluted with more water (25 ml vermiwash with 75 ml water) can improve seed germination of okra plant (Senthilmurugan *et al*., 2018**).**

2.7. Role of vermicompost on crop production

Vermicompost contains higher quantity of nutrients, a large beneficial microbial population and biologically active metabolites, which can be applied alone or in combination with other organic or inorganic fertilizers to get better yield and quality of diverse crops (Ahirwar and Hussain, 2015). AS Gupta, (2014) suggested that growth and flowering of plants improved with the application of vermicompost in the growing media at the required amounts and maximum growth and productivity of marigold plants had observed in vermicompost amended potting media. Vermicompost has been shown to enhance plant growth, yields and quality through an improvement of physical, chemical and biological properties in the growth medium. The addition of 25 to 50% vermicompost to a growing medium results in an increase in plant growth and yield for several horticultural crops of vegetables, fruits, and ornamentals (Arancon *et al.*, 2008; Arguello *et al.*, 2006 ; Chand *et al.*, 2007). Low to moderate concentrations of vermicompost increased vegetative and reproductive growth is due to appropriate modification of the physico-chemical and microbiological status of growing medium (Truong and Wang, 2015). In line with Atiyeh et al. (2000) reported that 100% vermicompost caused tomato seedling relatively short, with few leaves and lesser weight. Specific nutrients of the plants are also influenced by the use of vermicompost feedstock source as organic fertilizer. The concentration of nutrients in plant tissues have been shown to be directly proportional to the concentration of nutrients in medium.Vermicompost application has been proved to be efficient in promoting the root formation, plant height and plant biomass as observed in many horticultural plants (Singh *et al.*, 2008). Total sugars, reducing sugars, non-reducing sugars, and starches were enhanced in banana (Ganapathi and Dharmatti, 2018) with vermicompost application. The concentration of phenolic compounds is also increased in rosemary (Ganjali and Kaykhaii, 2017). Aroma components of oil in marigold are ameliorated with the application of vermicompost (Pandey *et al.,* 2015). The effect of vermicompost to plant growth response has been due to the presence of plant growth hormones produced from microbial activity, which may enhance plant growth in small doses, but inhibit it at higher dose (Arancon *et al*, 2004). Vermicompost contains nitrogen that play important role for main part of amino acid, nucleic acid and chlorophyll and also increased protein content and accelerated vegetative growth so that the number of leaves well developed (Buckerfield *et al*., 1999). Also nitrogen in vermicompost are used optimally by plant so that photosynthesis process in leaves increased (Arancon *et al.,* 2004). According to Dwipa *et al*., (2020) states vermicompost application could stimulate root development, enhancing growth parameters on arabica coffee seedlings in Indonesia. In addition to this Zulhipri and Agung, (2021) reports four parts of soil with one part of vermicompost made from coffee husk waste increases on the variables of seedling growth performance of coffee in the nursery and it can substitute NPK inorganic fertilizer for coffee seedlings in the main nursery.

2.8. Effect of vermiwash on crop production

Vermiwash is coelomic fluid extraction that contains several enzymes, plant growth hormones (auxin, cytokinin and gibberline) and with micro and macro nutrients (nitrogen, potassium, magnesium, zinc, calcium, iron and copper) (Khan, *et al*., 2014). It also contains plenty of nitrogen-fixing and phosphate solubilizing bacteria (nitrosomonas, nitrobacter and actinomycetes (Buckerfield *et al.*, 1999; Zambare *et al*., 2008). In vermiwash nitrogen is present in the form of mucus, nitrogenous excretory substances growth stimulating hormones and enzymes (Tripathi and Bhardwaj, 2004). It also has soluble plant nutrients apart from some organic acids and mucus of earthworms and microbes (Shivsubramanian & Ganeshkumar, 2004). Fresh vermiwash contains many beneficial microbes helping plant growth and preventing disease (Kaur and Kaur, 2017). According to Buckerfeld *et al.,* (1999) reported that weekly applications of vermiwash increased radish yield by 7.3 %. Thangavel *et al.*, (2003) also showed that both growth and yield of paddy increased with the application of vermiwash extracts. Plants grown using different vermiwash in comparison to hydroponically grown plants show better seedling growth performance and resistance to insect damage (Ansari, 2010). Moderate rate of coffee husk vermiwash application in foliar spray result in increment on growth and seedling quality of Moringa and Jatropha plants (Girmay *et al.*, 2016). As vermiwash is the extracted body fluid of earthworms it rich in nutrients and it can promote the plant growth (Verma *et al.*, 2018). Vermiwash treated plants had extensive root system with greater root volume and root length and vegetative growth whereas plants treated with chemical fertilizers had weak, thin and poorly branched root system (Makkar *et al*., 2017). Vermiwash is 84% richer in phosphorous, 89.1% and 97.6% richer in Ca and Mg respectively and it is 97.8% richer in Na salts and it has higher amount of micronutrients as compared to the vermicompost (Manyuchi et al., 2013)

2.9. Combined effect of vermicompost and vermiwash on crop production and seedling growth

Different plants treated with the combination of 50% vermicompost and 50% of a foliar spray of vermiwash tends to the highest yielding plants with more branches, a higher number of capsules, tallest plant, high dry weight and maximum number of seeds (Makkar *et al*., 2017). Vermicompost fertilizer at 4 ton per ha combined with at 150 ml/ L foliar spray vermiwash had a positive effect for improving most vegetative growth, yield and nutrition status of lettuce plants (Yassen *et al*., 2020).

3. METHODS AND MATERIALS

3.1. Description of the experimental site

The experiment was carried out in a lath house at Hawassa University College of Agriculture campus from July 2022 to March 2023. The area is located in Sidama region, which is 275 kilometers from Addis Ababa, the capital city of Ethiopia. It is situated at 7° 3′ N latitude and 38° 28′ E longitude with altitude of 1708 m.a.s.l. The lath house was surrounded with metal wire.

3.2. Experimental materials

For the present study avocado waste and coffee husk were used as feedstock source for the preparation of both vermicompost and vermiwash. Avocado waste was collected from the avocado oil extraction factory at Yirgalem, Sidama region. The liquid avocado paste which is the end product of the extraction were collected and dried by sun and used as feedstock for vermicompost and vermiwash production. The Pulps of coffee were collected from wet coffee processing private plc at Yirgalem, Sidama region. These wastes were selected purposively because the area produces mainly coffee and slightly avocado and there is no experience of producing organic fertilizer through the conversion of these wastes to useful products. Exotic species of earth worm (*Eisenia fetida*) were purchased from farmer in Sidama region. Fresh coffee seeds, Koti-85257 variety were taken from Awada agricultural research sub-center. This variety is released due to its adaptability to the region and having good distinct character as described in the table1. Finally top soil at depth of 0-20 cm was collected from Hawassa University.

Table 1. Description of coffee variety that was used for the experiment

Variety	Origin	Altitude (masl)	released year	Characteristics
85257(Koti)	Kuoti	1550-2000	2010 E.C	CBD resistance Medium canopy Bronze leaf tip Small bean & round Shape high yielder

3.3. Vermicompost and vermiwash preparation

Both vermicompost and vermiwash were produced at Hawassa University College of Agriculture, Vermiculture Center. This was established by the financial support of GIZ project in 2020/21. This house built with concrete and the upper part of the wall is open for air exchange and covered with metal wire while the roof is partially transparent. Thus, 15.2^{o}C, 32.6^{o}C and 22.72^{o}C were the minimum, maximum, and average temperatures, respectively of the house. The maximum, minimum and average relative humidity of vermiculture house is 80.2(%), 32.4(%) and 56.11(%). Coffee husk and avocado waste were used as raw materials for both vermicompost and vermiwash preparation. The wastes were dried, chopped and grinded into smaller size in order to easily eaten by worms. Avocado waste which is liquid paste was dried by sun and then chopped manually and grinded by machine in order to reduce volume.

Whereas the coffee husk was dried and chopped manually. After feed stock preparation these wastes were added to the prepared cemented box separately for partial decomposition for 20 days in order to fasten the decompostion of vermicomposting process. The vermicompost production was done in three cement box having 0.5m width, 1.5m length and 0.5 heights. 30 kg wastes were added in each box based on the substrate used. Vermicompost production were prepared by three substrates such as avocado waste, coffee husk and 50% avocado waste plus 50% coffee husk. Animal manure and grass were used as starter and bedding material respectively added uniformly for all substrates. After 20 days of decomposition 0.86 kg of earth worms (*Esenia fetida*) was introduced for 30 kg feed stock in each box (Manyuchi *et al*., 2013).

The preparation was done by layering. For coffee husk vermicompost preparation, the first layer was bedding material which was 2 kg of dried grass was added in the bottom, then the next layer was 2kg of animal manure, then the third layer was 12 kg of coffee husk and finally the fourth and fifth layer was 2kg animal manure and 12 kg coffee husk respectively and water was added in all layering then 0.86 kg of earth worms were introduced on the top of substrate per box. For avocado vermicompost preparation, the first layer was bedding material which was 2 kg of dried grass was added in the bottom, then the next layer was 2kg of animal manure, then the third layer was 12 kg of avocado and finally the fourth and fifth layer was 2kg animal manure and 12 kg avocado respectively and water was added in each layering then 0.86 kg of earth worms were introduced on the top of substrate per box For combined of avocado and coffee husk vermicompost preparation, the first layer was bedding material which was 2 kg of dried grass was added in the bottom, then the next layer was 2kg of animal manure, then the third layer was 12 kg of coffee husk and finally the fourth and fifth layer was 2kg animal manure and 12 kg avocado respectively and water was added in each layering then 0.86 kg of earth worms were introduced on the top of substrate per box

Proper watering and follow up were done until final vermicomposting. Animal manure and grass were used as starter and bedding material due to their alkaline properties. Some toxic chemicals, like caffeine, tannin, and polyphenols, are found in coffee husks. Therefore, it is important to add alkaline residues like manure and plant residue in order to reduce their effect on worm activity (Mussatto *et al.*, 2011). By visual observation, the final vermicomposting stage was judged and vermicompost were ready to harvest within two months after worm entrance. Vermicompost harvesting was done manually by separating the vermicompost from earthworm. The final produced vermicompost were air dried and put in sack and stored in cool area until applying to the experiment. Three vermicompost samples were prepared for laboratory nutrient analysis. Finally 200g of vermicompost was applied to the experiment according to the treatment allocation.

Table 2. The type and quantity of feedstock used for vermicompost production

N	Type of feedstock used	Total waste added (kg)	Amount of feedstock (kg) for making mixed substrate
1	Coffee husk, animal manure, grass	30	24kgCH+4kg AM+2kg G
2	Avocado waste, animal manure, grass	30	24kg A +4kgAM+2kgG
3	50% coffee husk +50% avocado waste, animal manure, grass	30	12kgA+12kgCH+4kg AM+2kg G

Key: CH =coffee husk, A=avocado, AM= animal manure, G= grass

Vermiwash preparation

Vermiwash were produced from 50% avocado waste plus 50% coffee husk feed stocks. These feed stocks were prepared properly and added into cement box for pre-composting. After pre-composting for 20 days, a similar procedure was followed as in the prior vermicomposting experiment. However, the difference was the amount of worms and water added, which was more than in the prior vermicomposting experiment, as vermiwash is the liquid secretion of worms by draining water. 30 kg of wastes (12kg avocado, 12 kg coffee husk and 4kg animal manure and 2 kg grass) were used as waste material for vermiwash preparation. These wastes were added to the box as similar to the previous vermicomposting process, in this case 1.2 kg of earthworms were introduced into 30 kg wastes at the top of substrates then the box were covered by sack. Water was applied properly and after one month of worm entrance the vermiwash was ready to extraction. The final vermicompost with earthworms was used for extraction of vermiwash. The extraction was done by 500 g of vermicompost soaked in 2.5 L of distilled water for 48 hours (Tadayyon *et al.*, 2018). Then, the extract were done using a sieve wire and collected in a plastic container. After collecting the vermiwash was stored properly and applied to the experiment at different growing stage of coffee seedling starting from sowing until the seedling attending to five pair of leaves in equal rate for the treatment allocations. 20 ml of vermiwash diluted five times with tap water was applied in one round and the application was done at five rounds within one month interval after germination. Totally 100 ml of vermiwash were applied per seedling in half of the experimental unit (polyethylene bag).

3.4. Experimental design and treatments

The experiment was conducted in 2X 5 factorial arrangement using a complete randomize design (CRD). It consisted two factors ,the first factor had five levels with three of them were vermicompost made from avocado solid waste, coffee husk, combined of 50% coffee husk plus 50% avocado waste as well as two other treatments including soil (negative control) and recommend rate of coffee growing media 3:1 ratio of soil and compost (positive control). The second factor consisted of two levels of vermiwash, with and without vermiwash application. The treatment combinations are shown in Table 3. The experiment consisted of 10 treatments in total, and with three replications, it consisted of 30 experimental plots. Each experimental plot consisted of 8 plants, and hence, 240 seedlings were established on 240 polyethylene bags.

Table 3. Experimental treatment combination

TRT NO	Vermiwash	Vermicompost	Treatment Combination
1	With Vermiwash	Coffee husk	CHVC + with VW + soil
2	With Vermiwash	Avocdo waste	AVC + with VW + soil
3	With Vermiwash	Combined	COVC + with VW + soil
4	With Vermiwash	Soil	soil + with VW
5	With Vermiwash	Recommended	3:1 soil with compost + with VW
6	Without Vermiwash	Coffee husk	CHVC+ without VW + soil
7	Without Vermiwash	Avocdo waste	AVC+ without VW + soil
8	Without Vermiwash	Combined	COVC + without VW + soil
9	Without Vermiwash	Soil	soil + without VW
10	Without Vermiwash	Recommended	3:1 soil with compost + without VW

Where, A =Avocado waste, CH=Coffee husk, CO= Combined of 50% avocado waste + 50% coffee husk, VC = Vermicompost, VW =Vermiwash

3.5. Experimental procedure and establishment

The experiment was initially established at green house condition until the seed were emerged. After germination the seedlings were transferred to lath house which were constructed from black mesh at Hawassa University College of Agriculture Research site. Black polyethylene bag having 22x16 cm sizes were used for experimental unit. Top soil taken from Hawassa University College of Agriculture Research open field and sieve the soil carefully and used as media preparation. The media were prepared from 2Kg of top soil mixed with 200g of vermicompost (Zulhipri and Agung, 2021) for all polyethelene bags except negative control(soil alone) and positive control (recommended rate of coffee growing media), then moist their composition by sprinkling cold water inorder to easily filling to the polyethylene bags.

After media preparation nursery area was cleaned and labeled. The experimental polyethylene bags were put on the prepared nursery area and arranged it in three rows. The media were watered for three days before seed sowing inorder to moist and loose the media. The released coffee variety seed (Koti)was used as planting material which is the improved variety released for Sidama and Yirgachefe coffee growing areas having superior yield and growth performance and it is more acceptable in this region due to high yielding, disease resistance (CBD and CLR) and adaptability characters .The clean coffee seeds were socked in slightly hot water for 48 hours in order to removing harmful pathogens. The clean coffee was used for better performance of seedling growth over the parchment seed (Wosene *et al*., 2010). After socking the seeds, two coffee seeds were sown per bag in grooved side of the seed down with 1 cm depth. Vermiwash was applied after sowing and mulching prepared from dry grass was done after sowing and water applications were applied within two days interval until seed emergence. After germination mulch were removed and the experiment were translated to lath house. When the seedlings attainted to one pairs of true leaf thinning were done. And all the agronomic management practices (watering, cultivation, weeding) were done as per required.

3.6. Physico-chemical properties of soil, vermicompost and vermiwash

Sample preparation of vermicompost, vermiwash and soil for laboratory analysis was done. Soil samples were collected at 0-20 cm depth by auger from Hawassa College of Agricultural Research open field. The soil samples were air dried and grounded to pass through 2 mm sieve before laboratory analysis, and the samples were analyzed for parameters relevant to the study at Hawassa University Collage of Agriculture Soil Laboratory. Soil analysis was made as per the standard laboratory procedure. The soil and vermicompost pH value was determined in soil water suspension 1:2.5 using glass electrode pH meters (Sahlemedin and Taye, 2000). Determination of particle size distribution (texture) was carried out by hydrometer procedure (Bouyoucos, 1951). Cation exchange capacity (CEC) was determined by 1M ammonium acetate (pH) method. The organic carbon in the samples was determined using Walkley's and Black chromic acid wet oxidation method. This procedure involves oxidizing oxidizable organic carbon in the sample with a potassium dichromate ($K_2Cr_2O_7$) solution in the presence of concentrated sulphuric acid. Total nitrogen was determined as mentioned by using Kjeldahl procedure (Nelson and Sammers, 1980). Available P, exchangeable base cations (K+, Na+) were determined by Mehlich-3 (Mehlich, 1984).While the laboratory analysis of vermiwash were done as followed. The organic carbon of vermiwash was determined using potassium di-chromate and concentrated sulphuric acid as extracts using hot water bath, and then followed the method of Walkley and Black (1934). Total nitrogen was determined in vermiwash samples by the Kjeldahl method using concentrated H_2SO_4, K_2SO 4 and selenium to digest sample and was estimated according to (Bremner and Mulvaney, 1983). Total available P was determined by the colori-metric method of Olsen *et al.,* (1954). Total potassium and sodium were determined by flame photometer. pH was estimated by pH meter while electrical conductivity was determined by a Conductivity meter.

Table4. Physico-chemical properties of soil, vermiwash and vermicompost used for the experiment

Parameters	Soil	Coffee	Combined	Avocado	Recommended	Vermiwash
Sand(%)	58					
Silt(%)	29					
Clay(%)	13					
Soil textural class	Sandy loam					
PH(1:2.5 H2o)	6.8	8.2	8.5	9.4	7.2	8.2
OC(%)	1.8	12.3	10.3	8.2	11	13.2
EC(ds/M)	0.23	4.2	5.3	6.56	5	0.56
CEC(cmol(+)kg^{-1}	19.5	70	62	48	58	67
Na(cmol(+)kg^{-1}	0.4	6.5	7.1	8.7	6	9.2
Total Nitrogen(TN(%)	0.07	2	1.7	1.1	1.2	2
K (cmol(+)kg^{-1}	1.7	25	20.6	12	20	28
Available Phosphorus/P/(ppm)	4.7	173.8	169.2	114.8	169	174

Where, EC= Electrical Conductivity, CEC= Cation Exchange Capacity, OC= Organic Carbon, combined =50% coffee husk plus 50% avocado waste, Recommended =3:1 ratio of top soil with compost

3.7.Data collection

In this experiment germination and different morphological data of coffee seedlings were collected at the proper growth stage of coffee seedlings.

3.7.1. Germination and Growth Data

Days to 50% Emergence

It was taken when 50% of the seeds in the polyethylene bag had emerged. It was recorded by counting the number of days from sowing until 50% of the seed population per treatment had emerged.

Seedling height

The average plant heights of five randomly selected plants were measured from each experimental unit. It was measured from the ground level to the tip of the main stem of the plant by using ruler manually.

Leaf Area

First destructing the plant and cutting the leaf part by hand and putting on the machine (LI-3100C Area meter (precision Square cm), LI-COR. Bio science area meter, Australia. It was done at transplanting stage of coffee seedlings and the sample were taken from all leaves of five selected plants per experimental units

Leaf Number

The average leave numbers of five randomly selected plants were counted manually per experimental unit at mid growing stage and at final growing stage

Number of node

It was done by counting the node of five randomly selected plants manually for all experimental units at mid growing stage and at transplanting stage and the average node number was used for analysis

Internode Length

The average internode length was measured by ruler manually. Five plants were selected randomly and measure the length of node between node of main stem of seedlings at mid and transplanting growth stage

Leaf fresh weight

The destructed five randomly selected plant leaves were used for sampling from all experimental units. Sample preparation was done by separating the leaves from stems of the plant and putting the leaves and stems separately on paper bag. Then the leaves fresh weights were measured by using electronic sensitive balance at transplanting stage of the coffee seedlings.

Stem fresh weight

The destructed five randomly selected plant stems were used for sampling from all experimental units and the stem fresh weight were recorded using electronic sensitive balance at transplanting stage of the coffee seedlings

Leaf dry weight

It was measured by electronic sensitive balance after the samples had oven-dried (48 hr at 70℃) at transplanting stage from all leaves of five randomly selected plants in each treatment

Stem dry weight

It was measured by electronic sensitive balance after the samples had oven-dried (48 hr at 70℃) at transplanting stage from all stems of five randomly selected plants in each treatment

Shoot fresh weigh

Five randomly selected destructive plant samples were measured by putting total leaves and stems of the selected samples on electronic sensitive balance. The measurement were done at transplanting stage of coffee seedling of each experimental plots

Total fresh weight

First destruct five randomly selected plants and cut the root parts properly and washed the root parts then after put the shoot part and root part on paper bag separately. Both the shoot part and roots part were measured by electronic sensitive balance separately and finally the sum of fresh shoot weight and fresh root weight were used as total fresh weight. Data collection was taken at transplanting stage of coffee seedlings for all experimental units.

Root length

Root was uprooted first by adding clean water to the media properly in order to moist the growing media for destructing the root easily without disturbing the root tip. After carefully uprooting the root were washed by tap water and dried it. Then it was measured using ruler placed along-side from the underground surface to the root tip of the seedlings of five randomly selected plants from all experimental plots at transplanting stage

Root Fresh weight

After destructing five selected plants from each treatment then, the root parts were cut and washed by tape water and then it was measured by sensitive balance at transplanting growing stage

Shoot dry weight

It was recorded after seedling fresh weight gathered samples placed in paper bags and then put on oven dry for 48 hours at 70^0C temperature and it was measured using electronic sensitive balance at transplanting stage of five selected plants from each treatment

Root dry weight

After measuring root fresh weight those samples were used as measuring root dry weight and these were put in oven dry with 70^0C for 48 hours after drying it was measured by sensitive balance from all experimental treatments of five selected plants at transplanting growing stage

Total dry weight

The sum of root dry weight and shoot dry weight were used as total dry weight which was measured at final growing stage of coffee seedlings. The sample were measured by electronic sensitive balance after the shoot and root parts were oven dried for 48 hours in 70^0C from five randomly selected plants of all experimental treatments.

3.8. Data Analysis

All the collected data were analyzed statistically using analysis of variance (ANOVA), followed by means separation using least significant test at p 5% (0.05).The analysis was performed using SAS software package version 9.3 (SAS Institute, 2008).

4. RESULT AND DISCUSSION

4.1. Germination and 50% days to Emergence

50% days to emergence were significantly ($P < 0.001$) influenced by the interaction effect of vermicompost and vermiwash (Appendix table1). The result indicated the early days to emergence (30.07) was recorded from the interaction between coffee husk vermicompost with vermiwash application (Table5). While the longest days to emergence was recorded (65) from soil alone without vermiwash application (negative control). Application of vermicompost and vermiwash to coffee seedling could improve seed emergence. This might be due to the presence of micronutrients, macronutrients on both vermiwash and vermicompost that promotes seed imbibition and enhance seed germination (Senthilmurugan *et al*, 2018). Growth regulator hormones in vermicompost facilitate osmotic regulation and metabolic repair of seed results in better seed germination (Javed *et al*., 2020; Kaur, 2017). Vermiwash as enrich source of essential nutrients and beneficial microorganisms it can promote germination and improve soil fertility (Sundararasu, 2016).The current experiment also agreed by (Chattopadhyay, 2015; Senthilmurugan *et al*., 2018) who reported, seed germination had faster in vermicompost containing media this is due to its high nutrient composition, organic matters and different hormones that promote germination and in overall it created favorable growing condition for seed germination. The other authors Senthil *et al*., (2022) also support the present result who reported that the germination of coffee was higher in soil plus vermicompost growing media.

Table 5. Interaction effect of vermicompost and vermiwash on 50% days to emergence

Vermiwash	Vermicompost	
With vermiwash	Coffee Husk	30[a]
	Avocado Waste	40[c]
	Combined	35[b]
	Soil	48.34[e]
	Recommended	37[c]
Without vermiwash	Coffee Husk	44.34[d]
	Avocado Waste	60[f]
	Combined	40[c]
	Soil	65[g]
	Recommended	50[ef]
LSD		3.26
CV		4.23

Key, Means with different letter on the table are statistically significant at P-values < 0.05, CV = Coefficient of variance, LSD= List significant difference

4.2. The morphological growth parameters of coffee seedlings

The interaction effect of vermicompost and vermiwash had highly significantly ($p \leq 0.001$) affected to morphological growth performance of coffee seedlings (Appendix table1).

Seedling height and leaf number

Seedling height and leaf number of coffee seedlings were highly significantly ($p \leq 0.001$) influenced by the interaction effect of vermicompost and vermiwash (Appendix table1). According to the result indicated addition of coffee husk vermicompost plus with vermiwash application increased to seedling height and leaf number of coffee. The tallest plant (21cm) was obtained from the integrated application of coffee husk vermicompost plus with vermiwash application. Moreover, the combined of 50% coffee and 50% avocado waste vermicompost plus with vermiwash application also showed significant influence on plant height (18.67cm). While the shortest plant height(9.7) were measured from soil plus without vermiwash (negative control) (Table6) As the result indicated addition of coffee husk vermicompost plus with vermiwash to coffee growing media increased plant height by 54.55 % over the negative control (soil alone) treatment. This may be due to chemical and microbiological properties of vermicompost obtained from coffee husk enhance nutrient value and microbiological quality of vermicompost and it utility as a good source for plant nutrients and soil fertility and also an enhancement in coffee growth performance (Raphael and Velmourougane, (2011. The structure and texture of coffee growing media could be improved by the addition of vermiwash and vermicompost, these increased nutrient absorption by root this lead to enhancing the seedling vegetative growth.

The maximum number of leaf (12) was recorded from the integrated application of coffee husk vermicompost plus with vermiwash. While the minimum number of coffee leaf (4.1) were counted from soil alone (negative control) and avocado plus without vermiwash treatment (Table6). This result showed that addition of coffee husk vermicompost and vermiwash had a positive effect in increasing coffee leaf number by 65% over negative control and avocado vermicompost. This might be due to the physico chemical properties of vermicompost and vermiwash obtained from coffee husk waste (Joshi *et al*., 2015). The earlier authors reported that available form of nitrogen (nitrate) is greater in vermicompost, which can increase the growth and leaf number of the plant. Vermicompost made from Coffee husk contains plant nutrients of 2.07 N, 0.55% P2O5 and 2.87 K2O, which improved the crop performance (Dzung *et al*., 2013).

As the current laboratory analysis result showed that physico chemical properties of coffee husk vermicompost had good nutrient composition like increased organic carbon, total nitrogen, available phosphorus and favorable pH range (> 6.5) which could create suitable growing media that enhancing coffee seedling growth (Table 4).

The present experiment is in agreement with the finding of (Dwipa *et al*., 2020) who reported that coffee husk vermicompost had a positive effect on the increasing plant height and leaf number of coffee seedlings. Addition of coffee husk vermicompost to coffee can enhance the availability of nutrients to the growing media and it increased plant growth through its good properties of physical, chemical and biological status that improves the fertility level of coffee growing media (Zulhipri and Agung, 2021). The nutrient content of vermicompost vary greatly depending on the feed stock materials used and organic bio remediated matter that differs from other organic fertilizers in its level of humification and the greater presence of microbial metabolites(Akhter *et al*, 2012). Moreover application of vermiwash also a positive effect on enhancing plant height and number of leaves of plants at nursery growth stage (Grmay, *et al* 2016).

Leaf area and number of node

The interaction effect of vermicompost and vermiwash had highly significantly affected ($p \leq 0.001$) to leaf area and number of node of coffee seedlings (Appendix table1). The highest leaf area (75cm^2) was obtained from the integrated treatment of coffee husk vermicompost plus with vermiwash application and the maximum number of node (6) were also obtained from coffee husk vermicompost plus with vermiwash application. While the lowest leaf area (18.3) and the minimum number of node (2) were obtained from the soil without vermiwash (negative control). These results indicated that addition of coffee husk vermicompost and vermiwash had a significant role on leaf area and number of node on coffee seedlings. Accordingly, addition of coffee husk vermicompost and vermiwash improved in coffee seedlings leaf area and number of node by 75.6% and 66.6% over negative control respectively. This might be due to ingestion of the coffee husk by the earthworms, results an increase in available P, Ca, and Mg and N (Orozco *et al*. 1996). According to (Raphael *et al.*, 2012) vermicompost obtained from coffee husk results the increment in nutrient composition and microbiological quality of the growing media and it can be good source for plant nutrients and soil fertility improvement in coffee farms. Leaf area and number of node might be increased by the positive effect of growth hormone in vermicompost and vermiwash such as auxin, cytokinin and gibberellin could affect the plant growth (Aalok *et al*., 2008). The authors stated that cytokinin content could produce more cell division and formed new shoot that affected total leaf area. Taye (1998), also reported various proportions of organic manures including decomposed coffee husk and farm yard manure mixed with top soils were significantly affected most of the coffee seedling growth parameters at Jimma, South West. The present result in line with the finding of Senthil *et al.*, (2022) who reported that soil amended with vermicompost had maximum leaf area and number of node in coffee seedling at nursery.

Inter node length

The interaction effect of vermicompost and vermiwash were not statically significantly affected internode length of coffee seedlings (Appendix table1). The highest internode length were obtained from combined of 50% coffee husk and 50% avocado waste plus with vermiwash. While the minimum internode length of coffee seedling was obtained from avocado plus vermiwash application (Table6). This might be internode length cannot influenced by nutrient management it may be influenced by other factors like variety, environment.

Root length

The interaction effect of vermicompost and vermiwash had significantly affected root length of coffee seedlings ($p \leq 0.001$) (Appendix table1). According to the result indicated that the longest root length (21.3) were obtained from coffee husk vermicompost plus with vermiwash application and combined of 50% coffee husk + 50% vermicompost plus with vermiwash application were the next best performing treatment by obtaining (20.167cm) root length of coffee seedlings (Table6). While the shortest root length (9.67cm) were obtained from the negative control (soil without vermiwash). As the present result showed that addition of vermicompost and vermiwash to coffee growing media could improve the root length of coffee by 53.4% over the negative control. This is due to the availability of growth promoting hormone in both vermicompost and vermiwash, especially auxion hormone which is important to increasing root growth of plants (Nigussie *et al*., 2017). The result is in line with the finding of (Makkar *et al*, 2017 :Lim *et al*., 2015) who stated that vermiwash and vermicompost treated plants had extensive root growth with greater root volume and root length and vegetative growth whereas plants treated with chemical fertilizers had weak, thin and poorly branched root system. This result also supported by the study of Dwipa *et al* (2020) who reported that coffee husk vermicompost application could stimulate root development and enhancing growth parameters on arabica coffee seedlings.

Table 6. Interaction effect of vermicompost and vermiwash on morphological growth parameters of coffee seedlings

Vermiwash(ml)	Vermicompost(g)	SH	LN	NN	LA	RL	IL
With vermiwash	Coffee husk	21.34^{a}	12^{a}	6^{a}	75^{a}	21.34^{a}	3.2^{a}
	Avocado waste	15^{d}	6.2^{d}	3.1^{d}	35.67^{e}	12.07^{e}	1.5^{b}
	Combined	18.7^{b}	10^{b}	5^{b}	57.07^{b}	20.17b	1.76b
	Soil	9.8^{f}	4.2^{i}	2.17^{gh}	23.94^{f}	10^{f}	1.54^{b}
	Recommended	17.7^{bc}	8.07^{c}	4.03^{c}	47.17^{c}	16.17^{c}	1.8b
Without vermiwash	Coffee husk	16.5^{cd}	5.47^{e}	2.7^{e}	45.34^{cd}	11.34^{e}	1.62^{b}
	Avocado waste	9.75^{f}	4^{i}	2.04^{hi}	24.6^{f}	10.34^{f}	1.66^{b}
	Combined	16.5^{4c}	5^{f}	2.5^{f}	42.45^{cde}	12^{e}	1.62^{b}
	Soil	9.7^{f}	4^{i}	2^{i}	18.17^{g}	9.67^{f}	1.46^{b}
	Recommended	13.33^{e}	4.6^{g}	2.3^{g}	$38,67^{de}$	13^{d}	1.6^{b}
LSD		1.48	0.28	0.14	8.02	0.89	NS
CV		5.74	2.58	2.58	11.45	3.82	44.54

Key, combined= 50% avocado waste + 50% coffee husk, Recommended= 3:1 ratio of top soil with compost, SH= Seedling height, LN= leaf number, NN= Number of node, LA = Leaf area, RL= Root length, IL=Internode length, within column means with different letter on table are statistically significant at p- values <0.05 based on the LSD (List significant difference) comparison method, CV= coefficient of variance

4.3. Shoot and root fresh weight of coffee seedling parameters

Both shoot and root fresh weight of coffee seedling parameters were highly significantly influenced (p<0.001) by the interaction effect of vermicompost and vermiwash (Appendix table2).The highest root fresh weight, leaf fresh weight, stem fresh weight, shoot fresh weight and total fresh weight (5.1, 7.7. 8, 1.32, 9.09, 14. 19) respectively were obtained from coffee husk vermicompost plus with vermiwash. While the lowest root fresh weight, leaf fresh weight, stem fresh weight, shoot fresh weight and total fresh weight (1.7, 1.3, 0.41, 1.47, and 3.17) respectively were measured from negative control (Table 7). Addition of coffee husk vermicompost plus with vermiwash application improve root fresh weight, leaf fresh weight, stem fresh weight, shoot fresh weight and total fresh weight of coffee seedlings by 66.7%,83%,89.4%,83.8% and 77.6% over negative control respectively. This is due to the nutrient content of coffee husk and availability of cytokinin hormone in both vermicompost and vermiwash. Kieber and Schalle, (2018) who stated that cytokinin is an important growth enhancing hormone that encourages side part shoots, apical dominance and leaves expansion, this can affect total shoot growth. Appling vermicompost to the coffee growing media might considerably improve the nutrient availability particularly phosphorus and nitrogen these can improve the vegetative growth of plants (Lim *et al*., 2015). The current result are agreed with the result of (Zuihipri and Agungl, 2021) who reported that coffee husk vermicompost had a positive effect on the variable of coffee seedling fresh weight (stem fresh weight ,leaf fresh weight and total fresh weight) of coffee seedling at nursery condition of coffee Arabica in Indonesia.

Table 7. Interaction effect of vermicompost and vermiwash on root, leaf, stem, shoot and total fresh weight of coffee seedlings

Vermiwash(ml)	Vermicompost(g)	RFW	LFW	SFW	SHFW	TFW
With vermiwash	Coffee husk	5.1[a]	7.78[a]	1.32[a]	9.09[a]	14.19[a]
	Avocado waste	3.64[d]	3.94[c]	0.81[c]	4.75[c]	8.38[d]
	Combined	4.54[b]	5.04[b]	1.3[a]	6.34[b]	10.87[b]
	Soil	2.57[h]	2.3[de]	0.25[f]	2.55[ef]	5.12[g]
	Recommended	4.24[c]	3.88[c]	1.1[b]	4.99[c]	9.22[c]
Without vermiwsh	Coffee husk	3.47[e]	3.37[c]	0.52[d]	3.89[d]	7.35[e]
	Avocado waste	2.27[i]	2[e]	0.22[f]	2.22[f]	4.49[g]
	Combined	3.27[f]	3.47[c]	0.33[e]	3.8[d]	7.063[e]
	Soil	1.7[j]	1.34[f]	0.14g	1.47[g]	3.17[h]
	Recommended	3.04[g]	2.67[d]	0.25[f]	2.92[e]	5.96[f]
LSD		0.12	0.65	0.06	0.65	0.69
CV		2.04	10.52	5.2	9.04	5.27

With column means with different letters on the table are statically significant at P value value (0.05) based on the LSD (list significant difference) comparison methods, CV= coefficient of variance, RFW=root fresh weight, LFW=leaf fresh weight, SFW=stem fresh weight ,SHFW=shoot fresh weigh, TFW=total fresh weight, Recommended= 3:1 ratio of soil with compost and Combined = 50% avocado waste + 50% coffee husk

4.4. Shoot dry weight and root dry weight of coffee seedling parameters

Both root and shoot dry weight of coffee seedlings were highly significantly affected by the interaction effect of vermicompost and vermiwash application (Appendex table3). The highest root dry weight (0.67), leaf dry weight (2.3), stem dry weight (0.55), shoot dry weight (2.86) and total dry weight (3.53) were obtained from the integrated treatment of coffee husk vermicompost plus with application of vermiwash (table8). While the lowest root dry weight (0.11), leaf dry weight (0.12), stem dry weight (0.01), shoot dry weight (0.13) and total dry weight (0.24) were obtained from negative control. This might be due to the optimum phyisico chemical properties of vermicompost and vermiwash are rich in nitrate, available phosphorus, potassium, calcium and magnesium that increase the growth of plant (Gopinath *et al.*, 2010). Coffee Husk had the potential for vermicomposting due to having a higher quantity of cellulose apart from potash and lignin and it has magnificent moisture retaining capacity. As Arancon and Edwards, (2005) reports vermicompost used as growing media that increases the growth parameters of plant,it results in the increment of the shoot fresh weight and shoots dry weight of the plant. The current result also agreed with the findings of (Sentheil *et al.*, 2022) who found that coffee sowing in vermicompost growing media increase both shoot fresh weight and shoot dry weight of coffee seedlings. The present result also supported by Takala *et al.*, (2020) who reported that media amended with coffee husk compost reviled the highest shoot and root dry weight of coffee seedling.

Table 8. Interaction effect of vermicompost and vermiwash on leaf, stem, shoot, root and total dry weight of coffee seedlings

Vermiwash(ml)	Vermicompost(g)	RDW	LDW	SDW	SHDW	TDW
With vermiwash	Coffee husk	0.67a	2.31^{a}	0.55a	2.86a	3.53a
	Avocado waste	0.38d	1.2^{d}	0.25^{d}	1.45^{d}	1.8^{d}
	Combined	0.51b	1.9^{b}	0.45b	2.37^{b}	2.9^{b}
	Soil	0.25^{h}	0.3^{g}	0.09^{h}	0.4g^{h}	0.6^{h}
	Recommended	0.46^{c}	1.6^{c}	0.3^{c}	1.907c	2.37^{c}
Without vermiwash	Coffee husk	0.34^{e}	0.8^{e}	0.22^{e}	1.07e	1.4e
	Avocado waste	0.22^{i}	0.34^{g}	0.05^{i}	0.38h	0.6h
	Combined	0.31^{f}	0.64^{f}	0.19^{f}	0.82^{f}	1.12^{f}
	Soil	0.11^{j}	0.12^{h}	0.01^{j}	0.1i	0.24i
	Recommended	0.29^{g}	0.41^{g}	0.11^{g}	0.5^{g}	0.8^{g}
LSD		0.005	0.128	0.07	0.13	0.13
CV		1.39	7.73	2.55	6.32	4.82

With column means with different letters on the table are statically significant at p-value 0.05

based on the LSD (List significant difference) comparison methods CV= coefficient of variance, RDW=root dry weight, LDW =leaf dry weight, SDW=stem dry weight, SHDW=shoot dry weigh, TDW=total dry weight

4.5. Pearson correlation coefficients result among morphological growth with fresh weight and dry weight of coffee seedlings

Correlation measures the statistical relationship or association between two continuous variables and gives information about the magnitude of the association as well as the direction of the relationship (Schober and Schwarte, 2018). Positive and significant relations was observed between morphological growth parameters with shoot and root fresh weight as well as shoot and root dry weight of coffee seedlings (Table 9 and 10). All morphological growth parameters showed a positive and strong correlation with plant root and shoot fresh weight and dry weight of coffee seedlings. Plant height was strongly correlated with leaf fresh weight (r=0.9***), root fresh weight (r=0.95***), shoot fresh weight (r=0.9***), root dry weight (r=0.92***) and shoot dry weight (r=0.9***). Increasing morphological growth parameters in line with root and shoot fresh weight as well as root and shoot dry weight of coffee seedlings. This may be due the highly availability of mineral nutrients like NPK in vermicompost that increased the production of cells and tissues in plants metabolism process, that promotes the rate of vegetative growth of seedlings and this is directly affect both above ground and underground fresh weight and dry weight of plants (Huang *et al.*, 2019).

Table 9. Pearson correlation coefficient among the growth parameters and fresh weight of coffee seedlings

	Sh	Ln	Nn	Il	la	Rl	rfw	Lfw	Sfw	Shfw	Tfw
Sh	1										
Ln	0.86	1.00									
Nn	0.86	1.00	1.00								
Il	0.37	0.48	0.48	1.00							
La	0.92	0.89	0.89	0.43	1.00						
Rl	0.83	0.96	0.96	0.48	0.88	1.00					
Rfw	0.95	0.92	0.92	0.41	0.92	0.90	1.00				
Lfw	0.89	0.93	0.93	0.53	0.93	0.88	0.92	1.00			
Sfw	0.85	0.95	0.95	0.38	0.82	0.91	0.93	0.86	1.00		
Shfw	0.90	0.96	0.96	0.51	0.93	0.91	0.95	0.99	0.91	1	
Tfw	0.93	0.96	0.96	0.48	0.94	0.92	0.97	0.98	0.93	0.9945	1

Where, Sh= Seedling height, ln=Leaf number, il= internode length, la=Leaf area, rl=root length, lfw= leaf fresh weight, sfw= stem fresh weight, rfw= root fresh weghit. Shfw= shoot fresh weight, tfw=total fresh weigh

Table 10. Pearson correlation coefficient among the growth parameters and dry weight of coffee seedlings

	Sh	Ln	Nn	Il	La	Rl	Rdw	Ldw	Sdw	Shdw	Tdw
Sh	1										
Ln	0.9	1.0									
Nn	0.9	1.0	1.0								
Il	0.4	0.5	0.5	1.0							
La	0.9	0.9	0.9	0.4	1.0						
Rl	0.8	1.0	1.0	0.5	0.9	1.0					
Rdw	0.9	1.0	1.0	0.5	0.9	0.9	1.0				
Ldw	0.9	1.0	1.0	0.4	0.9	0.9	1.0	1.0			
Sdw	0.9	1.0	1.0	0.5	0.9	0.9	1.0	1.0	1.0		
Shdw	0.9	1.0	1.0	0.4	0.9	0.9	1.0	1.0	1.0	1.0	
Tdw	0.9	1.0	1.0	0.4	0.9	0.9	1.0	1.0	1.0	1.0	1.0

Where, Sh= Seedling height, Ln=Leaf number, Il= internode length, La=Leaf area, Rl=Root length, Ldw= leaf dry weight, Sdw= stem dry weight, Rdw= root dry weight. Shdw= shoot dry weight, Tdw=total dry weight

5. SUMMARY AND RECOMMENDATION

Coffee Arabica is an important cash crop for the small scale coffee growers as well as the national economy of Ethiopia. However the production of coffee in Ethiopia is low as compared to other coffee producing countries. This is due to various problems like traditional farming system, poor agronomic practice, and poor supply of nutrients. In the evaluation of the response of coffee (Coffea arabica L.) seedlings growth performance, all the growth parameters except internode length were significantly influenced by vermicompost and vermiwash application. The result showed that vermicompost prepared from coffee husk had higher nutrient value and had significant effect on the growth parameters of coffee seedlings. Vermiwash also had a significant effect on coffee seedlings growth. The interaction effect between applications of vermicompost with vermiwash had significantly affected coffee seedling growth performance. Vigorous coffee seedlings were obtained from coffee husk vermicompost with vermiwash application. Therefore the potential use of coffee husk vermicompost with vermiwash application enhanced coffee seedling growth performance by improving the nutrient availability in the coffee growing media. According to the current research findings, coffee husk vermicompost plus with vermiwash > combined vermicompost (50% of coffee husk + 50% of avocado waste) vermicompost plus with vermiwash > recommended rate of coffee growing media (3:1 top soil and compost) plus with vermiwash > avocado vermicompost plus with vermiwash > soil plus with vermiwash application were the rank of treatment combination that obtained from the present study. However further studies will be required to determine the rate of vermicompost and vermiwash on coffee seedlings because the present study were done only on the source of raw materials for vernicompost and vermiwash production, but not on the rate. So that to determining the level of coffee husk vermicompost and vermiwash is necessary to conduct in the future research work.

The preparation methods of vermicompost and vermiwash and the time taken to vermicomposting also considered as the critical issue because the improper preparation methods and harvesting of vermicompost within short time affect the growing media and seedling growth performance by creating unsuitable condition to the growing media.

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7. APPENDIX TABLES

Appendix table 1. Analysis of variance of leaf area, internode length, root length and root fresh weight as affected by vermicompost and vermiwash and their interaction

		Mean square						
Source of varation	DF	50% days of emergence	Seedling height	Leaf number	Number of node	Leaf area	Inter node length	Root length
Replication	2	4.27	0.14	0.13	0.03	6.09	0.52	0.09
Vermicompost	4	1428.3***	72.16***	91.5253***	22.8813***	1450.19***	1.026ns	164.27***
Vermiwash	1	1685.8***	112.13***	19.8713***	4.97***	1442.26***	0.8ns	51.83***
VC*VW	4	187.53***	2.93**	8.7553***	2.19***	132.74****	0.7ns	26.37***
Error	18	65.07	0.74	0.0271	0.007	21.84	0.63	0.27
Total	29							
CV(%)		4.23	5.75	2.58	2.58	11.45	44.54	3.82

ns,** and *** indicates non-significant difference (p<0.05) highly significance (p<0.01) and very highly significant (p< 0,001) respectively, CV = coefficient of variance, Df= degree freedom, VC=vermicompost, VW= vermiwash

Appendix table 2. Analysis of variance of leaf fresh weight (lfw), stem fresh weight(sfw), shoot fresh weight(shfw),total fresh weight (tfw) as affected by vermicompost and vermiwash and their interaction

		Mean squares			
Source of varation	Df	Lfw	Sfw	Shfw	Tfw
Replication	2	0.09	0.001	0.08	0.113
Vermicompost	4	30.54***	3.31***	53.97***	116.9
Vermiwash	1	11.99***	0.48***	17.02***	37.82
VC*vw	4	2.88***	0.17***	3.51***	4.82
Error	18	0.14	0.001	0.14	0.16
Total	29				
CV(%)		10.52	5.2	9.04	5.3

** and *** indicates (p>0.05), highly significance(p<0.01),and very highly significant (p<0.001), CV =Coefficient of variance, DF= degree freedom

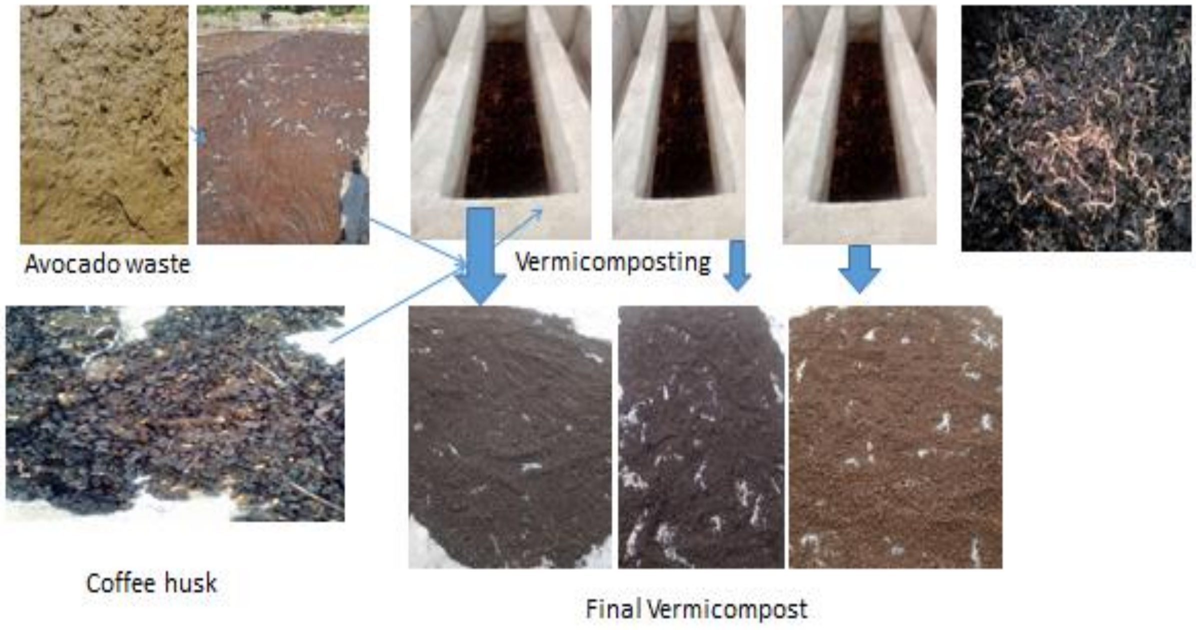
Appendix table 3.Analysis of variance of leaf dry weight (dw), stem dry weight(sdw),shoot dry weight(shdw),total dry weight (tdw) as affected by vermicompost and vermilwash and their interaction

Mean squares

Source of variation	Df	Ldw	Sdw	Shdw	Rdw	Tdw
Replication	2	0.003	0.00004	0.0035	0.00001	0.0036
Vermicompost	4	7.49***	0.34133***	11.0292***	0.3***	14.97***
Vermiwash	1	1.62***	0.10784***	2.5514***	0.08879***	3.59***
VC*VW	4	0.38***	0.01311***	0.5221***	0.00858***	0.6***
Error	18	0.006	0.00003	0.0057	0.00002***	0.0055
Total	29					
CV(%)		7.73	2.55	6.32	1.39	4.82

*** indicates very highly significance difference ($p<0.001$), CV =coefficient of variance, De = degree of freedom, VC= vermicompost, VW=vermiwash

8. APPENDIX FIGURES



Appendix figure 1.vermicompost preparation

Appendix figure 2. Method of vermiwash extraction

C

Appendix figure 3. Media preparation and experiment establishment

A B

Appendix figure 4. Seedling growth performance at mid(A) and final growth stage(B) of coffee seedlings

Appendix figure 5. Leaf area measuring and dry weight measuring

SKETCH OF BIOGRAPHY1

The author, Rahel Mengistu Amare was born on December 23, 1995 G.C at North Shewa. She attended her primary (1-8), secondary (9-10) and preparatory (11-12) school at Zewelde primary, Mojo secondary and preparatory school, respectively. After the completion of Ethiopian Higher Education Entrance Examination (EHEEE), she joined Jimma University in 2015 to pursue her first Degree and graduated with BSc Degree in Horticulture in July 2018 G.C. After her graduation, she had been employed as a junior researcher at Ethiopian institute of agriculture research. After serving two year at Wondogenet agricultural research center, she has got a chance to attend her Master's program and in 2020, she joined the Graduate program in Horticulture at Hawassa University.