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Effect of Integrated Use of Coffee Husk Compost and NPS Fertilizer on Soil Physicochemical Properties and Yield of Coffee (*Coffea arabica L.*) at Haru, Ethiopia

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Abstract: Integrated application of inorganic and organic fertilizers is the main sources for replenishing plant nutrients in agricultural soils. However, selecting the optimum combination of these resources based on soil type and crop species is necessary. In this context, field experiment was conducted at Haru research center to assess the effect of coffee husk Compost and NPS Fertilizer on soil physicochemical properties and Yield of coffee in 2018/2019. The treatments were the different rates of both compost and NPS fertilizers laid out in randomized complete block design. The results of the study showed that combined application of coffee husk compost and NPS fertilizers were improved soil moisture and total porosity over control, while, bulk density was decreased below the control. Combined application of coffee husk compost at (7.5 t ha^{-1}) and mineral NPS fertilizer at (50 kg ha^{-1}) has better improved yield of coffee crop. The experimental yield of Manasibu variety for present study from the station was 1.59 t ha^{-1}. Therefore, based on the result of the study it can be concluded that under condition of low soil pH of study area the availability of essential nutrients (e.g. P, N, K, Ca, Mg, and Mo) are critically affected. This indicates that the strong acid pH values at Haru Research sub-center require more attention. Moreover, the low levels of CEC, organic carbon, total nitrogen, and available P contents at study area soils confirm that soil fertility is among the constraints for sustainable coffee production in the Haru district. In response to this application of integrated NPS fertilizer and coffee husk compost with different rates improved soil physicochemical properties and coffee yield. The study recommended that the use of 7.5 t ha^{-1} coffee husk compost and 50 kg ha^{-1} of NPS fertilizer can be the best alternative integrated soil fertility management option in place of the sole application of inorganic fertilizers at study area tentatively. Nevertheless, in order to give conclusive recommendation further research studies are needed for more soil types and coffee crop varieties.

Keywords: Coffee Arabica, NPS Fertilizer, Organic Fertilizer, Growth, Yields

1. Introduction

Poor soil fertility is considered to be the major constraint to increased food production in most acid soils of Ethiopian high lands [1]. These situations have worsened by continuous cropping, nutrients mining and inadequate replacement of nutrients removed. In order to improve the fertility status of the soil, nutrient replenishment should be done. This is always done by applying chemical fertilizers. The use of inorganic fertilizers believed to alleviate the problem of decline in soil fertility; though it can increase crop productions for time being only. But coffee farm state plantation and local farmers have used mainly chemical fertilizers for long time which can cause degrading of soil. On the other hand, high cost of inorganic fertilizers and other agrochemicals along with cost of transportation make their use uneconomical for most smallholder farmers [2]. Similarly, Anteneh *et al.* [3] reported the timely unavailability of inorganic fertilizer and absence of credit system. To alleviate this problem of smallholder farmers with growing demands for sustainable agriculture the use of composting technology to excessively available coffee wastes (coffee husks) becoming inevitable for coffee producing areas [4].

Coffee waste product is one of the wastes, producing during coffee crop production, that have been studied by recycling through conventional and vermicomposting methods [5]. The coffee crop production at Haru district producing a large amount of coffee-products (coffee husk), amounting to about 500,000 tons per year are depositing without efficient use. However, when agricultural residues are deposited at higher doses, it could affect permeability and infiltration rate of the soils besides causing environmental pollution [6]. Coffee husk is normally burnt or covered on the coffee field of local farmers. Some farmers mix up coffee husk with manure, but this way showed less efficiency. Beside this, untreated coffee husk will spread diseases and pets to next crop. Currently there is a huge interest from regional and federal government to convert by products of coffee crop (for example coffee husk) into usable end products such as compost [7].

Adding inorganic fertilizer alone is not sufficient to retain a sufficient soil fertility status level. Moreover, in degraded soil where there is little organic matter, yield response is limited, even if artificial fertilizers are being used [8]. Beside this, coffee husk compost release nutrients very slowly to the plants. On other hand, nutrient content of compost is low compared to in organic fertilizers, so compost is usually applied at large rates. Nevertheless, applying large quantity of such material is difficult in smallholder farmers. Hence, an integrated approach, combining coffee husk compost and mineral fertilizer is better strategy for coffee crop production [9].

However, the present blended fertilizer recommendation did not consider the integrated soil fertility management practices such as inclusion of organic sources. In this view, integrated nutrient management approaches involving coffee husk and NPS blended fertilizers for coffee production need to be investigated as little information is available in the country. However, this research topic is still new in Haru district. Such information is a particular important input for coffee producing community and for land use planners in planning land management practices for sustaining the production and productivity of coffee at study area. So, there is a need to draw a mid-way between organic and inorganic extremities that may improve soil physicochemical properties and sustain coffee crop yield without deteriorating soil fertility in Western Wollega; by considering the nutrient dynamics with respect to agro ecological scenarios that would be helpful for further amendment of nutritional status in most of the coffee growing area. Keeping all these aspects in consideration, this study was initiated to assess the effect of combined application of coffee husk compost and NPS blended fertilizers on selected soil physicochemical properties and yield of coffee arabica in Haru research center.

2. Materials and Methods

2.1. Description of the Study Area

2.1.1. Location and Area Coverage

The study was conducted at Haru Agricultural Research Center which is located at a distance of 466 km from Addis Ababa within the Oromia National Regional State (ONRS). Haru Agricultural Research Sub-Center is found in Wara Baro Kebele Haru district in West Wollega Zone under Jimma Agricultural Research Center at latitude of 8°54'30"-9°5'30" North and longitude of 35°52'0"- 36°8'0" East. Haru district has 46,451.91 ha total cultivable land and the total area of land under cultivation at Haru Agricultural Research center is about 76 hectares [10] (Likasa, 2014).

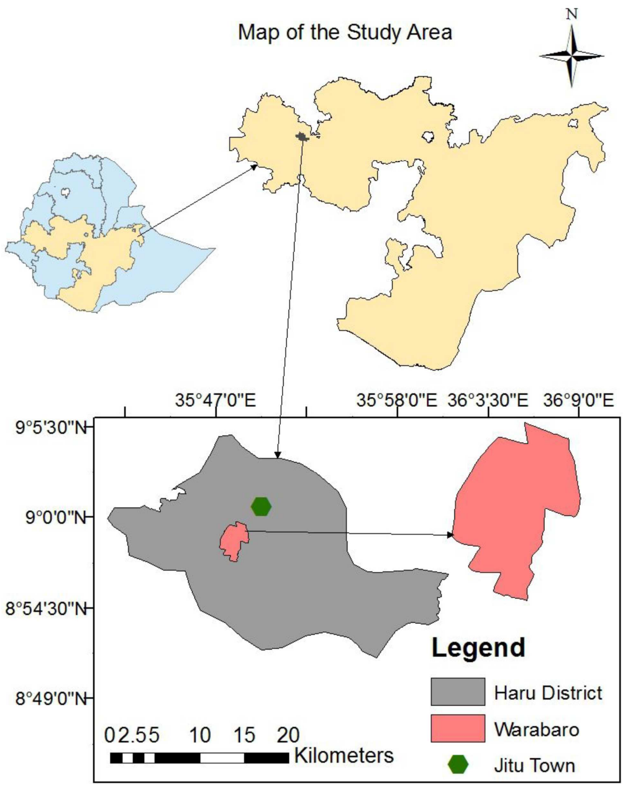

Figure 1. *Location map of study area.*

2.1.2. Climate and Topography

Haru agricultural research sub-center is characterized by unimodal rainfall pattern with an average annual rainfall of 1700 mm. The rainy season starts in March and ends on October and dry season is November to ends on February. It has the mean minimum and maximum temperature of 12.4 and 27.8°C, respectively [11]. The center consists of sub-humid tepid to cool mid highland coffee agro-ecological zone with altitude of 1750 meter. The topographic area of Haru district is highly variable, which reflects the past geological and erosion process. It consists of topographic patterns which include plateaus and steep hill slopes. More than 50% of coffee production at study area is found on land with slopes greater than 16% [12].

2.1.3. Soil Types and Geological Parent Materials

Most of coffee soils in the southwestern and southern region are classified as Nitisol, which are originated from highly weathered rock. Similarly, the dominant soil type in western Wollega Haru Research Sub-Center is also Nitisol which was formed from weathered acidic volcanic rocks parent materials [13].

2.1.4. Population, Land Use and Farming System

The total number of populations in Haru district is 93,600 from these 12,716 households are coffee producers (11,427 Male and 1,289 female). Haru district has 46,451.91 ha total cultivable land. Out of these the total land covered by coffee crop is 32,931 ha [14]. Traditional mixed crop livestock system that involves crop production and animal husbandry is the predominant farming system in the study area. The main crops grown in the study area are coffee, maize, sorghum and teff. The major livestock reared are cattle, poultry, sheep and goat. Inter crop, grazing and livestock production land use and traditional farming system are used in the Haru district. Oxen power is the main power source for ploughing and threshing activities in the study area.

2.2. Methods of Study

2.2.1. Compost Materials and Preparation Procedures

Coffee by products (coffee husk), farm yard manure (FYM), top soil, leguminous plant materials, fruit or vegetable wastes, stalk straw, leaves are materials that were used for compost preparation [15] (CCR, 2014). High quality compost was prepared from a mixture of 70% coffee pulp, 10% FYM, 10% leguminous plant materials and 10% top soil [16]. Pit site that drain easily so the pile never site in a pool of water was selected. Pit of the size 2 m length x 2 m width x 1.2 m height was prepared. Often, several pits were dig next to each other, to allow turning from one pit into the next [17].

Pits were formed and filled up with the residues as per composting procedures prepared by Cobo *et al*. [18]. Next compost materials were stacked in pit to form a pile. The stacking was done in way to permit drainage and ventilation (large size residues at bottom and fine residues to the top). A 20 cm layer of mixture was sprinkled with water for adequate moisture content (50%). Sprinkle water after each layer as required making the layers moist but not wet or soggy. Repeat the above step until your pile reaches the height of 120 cm. Forest soil was used to introduce beneficial microorganisms for decomposition. Cover the pit with broad leaves (like banana, enset) and grasses.

During compost processing at 21 days the materials were mixed and turned to next pit [19] (Dinesh *et al*., 2014). The compost was ready for use after three times turning (after 63 days) and after air drying [20]. Good decomposition can be detected by a pleasant odor, heat produced (this was even visible in the form of water vapor given off during the turning of the pile), growth of white fungi on the decomposing organic material, earthy smell, reduction of volume and by the change in color of the materials to brown. Finally, the composts prepared were air dried and incorporate compost to soil in the early spring at a depth of 2.5 cm–5 cm of compost into the top 7.5 cm–12.5 cm of soil. To determine the composition of the compost samples 10 g of samples were collected with four replicates from different spots in each pile for chemical analysis at Jimma Agricultural College of Agriculture and Veterinary Medicine Chemistry Research Laboratory.

2.2.2. Experimental Treatments and Design

The experiment was laid out in randomized complete block design with three replications. The treatment consists of combination of recommended coffee husk compost and NPS blended fertilizers recommended by Fekadu *et al*. [21] and ATA [22], respectively. The experiment consists of nine treatment combinations and 27 experimental units (plots). The following nine treatment combinations were evaluated.

Table 1. *Treatment combinations and their rates.*

Treatment	Treatment combinations (coffee husk compost in t ha^{-1} + NPS in kg ha^{-1}, respectively)
T1	10 + 0
T2	0 + 100
T3	2.5 + 100
T4	5 + 75
T5	5 + 50
T6	7.5 + 50
T7	7.5 + 25
T8	10 + 25
T9	0 + 0

2.2.3. Site Selection, Field Management and Experimental Procedures

Site selection, experimental lay out measurement were done and plots were leveled and the land was prepared by digging the hole size of 60 cm x 60 cm depth for coffee seedling transplantation. The total experimental area and area of each plot were 0.324 ha and 120 m^2, respectively. Spacing between plots and plants were 3 m and 2 m, respectively. The number of stand plants per each row was 5; while per each plot were 30. The soil samples before planting were taken to Jimma Agricultural Research Center laboratory for analyzes. Coffee seedling transplanting was done in 2015 using Manasibu coffee seed variety (high yielder than other varieties at the study area). After field transplanting of coffee seedlings all agronomic practice such as hoeing, weeding and sucker pruning were done by adopting the recommended agronomic practices of coffee production. NPS blended fertilizer and compost were broad casted by hand and thoroughly mixed with top soil near to the area of the canopy of the coffee plant in march at beginning of rainy season [23].

During the first year of coffee growth, no product was yielded by coffee tree; rather the tree directed all of its resources to develop a widely branched root system. At the end of second year, the coffee trees were partially ripened and a low yield was earned, about 1.5 kg of fresh cherries per tree. Complete and formal yield earning was started during the third year. At the end of third year, yield and yield components were harvested and soils were also taken from each plot and transported to Jimma College of Agriculture and Veterinary Medicine Chemistry Research Laboratory for analyses of nutrient contents after harvest in 2018/2019.

2.2.4. Soil Sampling and Preparation for Laboratory Analysis

In order to determine soil physicochemical properties, composite and undisturbed soil samples to a depth of 0-30 cm were randomly drawn from each experimental plot before planting and after harvesting [24]. To collect composite soil sample, disturbed samples were randomly taken from five different spots across each plot from a depth of 0-30 cm to make one composite sample. At the same time, core samples from 0-30 cm depth layer was also collected to determine soil bulk density of each plot. Soil samples were collected from the canopy of coffee tree, where fertilization is usually applied [25].

The collected soil samples were bagged, labeled and transported to the laboratory for preparation and analysis of soil properties. Sufficient amount of composite soil samples were air dried and ground to pass through a 2 mm sieve in preparation for the analyses of the selected physicochemical properties following standard laboratory procedures [26]. A portion of the disturbed soil samples were taken and sieved using 0.5 mm diameter for the determinations of organic matter and total nitrogen. Soil sample preparation and analysis was done at Jimma Agricultural College of Agriculture and Veterinary Medicine Chemistry Research Laboratory. The samples were analyzed for soil texture, dry bulk density, particle density, gravimetric soil water content, pH, available P and K, total N, organic carbon, exchangeable acidity, exchangeable basic cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}).

2.2.5. Laboratory Analysis

(i). Soil Physical Analysis

Particle size distribution was determined by the hydrometer method [27]. After determining sand, silt, and clay separates; the soil was assigned to textural classes using the USDA soil textural triangle [28]. Bulk density was determined using the core method as described by Jamison *et al*. [29]. Particle density (ρp) was determined using pycnometer method following procedures described in Rao *et al.* [30]. Total porosity was calculated from the values of bulk density and particle density using the method described by Rowell [31]. Soil moisture content was determined using gravimetric method as described by Reynolds [32].

(ii). Soil Chemical Analysis

Soil pH in water was determined by the glass electrode pH meter [33] at 1:2.5 soils to water ratios. To determine organic carbon, wet digestion method following the procedure of Walkley and Black [34] was employed. Total N content of the soil was determined using the modified Kjeldahl procedure [35]. The organic matter content of the soil was calculated by multiplying the organic carbon percentage by 1.724. Relative amount of carbon to nitrogen was determined by taking the ratio of soil organic carbon to total nitrogen. Available P was extracted using Bray II [36]. The P extracted with this method was measured by spectrophotometer following the procedures described by Murphy and Riley [37]. Available sulfur (SO_4-S) was determined using gravimetric determination following extraction with ammonium acetate (1N NH_4OAc) [38].

Furthermore, cation exchange capacity (CEC) and exchangeable bases (Ca, Mg, K and Na) were determined from soil samples extracted by ammonium acetate (1N NH_4OAc) at pH 7.0. Exchangeable potassium and sodium were determined from extract using flame photometer as described by Chapman [39] while calcium and magnesium was determined by atomic absorption spectrophotometer method [40]. The Cation exchange capacity was determined by the method described by Champan [41]. Exchangeable acidity (exchangeable Al^{3+} and H^{+} ions) was determined by saturating the soil samples with potassium chloride solution and titrated with sodium hydroxide as described by Mclean [42]. The percent base saturation (PBS) of the soil samples was calculated by taking the ratio of the sum of the basic exchangeable cations (Ca^{2+}, Mg^{2+} and Na^{+}) to CEC as percentage [43].

(iii). Compost Sampling and Analysis

To determine the composition of the coffee husk compost, samples of 10 g was taken with four replicates per each pile for chemical analysis. Compost samples was analyzed for the chemical parameters such as pH, OC, total N, total P, K and sulfur contents as per standard procedures formulated by Karltun *et al. [44]*. Cation exchange capacity and exchangeable bases (Ca, Mg, K and Na) were determined from compost samples extracted by ammonium acetate (1N NH_4OAc) at pH 7.0. Exchangeable potassium and sodium were determined from extract using flame photometer as described by Dzung *et al*. [45], while calcium and magnesium was determined by atomic absorption spectrophotometer [46].

2.3. Agronomic Data Collection

At Haru research center usually yield and growth parameters are collected when coffee cherry is fully ripening or when it is ready for picking. For coffee yields determination each cherry was picked at a time, collected in baskets, and transferred to bags by site worker, after which it was weighed and transported to wet processing.

2.4. Data Analysis

Analytically determined soil physicochemical and yield data were subjected to analysis of variance using GLM procedures of the Statistical Analysis System Software (version 9.3) [47]. Whenever the ANOVA detects significant differences ($P < 0.05$) between treatments, mean separation was conducted using Fisher's Least Significant Difference test [48]. Simple correlation analyses were also conducted to identify useful associations among key soil chemical parameters and coffee plant variables.

3. Results and Discussion

3.1. Physicochemical Properties of the Experimental Site Soil Before Planting

The laboratory results of the selected physicochemical properties of the soil sample taken before planting are presented in Table 2. The results indicated that the soil has 37%, 24%, and 39% sand, silt and clay, respectively, and could be categorized as clay loam textural class on the basis of Hillel [49] soil textural triangle. The particle density of the experimental area was 2.65 g cm^{-3} which might be due to dominance of quartz mineral. The result further revealed that soil pH of the experimental site was 5.10 (Table 2), found in strongly acidic ranges, on the basis of pH limit proposed by Hazelton and Murphy [50]. The ideal soil pH for coffee plant growth is pH 5.50 to 6.50 [51]. Nevertheless, this finding showed that the pH of study area soils is out of this normal pH range. Under such condition the availability of essential nutrients (for examples P, N, K, Ca, Mg, and Mo) are critically affected. Beside this, toxicity of aluminum to plants greatly affects crop growth as well as nutrients absorption. Similarly, Abebe *et al*. [52] reported the effect of Al toxicity on crop growth at Haru area.

According to the classification of soil total nitrogen (0.15%), Organic carbon (0.76%) and available P (1.04 ppm) (Table 2) suggested by Landon [53], the soils of study area are found in low range (Table 2). The average contents of basic cations (potassium (K), sodium (Na), magnesium (Mg) and calcium (Ca) in the soil were 0.02, 0.04, 2.33 and 4.56 cmol (+) kg^{-1}, respectively (Table 2). As per the rating set by FAO [54] (2006) the base cations of study area are classified as very low for K and Na, moderate for Mg and low for Ca. The low and very low values of basic cations at study area might be attributed to leaching of surface soils by excessive rainfall. Similarly, Kidanu and Achalu [55] reported the leaching of appreciable amounts of exchangeable basic ions like calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K) from the surface of soil by excessive rainfall.

The CEC of the soil was (11.53 cmol (+) kg^{-1}) which is found in low range according to Landon [56] (Table 2). The low CEC of the soil might be due to low organic matter content and high soil acidity. Soils with a low value of CEC generally have a low fertility status and a low resistance to changes in soil chemistry that could be caused by land management practices. This finding is in agreement with Amini and Mohammad [57] who reported low CEC due to low organic matter of study area soils. The C: N ratio of the study area soil was 11.61 (Table 2) and this value indicates that soil organic reserve of the area is well decomposed and mineral N can be released for coffee plant use. This finding is in agreement with Tesfaye *et al. [58]* who reported that C: N ratio less than 20:1 can release mineral N.

Table 2. *Mean values of selected soil physicochemical properties prior to planting.*

	Mean value
Soil physical properties	
Clay (%)	39
Silt (%)	24
Sand (%)	37
Textural class	clay loam
Soil chemical properties	
pH (H_2O)	5.10
EA (cmol (+) kg^{-1})	1.20
Organic carbon%	0.76
Total Nitrogen %	0.15
Available P (mg $kg-^{1}$)	1.04
Exchangeable Na^{+} (cmol (+) kg^{-1}) (([+]/kg)	0.04
Exchangeable Ca^{2+} (cmol (+) kg^{-1})	4.56
Exchangeable Mg^{2+} (cmol (+) kg^{-1})	2.33
Exchangeable K^{+} (cmol (+) kg^{-1})	0.02
CEC (cmol (+) kg^{-1})	11.53
C:N ratio	11.61

CEC= cation exchange capacity; C: N= carbon to nitrogen ration; pH = power of hydrogen; EA = Exchangeable acidity.

Table 3. *Mean values of compost chemical properties.*

Chemical properties	Mean values of nutrient Concentrations
pH (H_2O)	8.96
Organic carbon %	12.48
Total Nitrogen %	1.77
Total P (mg/$kg-^{1}$)	47.75
Na^{+} (cmol (+) kg^{-1})	0.83
Ca^{2+} (cmol (+) kg^{-1})	22.45
Mg^{2+} (cmol (+) kg^{-1})	4.31
K^{+} (cmol (+) kg^{-1})	9.55
CEC (cmol (+) kg^{-1})	41.62
C:N ratio	11.73

CEC= cation exchange capacity; C: N = carbon to nitrogen ration; pH = power of hydrogen.

3.2. Chemical Composition of Compost

Chemical composition of the compost utilized as organic source in the study area are presented in (Table 3). The results of the analysis revealed that the compost contained the mean organic carbon and total nitrogen contents of 12.48% and 1.76%, respectively, with a resultant narrow C: N ratio of about 11.73 (Table 3). The narrow carbon to nitrogen ratio in the organic nutrient source indicates that the compost is well decomposed and matured [59]. The average pH (1:2.5 H_2O) reading of the compost was 8.96, which is alkaline in reaction. The concentration of total P in the compost was 47.75 ppm. In addition to this, the average concentrations of the exchangeable bases of compost were 22.45, 9.55, 4.31 and 0.83 cmol (+) kg^{-1}) for Ca, K, Mg and Na, respectively. Similarly, CEC of the compost was 41.62 (cmol (+) kg^{-1}) (Table 3).

3.3. Effect of Compost and NPS Fertilizer on Soil Physicochemical Properties After Planting

3.3.1. Effect of Compost and NPS Fertilizer on Soil Physical Properties

Bulk density, moisture content and total porosity of the post-harvest soil were presented in (Table 4).

(i). Bulk Density

The mean soil bulk density showed significant ($P < 0.05$) variation among the different treatments applied (Table 4). The maximum bulk density (1.24g.cm^{-3}) was obtained in control plots, while, the lowest bulk density (1.16g.cm^{-3}) was recorded in plots with 10 t coffee husks compost ha^{-1}. The relatively lowest bulk density recorded for plots with 10 t coffee husks compost ha^{-1}might be due to organic matter effect which can be evidenced by negative correlation (r = -0.30) between bulk density and organic matter (Table 7). Similarly, Tesfaye *et al*. [60] reported the inverse relationship between soil bulk density and organic matter content.

(ii). Porosity

The different rates of NPS fertilizer and coffee husk compost significantly ($p < 0.05$) affected total porosity of soil. The maximum porosity (56.10%) was obtained from application of 10 t coffee husk compost ha^{-1}. The minimum total porosity (53.00%) of soil was recorded in control plot (Table 4). The highest value of total porosity from full doze of coffee husk compost ha^{-1} might be due to corresponded higher organic matter contents and lower bulk density values of this plot. The finding is in agreement with Tamado and Mitiku [61] who reported that the highest total porosity was obtained from relatively highest FYM.

Table 4. *Effect of compost and NPS Fertilizer on selected soil physical properties.*

Treatments	Bulk density (g/cm^3)	Moisture Content (%)	Total porosity (%)
T1	1.16^{d}	45.60^{a}	56.10^{a}
T2	1.23^{ab}	41.30^{bc}	54.00^{bc}
T3	1.22^{abc}	42.60^{b}	54.00^{bc}
T4	1.22^{abc}	43.30^{ab}	54.00^{bc}
T5	1.20^{bc}	43.00^{ab}	55.00^{ab}
T6	1.19^{cd}	45.50^{a}	55.10^{ab}
T7	1.19^{cd}	41.60^{bc}	55.12^{ab}
T8	1.21^{abc}	43.60^{ab}	54.00^{bc}
T9	1.24^{a}	39.60^{c}	53.00^{c}
LSD (5%)	0.029	1.65	0.015
CV (%)	1.63	3.68	1.59

LSD = least significant difference; CV = coefficient of variation; numbers followed by the same letter in the same column are not significantly different at 5% probability level.

(iii). Soil Moisture Content

Soil moisture content was significantly ($P < 0.05$) affected by the different treatments applied. The maximum soil moisture content (45.60%) was obtained from application of 10 t coffee husk ha^{-1} while, the minimum soil moisture content was recorded in control plots (39.60%) (Table 4). The maximum soil moisture content might be due to the presence of organic matter supplied to soil in optimum amount to increase soil moisture content. Similarly, Islam *et al. [62]* reported increment in soil water content as a result of application of FYM.

3.3.2. Effect of Compost and NPS Fertilizer on Soil Chemical Properties

(i). Soil pH

Soil pH is the most important master chemical soil parameter and it reflects the overall chemical status of the soil and influences a whole range of chemical and biological processes occurring in the soils [63]. Soil pH was significantly ($P < 0.05$) and highly affected by applied NPS and coffee husk compost (Table 5). The highest soil pH (5.58) was recorded from application of 10 t coffee husk compost ha^{-1} alone followed by the application of 100 kg NPS ha^{-1} (5.11). While, the lowest soil pH (4.92) was obtained from control plot (Table 5). The result revealed improvement in soil pH by 11.82% (4.92 to 5.58) (Table 5). The increment of soil pH might be ascribed to the alkalinity of applied compost as noted from its high pH value (Table 3). Similarly, increase in soil pH due to the application of composts with high pH value was also reported by Kasongo *et al. [64]*.

(ii). Soil Organic Matter

The use of organic materials is an important component for sustainable agricultural production. Soil organic matter was significantly ($P < 0.05$) affected by application of NPS fertilizer and coffee husk compost (Table 5). The application of amendments with various levels increased soil organic matter over the control treatment (Table 5). The highest soil organic matter (6.99%) was recorded from application of 10 t ha^{-1} coffee husk compost. Whereas, the lowest soil organic matter (2.73%) was recorded from control plots. The increase in soil organic matter following application of compost might be attributed to the high content of organic matter in the coffee husk compost (Table 2). In line with this, finding Tesfaye *et al*. [65] also reported increase in soil organic matter following application of filter cake compost, filter cake and vinasse to soils.

(iii). Soil Total Nitrogen

Total soil nitrogen was significant ($P < 0.05$) affected by the treatments (Table 5). The highest soil total nitrogen (0.35%) was recorded from application of 10 t coffee husk compost ha^{-1}. The lowest soil total nitrogen (0.14%) was obtained from the control plots. The highest soil total nitrogen recorded from 10 t coffee husk compost ha^{-1} might be due to releasing of N from organic matter as a result of mineralization. This can be confirmed from highly significant positive correlation (r = 0.99) between total nitrogen and organic matter (Table 7). This finding is in agreement with Argaw [66] who reported direct association between total N content of a soil and organic carbon (OC) content.

(iv). Soil Available Phosphorus

Soil available phosphorus was significantly ($P < 0.05$) affected by NPS fertilizer and coffee husk compost (Table 5). Application of 10 t ha^{-1} coffee husk compost gave highest available phosphorus (11.24 ppm), while, the lowest soil available phosphorus (3.56 ppm) was obtained from the control plot (Table 5). The available phosphorus recorded for compost applied plot is beyond the critical level of available P (8 mg kg^{-1}) for Ethiopian soils reported by Tekalign and Haque [67]. The highest available phosphorus for compost plots might be due to increased soil pH as a result of coffee husk compost rates applied than applied inorganic fertilizer. The finding is in agreement with Anwar [68] who suggested increase in available P contents as result of applied coffee husk compost. Similar study by Nduka *et al. [69]* also reported that coffee husk compost could release organic substances that can form complex with ions of Fe and Al in soil solution consequently prevents phosphorus fixation.

(v). Soil Available Sulfur

Soil available sulfur was significantly (P < 0.05) affected by the different treatments (Table 5). Application of 75 kg NPS ha^{-1} + 5 t coffee husk compost ha^{-1} gave highest record (9.68 ppm) followed by 9.41 ppm from 50 kg NPS ha^{-1} +7.5 t coffee husk compost ha^{-1} (Table 5). While, the lowest value (6.84 ppm) was recorded in control plots. This could be one indication that moderate applications of coffee husk compost and NPS fertilizer supply adequate soil sulfur levels to soil. The values of Sulfur gained from the treatments are consistent with recommendation by Tisdale *et al.* [70] which stated concentrations of 3 to 5 ppm or more SO_4^{2-} in the soil solution is adequate for the growth of many plant species.

(vi). Exchangeable Acidity

The exchangeable acidity was significant (*P* < 0.05) and affected by different between treatments (Table 5). The highest soil exchangeable acidity values were recorded from both application of 100 kg NPS ha^{-1} alone (2.30 cmol (+) kg^{-1}) as well as from the control (2.30 cmol (+) kg^{-1}) (Table 5). While, the least exchangeable acidity was gained from the treatment of 25 kg NPS ha^{-1} + 10 t coffee husk compost ha^{-1} (1.81 cmol (+) kg^{-1}). The results were similar with Abdana (2013) who reported the mean soil exchangeable acidity of from West Wollega zone (3.84-1.98 cmol (+) kg^{-1}). This might be due to an increment of soil pH, that reduce exchangeable acidity and negatively correlated with pH (r = -0.85**) (Table 7). Similarly, other researchers were reported that Soil pH progressively increased while the exchangeable acidity decreased with increased rates of compost and lime [71] (Ayodele and Shittu, 2014).

Table 5. *Mean value of some soil chemical properties as affected by NPS and compost of coffee husk.*

Treatments	pH-H_2O	E.A (cmol (+) kg^{-1})	OM (%)	TN (%)	Ava. P (ppm)	Ava. S (ppm)
T1	5.58^{a}	1.65^{de}	6.99^{a}	0.35^{a}	11.24^{a}	8.22^{b}
T2	5.11^{bc}	2.30^{a}	5.31^{cd}	0.26^{cd}	9.91^{bc}	8.85^{ab}
T3	4.93^{d}	2.21^{ab}	4.88^{d}	0.24^{d}	10.45^{bc}	8.35^{bc}
T4	4.97^{cd}	2.15^{b}	6.41^{ab}	0.32^{ab}	10.57^{ab}	9.68^{a}
T5	5.01^{cd}	2.60^{bc}	5.67^{bcd}	0.28^{bcd}	10.27^{bc}	8.97^{ab}
T6	5.21_{b}	1.83^{c}	5.83^{bc}	0.29^{bc}	10.24^{bc}	9.41^{ab}
T7	5.21^{b}	1.81^{cd}	6.32^{ab}	0.32^{ab}	9.82^{c}	8.38^{b}
T8	5.46^{a}	1.61^{e}	5.94^{bc}	0.29^{bc}	10.42^{bc}	8.91^{ab}
T9	4.92^{d}	2.30^{a}	2.73^{e}	0.14^{e}	3.56^{d}	6.84^{c}
LSD (5%)	0.045	0.03	0.84	0.044	0.68	1.22
CV (%)	1.58	4.20	8.728	9.05	4.11	8.18

EA= Exchangeable acidity; TN= total nitrogen; Ava. p= available phosphorous; Ava. S= Available sulfur; Mean values within a row or column followed by the same letter(s) are not significantly different from each other at P ≤ 0.05.

(vii). Cation Exchange Capacity

The cation exchangeable capacity of the soil was showed significant (*P* < 0.05) difference with the application of NPS fertilizer and coffee husk compost (Table 6). Maximum CEC (17.26) cmol (+) kg^{-1}) was obtained from application of 10 t coffee husk compost ha^{-1} (Table 6). While, the least CEC (10.80 cmol (+) kg^{-1}) of soil was gained from control plots (Table 6). As per the rating set by Landon (1991), the highest and lowest CEC of this experiment are classified as medium and low range, respectively. The increase in CEC over the control might be due to the increase in OM contents and available nutrients with the applied organic fertilizers. This can be evidenced with positive and significant correlation (r = 0.66**) between CEC and organic carbon (Table 7). Similarly, Samuel *et al*. [72] reported direct correlation between organic matter and cation exchange capacity.

(viii). Exchangeable Bases

The exchangeable calcium showed highly significant (*P* < 0.05) difference with the application of NPS and coffee husk compost (Table 6). Highest exchangeable calcium (11.10) (cmol (+) kg^{-1}) result was recorded from the application of 10 t coffee husk compost ha^{-1}, while, the lowest value (7.15 (cmol (+) kg^{-1}) was obtained from the control plots (Table 6). This increment might be due to Ca^{2+} availability from compost applied to soil. Similarly, Asha and Devanna [73] reported higher exchangeable Ca^{2+}content supplied to soil as a result of releasing from mineralization of the compost.

The soil exchangeable magnesium also showed significant (*P* < 0.05) difference with the different treatments (Table 6). The maximum mean soil exchangeable magnesium (2.46 cmol (+) kg^{-1}) was recorded from the application of 10 t coffee husk compost ha^{-1}. While the lowest exchangeable Mg^{2+} value (2.24 cmol (+) kg^{-1}) was obtained from control (Table 6). This increment might be due to increase in Mg^{2+} availability through increasing pH as a result of the alkalinity of applied compost. This finding is in agreement with Samake [74] who reported increase in Mg^{2+} in the soil as a result of applied manure and improved soil pH.

The soil exchangeable potassium showed significant (*P* < 0.05) difference with the application of NPS and decomposed coffee husk to soil (Table 6). The maximum mean soil exchangeable potassium (0.94%) was recorded from the application of 10 t coffee husk compost ha^{-1} followed by 0.89% from application of 25 kg NPS ha^{-1} + 10 t coffee husk compost ha^{-1} rate on soil. The lowest exchangeable K^{+} value (0.42%) was obtained from control plots (Table 6). The increase in exchangeable K^{+} over the control might be due to exchangeable K^{+} released to soil through mineralization from coffee husk compost. In line with this, Kasongo *et al. [75]* reported increase in soil exchangeable K^{+} as a result of coffee husk compost applied to tropical acid soils.

The soil exchangeable sodium showed significant ($P < 0.05$) difference with the application of NPS and coffee husk compost (Table 6). The highest soil exchangeable sodium value (0.056 cmol (+) kg^{-1}) was obtained from 10 t ha^{-1} followed by (0.053 cmol (+) kg^{-1}) from application of 100 kg ha^{-1} NPS fertilizer. The lowest soil exchangeable sodium (0.039 cmol (+) kg^{-1}) was from control plots. The increment of exchangeable Na^+ over the control by 10 t decomposed coffee husk ha^{-1} might be due to added (Na^+) from decomposed coffee husk to soil. This finding is in agreement with Chaves *et al.* [76] who reported the increment of exchangeable Na^+ from application of compost to soils.

Table 6. *Mean value of soil CEC, exchangeable bases (Ca, Mg, K and Na) and PBS as affected by NPS and compost.*

Treatments	CEC (cmol (+) kg^{-1})	Ca (cmol (+) Kg^{-1})	Mg (cmol (+) kg^{-1})	K (cmol (+) kg^{-1})	Na (cmol (+) kg^{-1})	PBS (%)
T1	17.26^{a}	11.10^{a}	2.46a	0.94^{a}	0.056^{a}	92.54^{a}
T2	15.50^{b}	9.33^{b}	2.43^{abc}	0.56^{c}	0.053^{a}	80.10^{d}
T3	16.05^{b}	9.36^{b}	2.43^{abc}	0.76^{b}	0.047^{b}	91.10^{ab}
T4	15.51^{b}	9.30^{b}	2.45^{a}	0.56^{c}	0.046^{bc}	82.10^{cd}
T5	13.80^{c}	8.90^{bc}	2.33^{d}	0.49^{cd}	0.045^{bc}	85.30^{bcd}
T6	11.90^{d}	8.01^{cd}	2.35^{cd}	0.56^{c}	0.043^{bcd}	81.94^{cd}
T7	15.40^{b}	9.21^{b}	2.42^{bcd}	0.51^{c}	0.043^{bcd}	79.43^{d}
T8	13.76^{c}	8.80^{bc}	2.36^{bcd}	0.89^{a}	0.044^{bc}	87.90^{abc}
T9	10.80^{d}	7.15^{d}	2.20^{e}	0.42^{d}	0.039^{d}	78.74^{c}
LSD (5%)	1.09	0.85	0.09	0.07	0.0038	0.56
CV (%)	4.6	7.6	2.31	7.17	5.74	4.86

CEC = Cation exchange capacity: Ca = Calcium: Mg: Magnesium: K = Potassium: Na = Sodium: PBS= Percent of Base Saturation, Numbers Followed by same letter in the same column are not significantly different at 5% probability level.

3.4. Effect of Coffee Husk Compost and NPS Fertilizer on Yield of Coffee

The effect of NPS fertilizer and decomposed coffee husk rates showed significant ($p < 0.05$) difference on yields of coffee (Figure 2). The highest 1.59 t ha^{-1} mean yield was obtained with the application of fertilizers combined from application of 50 kg NPS ha^{-1} + 7.5 t coffee husk compost ha^{-1} followed by mean 1.48 t ha^{-1} clean coffee yield recorded from application of 75 kg NPS ha^{-1} + 5 t coffee husk compost ha^{-1}. The lowest 0.56 t ha^{-1} yield was obtained from the control without any fertilizer amendment (Figure 2). The combination of coffee husk compost at 7.5 t ha^{-1} and mineral NPS fertilizer at 50 kg ha^{-1} application were the highest promise for coffee yields and about 64.70% coffee yield increase over the control.

The highest yield from compost integrated with NPS fertilizer plot over the control might be attributed to extraction of large quantity of mineral nutrients of coffee crop from sufficient available nutrients supplied to soil by compost and blended fertilizers. Similarly, Chemura *et al.* [77] stated that incorporation of organic and inorganic fertilizers improved soil physical property and nutrient availability that may have a direct effect on coffee crop growth and yield attributes. Combined applications of coffee husk compost and NPS chemical fertilizers are more effective than sole application of coffee husk compost or NPS blended fertilizers for sustainable coffee productivity enhancement.

Moreover, there was significant positive correlation among coffee yield and soil OC, total N, and available P contents (r = 0.63**, 0.62**, 0.83**), respectively. The positive correlations among coffee yield and soil total N, available P and OC status indicates that the soil nutrient status may affects coffee yield and yield components directly. However, soil bulk density decreased due to application of organic fertilizer and showed a negative correlation (r = -0.22) with coffee yield (Table 7). This indicates that incorporating combination of coffee husk compost and blended NPS fertilizers in the soil not only improved the nutrient status, but also resulted in good physical conditions of the topsoil and thus, significantly favored optimum shoot and root growth parameters and thus, enhanced nutrient use efficiency by the coffee crop with ultimate increased coffee yield and coffee crop productions. Similarly, Wairegi *et al.* [78] also reported that coffee yields can only be enhanced and sustained by the addition of integrated form of compost and mineral fertilizers.

Table 7. *Pearson correlation coefficients among some soil chemical properties, yield and Growth parameters.*

	Yld	pH	EA	OC	Nt	Av.P	CEC	BD
Yld	1							
pH	0.40ns	1						
EA	-0.30	-0.85	1					
OC	0.63**	0.56**	-0.57	1				
TN	0.62**	0.56**	-0.57	0.99**	1			
Av.P	0.83**	0.41*	-0.40	0.83**	0.82**	1		
CEC	0.57**	0.23**	-0.15	0.66**	0.65**	0.76**	1	
BD	-0.218	-0.17	0.18	-0.30	-0.29	-0.28	-0.16	1

EA = Exchangeable Acidity; OC = Organic Carbon; TN = Total Nitrogen; Av. P = Available Phosphorus; Av. Sulfur; CEC = Cation Exchangeable capacity; yld = yield; Ht = plant height; ns = non-significant; * =significant at $p \leq 0.05$; **= highly Significant at $p \leq 0.01$.

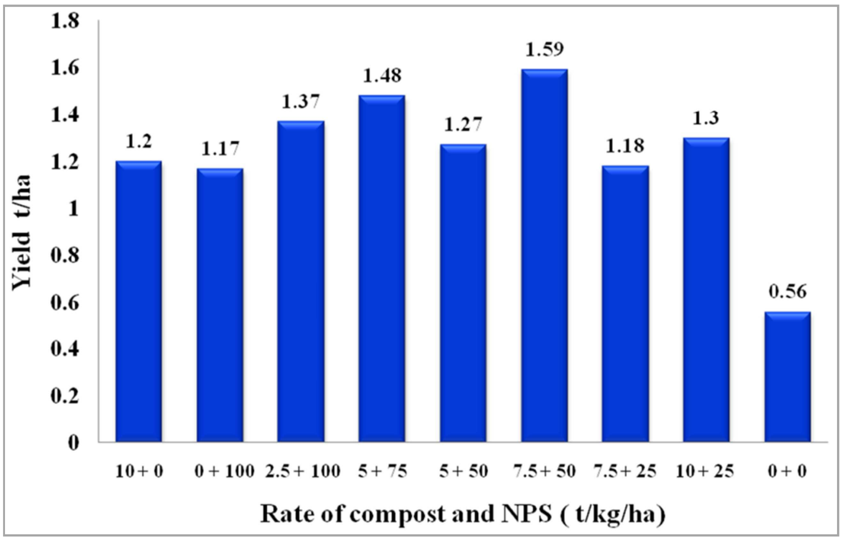

Figure 2. *Effects of compost and NPS fertilizer on coffee yields.*

4. Conclusions and Recommendations

4.1. Conclusions

The results of this study showed that the soil has 37%, 24%, and 39% sand, silt and clay, respectively, and categorized as clay loam textural class. Soil pH (5.1) of the experimental site was out of normal range for coffee crop production. Fertility limiting factors such as soil organic carbon (0.76%), total nitrogen (0.15%), available P (1.04 ppm) and CEC (11.53 cmol (+) kg^{-1}) of the soil were found in low range. The field study result revealed that combined application of coffee husk compost and NPS fertilizers were improved soil moisture and total porosity over control, while, bulk density was decreased below the control. The alkalinity of applied compost caused increment of soil pH after treating the plots by coffee husk compost. Moreover, the application of coffee husk compost along with inorganic fertilizers increased the contents of organic matter, total nitrogen, available phosphorus, available sulfur, exchangeable basis and CEC. Applying combined form of coffee husk compost at 7.5 t ha^{-1} and mineral NPS fertilizer at 50 kg ha^{-1} gave coffee yield of 1.59 t ha^{-1}.

Therefore, based on the result of the study it can be concluded that under condition of low soil pH of study area the availability of essential nutrients (e.g. P, N, K, Ca, Mg, and Mo) are critically affected. Beside this, toxicity of aluminum to plants greatly affects crop growth as well as nutrients absorption. This indicates that the strong acid pH values at Haru area require more attention. Moreover, the low levels of CEC, organic carbon, total nitrogen, and available P contents at study area soils confirms that soil fertility is among the constraints for sustainable coffee production in the Haru district. In response to this application of integrated NPS fertilizer and coffee husk compost with different rates improved soil physicochemical properties and yield coffee crop. Nevertheless, the potential coffee productivity in the area has not yet been exploited. Alleviating the soil fertility problems of the soils of study area through integrated application of local available coffee husk compost and blended NPS fertilizer could be one option to reduce the yield gap.

4.2. Recommendation

Based on the findings and conclusions of this study the following recommendations are given:

1) Soil management practices that can increase low soil fertility status and soil pH are important at Haru area.
2) This study suggested that the use of 7.5 t ha^{-1} coffee husk compost and 50 kg ha^{-1} of NPS fertilizer can be the best alternative integrated soil fertility management option in place of the sole application of inorganic fertilizers at study area tentatively.
3) Nevertheless, in order to give conclusive recommendation further research studies are needed for more soil types and coffee crop varieties.

Conflict of Interests

The authors declare that they have no competing interests.

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References

[1] Zelleke Gete, Getachew Agwgnehu, Dejene Abera and Shahid Rashad, 2010. Fertilizer and Soil Fertility Potential in Ethiopia: Constraints and opportunities for enhancing the system. Working Paper, International Food Policy Research Institute. http://www.Ifpri.org/sites/default/files/publications/Ethiopianagsectorwp_soil.pdf.

[2] IFPRI (International Food and Policy Research Institute), 2010. Fertilizer and Soil Fertility Potential in Ethiopia. Constraints and opportunities for enhancing the system.

[3] Anteneh Netsere, Solomon Endris, Ashenafi Ayano and Berhanu Mulatu, 2010. *Coffee Production Potentials and Constraints in Daro labu District of West Hararge Zone*. Research Report 83, Addis Ababa, Ethiopia Institute of Agricultural Research.

[4] Chemura, Abel, 2014. The growth response of coffee (*Coffea Arabica* L.) plants to organic manure, inorganic fertilizers and integrated soil fertility management under different irrigation water supply levels. *International Journal Recycling Organic Waste Agriculture,* 3, 1-9.

[5] Adi, A. J., Noor, Z. M., 2009. Waste recycling: Utilization of coffee grounds and kitchen waste in vermi-composting. *Bio Resource Technology*, 2, 1027-1030.

[6] Nguyen Anh Dzung, Tran Trung Dzung, and Voi Thi Phuong Khanh, 2012. Evaluation of Coffee Husk Compost for Improving Soil Fertility and Sustainable Coffee Production in Rural Central Highland of Vietnam, *Journal of Resources and Environment*, 3, 77- 82.

[7] Gezahegne Barecha, Fikre Lamessa and Mulatu Wakjira, 2011. Exploring the suitability of coffee pulp compost as growth media substitute in greenhouse production. *International Journal Agriculture Research*, 6, 255-267.

[8] Madeleine I., Peter S., Tim T. and Tom V., 2005. Agrodok no. 8: The preparation and use of compost. Agronomic Foundation, Wagenningen, Digigrafi, the Netherlands.

[9] Vanlauwe B, Bationo A, Chianu J, Giller K. E, Merck R, Mokwunye U, Ohiokpehai O, Pypers P, Tabo R, Smaling E, Woomer P. L. and Sanginga. N., 2010. Integrated soil fertility management: Operational definition and consequences for implementation and dissemination. *Out on Agriculture*, 39, 17–24.

[10] Likassa Ebisa, 2014. Effect of Dominant Shade Trees on Coffee Production in Manasibu District, West Oromia, Ethiopia. *Science, Technology and Arts Research Journal*, 3, 18-22.

[11] Bikila Takala, 2018. *Effects of Lime and Compost on acidic Soil Amelioration and Growth of Coffee (Coffea Arabica L.) Seedlings at Haru, West Wollega*. M.Sc. Thesis Submitted to School of Graduate Studies of Jimma University College of Agriculture and Veterinary Medicine, Department of Natural Resource Management.

[12] Zarihun Kebebew, 2013. Coffee Based Rehabilitation of degraded land; the case of Haru district, West Oromia, Ethiopia. *American Eurasian Journal of Agricultural Research,* 13, 907 - 913.

[13] Abayneh Melke and Fisseha Ittana, 2015. Nutritional Requirement and Management of Arabica Coffee (*Coffea arabica L.*) in Ethiopia National and Global Perspectives, College of Natural Sciences, Department of Plant Biology and Biodiversity Management, Addis Ababa University. *American Journal of Experimental Agriculture*, 5, 400 - 418.

[14] Dejen Yemane, Abebe Beyene, Hailu Taffere, Addis Waste and Azeb Gebresilassie, 2015. Effect of coffee processing plant effluent on the physicochemical properties of receiving water bodies, Jimma zone Ethiopia. *American Journal of Environmental Protection*, 4, 83-90.

[15] Central Coffee Research Institute, 2014. Coffee Guide; Central Coffee Research Institute, Coffee Research Station: Chikm agalur District, Chikmagalur, India.

[16] Solomon Endris, 2006. Accelerated composting of coffee processing by products: an organic option for soil fertility management in the coffee based cropping system of south western Ethiopia. Proceeding of 21st International scientific conference on coffee science (ASIC), Montpelier, France, 1084-1089p.

[17] Gershuny Grace, 2011. Compost, Vermicompost, and Compost Tea: Feeding the Soil on the Organic Farm. White River Junction, VT: Chelsea Green Publishing.

[18] Cobo, J., Dercon, G. and Cadisch, G., 2010. Nutrient balances in African land use systems across different spatial scales: a review of approaches, challenges and progress. *Agriculture, ecosystems and environment*, 136, 1-15.

[19] Dinesh Kumar, Mahesh wari, Shrivardhan Dheeman and Mohit Agarwal, 2014. Decomposition of Organic Materials into High Value Compost for Sustainable Crop Productivity. Gurukul Kangri University, Haridwar, India. Composting for Sustainable Agriculture, *Sustainable Development and Biodiversity,* 4, 245-267.

[20] Tra Thi thong, 2013. *Compost Effect on plant Growth*. M.sc. A thesis submitted to University of Adelaide.

[21] Fekadu Sh, Brandon, M. G. Franke, I. H., Praehauser, B., Insam, H. and Fassil A., 2014. Coffee husk composting: An Investigation of the Process Using Molecular and Non-Molecular Tools. *Waste Management*, 34, 642–652.

[22] Agricultural Transformation Agency (ATA), 2013. Status of soil resources in Ethiopia and priorities for sustainable management. Nirobi, Kenya.

[23] Anteneh Netsere, Taye Kufa and Tesfaye Shimber, 2015. Review of Arabica Coffee Nursery Management Research in Ethiopia. *Journal of Biology, Agriculture and Healthcare,* 13, 2224-3208.

[24] Daniel Capa, Javier Pérez-Esteban and Alberto Masaguer, 2015. Un-sustainability of recommended fertilization rates for coffee monoculture due to high N_2O emissions. *Agronomy for Sustainable Development*, 35, 1551–1559.

[25] Sousa J. S, Neves J. C. L, Martinez H. E. P and Alvarez, V. H., 2018. Relationship between coffee leaf analysis and soil chemical analysis. *Reversa Brasia science,* 42, 1-14.

[26] Sahlemedhin Sertsu and Taye Bekele, 2000. Procedures for soil and plant analysis. National Soil Research Centre, Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia. 110p.

[27] Bouyoucos, J., 1962. Hydrometer method improved for making particle size analysis of soil *Agronomy Journals,* 5, 464-465.

[28] Survey Staff, 1999. Soil Taxonomy. A basic system of soil classification for making and interpreting soil surveys. Second edition. Agriculture Handbook 436. Washington, DC, USDA. 886p.

[29] Jamison, V. C., Weaver, H. H. and Reed, I. F. 1950. A hammer driven soil core sampler. *Soil Science,* 6, 487–496.

[30] Rao's, D. V. K. Nageswara Vijayakumar and K, R., 2005. Effective soil based recommendation. International Natural Rubber Conference, India.

[31] Rowell, D. L., 1994. Soil Science: Methods and application. Addison Wesley Longman, Limited, England.

[32] Reynolds, S. G., 1970. The gravimetric method of soil Moisture determination method South Pacific Regional College of Tropical Agriculture Alfua Westren Samoa. *Journal of Hydrology,* 11, 258-273.

[33] Page, A. L., 1982. Methods of soil analysis Part 2. Dordrecht, the Netherlands, Chemical and micro biological properties Press Publishers. 481–509p.

[34] Walkley, A. and Black, I. A., 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science*, 37, 29 - 38.

[35] Jackson, M. L, 1958. Soil Chemical Analysis. USA, Englewood Clifs, N. J., Prentice Hall. 498p.

[36] Bray, R. H and Kurtz, L. T., 1945. Determination of total, organic and available forms of phosphorus in soils. *American Soil Science Society,* 1, 36-45.

[37] Murphy, J and Riley, J. P., 1962. A modified single solution method for the determination of phosphorus in natural waters. *Analytical Chimical Acta,* 27, 31-36.

[38] Warman, P. R. and Sampson, H. G., 1992. Evaluation of soil sulfate extractants and method of analysis for plant available sulfur. *Communication in Soil Science and Plant Analysis*, 7, 793-803.

[39] Chapman, H. (1965). Cation exchange capacity by ammonium saturation. 9: Inc 891-901. Black, C., Ensminger, L and Clark, F. (Ed.), *Method of soil analysis*. *American Society of Agronomy,* Madison Wisconsin, USA.

[40] Hesse, P. R., 1972. A textbook of soil chemical analysis., London, Great Britain. John Murry Limited, 470p.

[41] Champan, H. D., 1965. Cation exchange capacity by ammonium saturation. Methods of Soil Analysis. Agronomy. Part II, *American Society of Agronomy*. Madison, Wisconsin, 9, 891-901.

[42] Mclean, E. O., 1965. Aluminum in Methods of Soil Analysis. American Science Agronomy Madison, Wisconsin, 978 – 998p.

[43] Barauah, T. C. and Barthakulh, H. P., 1997. A text book of soil analyses. New Delhi, Vikas Publishing House Pvt. Ltd., 334p.

[44] Karltun E, Tekalign Mamo, Taye Bekele, Samuel Gameda and Selamyihun Kidanu, 2013. Towards improved fertilizer recommendations in Ethiopia nutrient indices for categorization of fertilizer blends from Ethiopian Soil Information System (Ethio-SIS) District Soil Inventory Data: A Discussion paper, Addis Ababa, Ethiopia.

[45] Dzung, N. A., Dzung, T. and Khanh, V. T. P., 2013. Evaluation of Compost for Improving Soil Fertility and Sustainable Coffee Production in Rural Central Highland of Vietnam. *Resources and Environment, 3*, 77-82.

[46] Okalebo, J. R., K. W. Gathua and P. L. Womer, 2002. Laboratory Methods of Soil and Plant Analyses. A Working Manual, 2 ed. TSBF-CIAT and SACRED nd Africa, Nairobi, Kenya.

[47] SAS Institute Inc. 2013. SAS 9.3 Macro Language: Reference. Cary, NC: SAS Institute.

[48] Steel, R. G. D. and Torrie, J. H., 1980. Principles and procedures of statistics. A biometrical approach, 2nd Edition, Mc Graw-Hill Book Company, New York. *Agricultural science*, 1, 252.

[49] Hillel, D. (2014). Environmental soil physics. *Academic Press*, London, England.

[50] Hazelton, P. and Murphy, B., 2007. Interpreting soil test results, what do all the numbers mean. Victoria, CSIRO Publishing.

[51] Taye Kufa, 2011. Chemical properties of wild coffee forest soils in Ethiopia and management implications. *Agricultural Science*, 4, 443 - 450.

[52] Abebe Nigussie, Gebremedihin Ambaw and Endalkachew Kissi, 2013. Fertility status of eutric nitisol and fertilizer recommendation using numass in the selected areas of Jimma zone, south western Ethiopia. *Tropical and Subtropical Agro ecosystems*, 3, 48 - 495.

[53] Landon, J. (2014). Booker tropical soil manual: A handbook for soil Survey and agricultural land evaluation in the tropics and subtropics. Booker Tate limited, London, England.

[54] FAO (Food and Cultivated Organization),(2006). Plant Nutrition for Food Security: A guide for integrated nutrient management. FAO Fertilizer and Plant Nutrition Bulletin Food and Agriculture Organization, Rome, Italy. Available at: access date. No. 16.

[55] Kidanu Motuma and Achalu Chimdi, 2018. Availability of Boron, Sulfur and Zinc and Status of other Selected Soil Properties under Acidic Soils of Different Land Use Types: The Case of WayuTuka District, East Wollega Zone. *Journal of Agriculture and Environmental Science*, 18, 17-22.

[56] Landon, J. R., 1991. Booker Tropical Soil Manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics. (Ed.). New York, John Wiley and Sons Inc.

[57] Amini, Sh. and Mohammad Ali., 2015. Investigation the Effect of Conservation Tillage on Soil Organic Matter and Soil Organic Carbon. The review, 8, 16–24.

[58] Tesfaye Wakgari, Kibebew Kibret, Bobe Bedadi, Melesse Temesgen and Teklu Erikossa, 2018. Long Term Effects of Cultivation on Physicochemical Properties of Soils at Metahara Sugar Estate. *American- Eurasian Journal of Agricultural Research,* 18, 246-257.

[59] Brady, N. and R. Weil, 2002. The Nature and Properties of Soils, 13th Edition. Prentice Hall. Upper Saddle River, New Jersey. 960p.

[60] Tesfaye Wakgari, Kibebew Kibret, Bobe Bedadi, Melesse Temesgen and Teklu Erikossa, 2020. Effects of long term sugarcane production on soils physicochemical properties at Finchaa sugar Estate. *Journal of Soil Science and Environmental Management,* 11, 30-40.

[61] Tamado Tana and Mitiku Woldesenbet, 2017. Effect of Combined Application of Organic and Mineral Nitrogen and Phosphorus Fertilizer on Soil Physicochemical Properties and Grain Yield of Food Barley (*Hordeum vulgare* L.) in Kaffa Zone, South-western Ethiopia. Haramaya University, School of Plant Sciences, Dire Dawa, Ethiopia. *Momona Ethiopian Journal of Science* (MEJS), 2, 242-261.

[62] Islam, M. R, S. Sikder, M. M. Bahadur and. Hafiz, M. R., 2012. Effect of Different Fertilizer Management on Soil Properties and Yield of Fine Rice Cultivar. *Journal of Environmental Science and Natural Resources,* 5, 239-242.

[63] Bloom, P. R., 2000. Soil pH and pH buffering. In Sumner, M. E. (eds). Handbook of Soil Science. Boca Raton, FL: CRC Press.

[64] Kasongo, R. K., Verdoodt, A., Kanyankagote, P., Baert, G. and Van Ranst, E., 2011. Coffee Waste as an Alternative Fertilizer with Soil Improving Properties for Sandy Soils in Humid Tropical Environments. *Soil Use and Management*, 2, 94–102.

[65] Tesfaye Wakgari, Kibebew Kibret, Bobe Bedadi, Melesse Temesgen and Teklu Erikossa, 2019. Effects of Sub-soiling and Organic Amendments on Selected Soil Physicochemical Properties and Sugar Yield in Metahara Sugar Estate. *American- Eurasian Journal of Agricultural Research*, 19, 312-325.

[66] Argaw Antene, 2017. Organic and inorganic fertilizer application enhances the effect of Brady rhizobium on nodulation and yield of peanut (*Arachis hypogea* L.) in nutrient depleted and sandy soils of Ethiopia. *International Journal Recycle Organization Waste Agriculture*, 3, 219–231.

[67] Tekalign, T., Haque, I. and Aduayi, E. A., 1991. Soil, plant, water, fertilizer, animal manure and compost analysis manual. Plant Science Division working document, ILCA, Addis Ababa, Ethiopia. 13, 103.

[68] Anwar Abasanbi, 2010. *Assessment of Coffee Quality and its related problems in Jimma Zone of Oromia Regional State*. M.sc. Thesis in Agronomy Jimma University, College of Agriculture and Veterinary Medicines Department of Horticulture and Plant Sciences.

[69] Nduka, B. A., Adewale, D. B., Akanbi, O. and Adejobi, K. B., 2015. Nursery soil amendments for Cashew seedling production: A Comparative analysis of coffee husk and NPK. *Journal of Agricultural Science*, 3, 111-122.

[70] Tisdale, S. L., Nelson, W. L., Beaton, J. D. and Havlin, J. L., 1995. Soil Fertility and Fertilizer. 5th Edition, Prentice-Hall of India, New Delhi, *Natural resources*, 1, 684.

[71] Ayodele, O. J. and Shittu, O. S., 2014. Fertilizer, Lime and Manure Amendments for Ultisols Formed on Coastal Plain Sands of Southern Nigeria. *Journal of Agriculture, Forestry and Fisheries*, 3, 481- 488.

[72] Samuel T, Werner. N, James. B, and John. H., 2000. *Soil fertility and fertilizers,* 5th edition, Prenticehall of India private limited, New Delhi.

[73] Asha K, C. R and Devanna. N., 2017. Evaluation of Physical and Chemical Properties of Coffee Pulp for its Potentiality as Soil Fertilizer*, Journal of Agro ecology and Natural Resource Management,* 5, 388-390.

[74] Samake, A., 2014. *Use of locally available amendments to improve acid soil properties and maize yield in the savanna zone of Mali.* Ph.D Thesis, Kwame Nkrumah University of Science and Technology, Kumasi.

[75] Kasongo, R. K., A. Verdoodt, P. Kanyankogote, G. Baert, and Van Ranst E., 2013. Response of Italian Ryegrass (*Lolium Multiflorum* L.) to Coffee Waste Application on a Humid Tropical Sandy Soil. *Soil Use and Management*, 1, 22–29.

[76] Chaves A. R. M, Martins, S. C. V, Batista, K. D, Celin E. F, and Da Matta, F. M., 2012. Varying leaf-to-fruit ratios affect branch growth and dieback, with little to no effect on photosynthesis, carbohydrate or mineral pools, in different canopy positions of field-grown coffee trees, https://www.sciencedirect.com/science/journal, 77, 207- 218.

[77] Chemura, A, Waheed, A., Hamid, F. S., Kutywayo, D. and Chingwara, V., 2010. Effect of Organic and inorganic fertilizer on growth, yield and economic performance of Coffee. *International Journal Recycling Organic Waste Agriculture*, 29, 11–15.

[78] Wairegi, L. W. I, van Asten P. J. A, Giller K. E and Fairhurst, T., 2014. Banana coffee system cropping guide. Africa Soil Health Consortium, Nairobi.