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Response of Coffee Growth and Yield to Integrated Use of Lime, Coffee Husk Compost and Inorganic Fertilizer on Acidic Soil of Anfilo District, Western Ethiopia

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Abstract: *Soil acidity has become a serious threat to crop production in most highlands of Ethiopia in general and in the western part of the country in particular. Furthermore, technical information with regard to the role of liming and its interaction effect with coffee husk compost for soil acidity amelioration is scarce in Anfilo areas for crop production in general and coffee in particular. A field experiment was conducted to assess the effects of lime, coffee husk compost, NP fertilizer and their combinations on growth response and yield of coffee (Coffea arabica L.) at Mugi Agricultural Research Sub-Center in Anfilo district, Western Ethiopia. The treatments consisted of ten combinations of different rates of coffee husk compost, lime and NP fertilizers, and laid out in randomized complete block design with three replications. Soil samples were taken and analyzed for selected physicochemical properties following the standard laboratory procedures. All relevant coffee growth parameters and yield data were collected and subjected to Analysis of Variance using SAS package and treatment means were compared at 0.05 probability level using least significant difference test. The results revealed that integrated application of coffee husk compost and lime with NP fertilizer significantly increased growth parameters and yield of coffee. The highest growth performance of coffee (plant height, number of primary branch and stem girth) and highest yield of coffee (1928.08kgha^{-1}) were recorded from the integrated use of 50% recommended coffee husk compost and lime with NP fertilizer (5 t ha^{-1} coffee husk compost + 1.1 t ha^{-1} lime + 86 kg ha^{-1} N and 38 kg ha^{-1}P fertilizer). From the study, it can be concluded that integrated application of 5 t ha^{-1} coffee husk compost and 1.1 t ha^{-1} lime with 86 kg ha^{-1} N and 38 kg ha^{-1}P fertilizer to acidic soil could be a promising alternative amendment for acid soil management and sustainable coffee production in Anfilo district, western Ethiopia*.

Keyword: Amendment, Coffee husk compost, Lime, Coffee growth and Soil acidity

INTRODUCTION

The environmental conditions of Ethiopian coffee growing areas are part and parcel of tropical climate whereby highly weathered and leached soils, such as *Nitisols and Cambisols* are dominant (Anteneh *et al.*, 2015). These soils are inherently low fertile and characterized by low organic

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matter, nitrogen, phosphorus and exchangeable bases (Ca^{2+} and Mg^{2+}) and having a pH of 4.3 - 6.5 (Anteneh *et al.,* 2015). As a result, the soils constitute an important growth and yield limiting factor for crops.

Acidic conditions enhance the presence of trivalent cation (Al^{3+}) (Merino *et al.,* 2010), which is the most toxic of all Al species available to plants (Kochian *et al.,* 2004). This results in alterations of the physiological and biochemical processes of plants and consequently loss of productivity. Under acidic conditions, some of the vital nutrients such as P, Ca and Mg are made unavailable in the soil solution for plant uptake due to the abundance of elements such as Al and Mn (Mesfin, 2007). At low pH, Al toxicity is reportedly the main stress factor for coffee plants (Cyamweshi *et al.,* 2014).The high levels of Al in the soils results in the death of root cells, hindering root development. The damaged roots explore less soil volume, decreasing the amount of water and nutrients absorbed by the plants. Since exchangeable Al impairs the development of the root system, it interferes in P, Ca and Mg absorption and movement by the plant (Kochian *et al.,* 2004; Cyamweshi *et al.,* 2014).

Soil acidity limits or reduces crop production primarily by impairing root growth there by reducing nutrient and water uptake (Marschner, 2012). Moreover, low pH or soil acidity converts available soil nutrients in to unavailable form and also acidic soils are poor in their basic cations such as Ca, K, Mg and some micronutrients, which are as essential to coffee plant growth and development (Cyamweshi *et al.,* 2014).Coffee plants deficient in Ca and Mg might have their development reduced up to 50%, in relation to plants cultivated in limed soils with low acidity and normal Ca and Mg levels. The correction of soil acidity makes coffee plants more tolerant to drought and avoids the cation competition effect of K, which is supplied in high doses due to its importance to grain fulfillment (Cyamweshi *et al.,* 2014.)

In the major coffee growing areas of western Ethiopia, most soils are exposed to nutrient leaching over a long period resulting in low organic matter content and require careful management to support good crop yields (Likassa, 2014). He pointed out that soil acidity status and moisture content have significant influence on coffee production (to be higher or lower) than top soil macro nutrients. Accordingly coffee production (yield) was increased with decreasing soil acidity and increasing soil moisture contents.

Also repeatedly production of coffee without supplying the lost nutrient results in the total loss of minerals from the soil and subsequent decline in yield and vigor of the tree (Anteneh *et al.,* 2015). The method of application, amount, frequency and time and type of fertilizers to be applied are dependent up on type of crop, inherent soil fertility status, the level of productivity, and cultural practices such as irrigation, spacing, mulching, e.t.c. and climatic condition (Melke and Ittana, 2015), though these aspects remain to be studied for coffee production in the country.

Coffee growers in Ethiopia still demands for mitigation to obtain various technologies and services from appropriate partners *(Government, Research Institutes (regional or National). And NGOs)* for maintaining soil fertility. Various locally available resources such as lime and organic

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resources alone or in combination with mineral fertilizers has to be used in improving nutrient use efficiency and productivity of coffee plant. Maximal use of locally available nutrients through low-external input technologies and techniques, combined with optimal use of external nutrients appears to be the best option to boast coffee production and productivity (Anteneh *et al.,* 2015; Dzung *et al.*, 2013). Integrated nutrient management will be another area of focus whereby different plant nutrient sources (organic or inorganic) will be investigated with appropriate ratios in order to reduce costs for commercial fertilizers and sustain productivity through balanced fertilization. In addition to the current endeavors in the field, more research activities are still required to address the tangible concerns regarding soil erosion. Hence, action oriented research activities are to be devised in the areas of inorganic fertilizer management, integrated nutrient management, and soil erosion control to manage nutrient and soil pH status in the suitable range for coffee cultivation(Melke and Ittana, 2015). Therefore, this study was initiated with the objective of to investigate integrated effects of lime, coffee husk compost and inorganic fertilizer (NP) to improve coffee production and productivity on acid soil of Anfilo, western Ethiopia.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted at the Mugi Agricultural Research Sub-Center in Anfilo district, Western Ethiopia (Figure1). Mugi Agricultural Research Sub-center of the Jimma Agricultural Research Center was established primarily to address the potentials and constraints in Kellem Wollega specialty coffee growing areas. It is 610 km far from Jimma city to North West direction. It is located at altitude of 1570 m a.s.l and receive 1655 mm annual rain fall. Also, it has Nitisol soil type Dubale (2001) and minimum 17°C and maximum 29°C temperature for this location.

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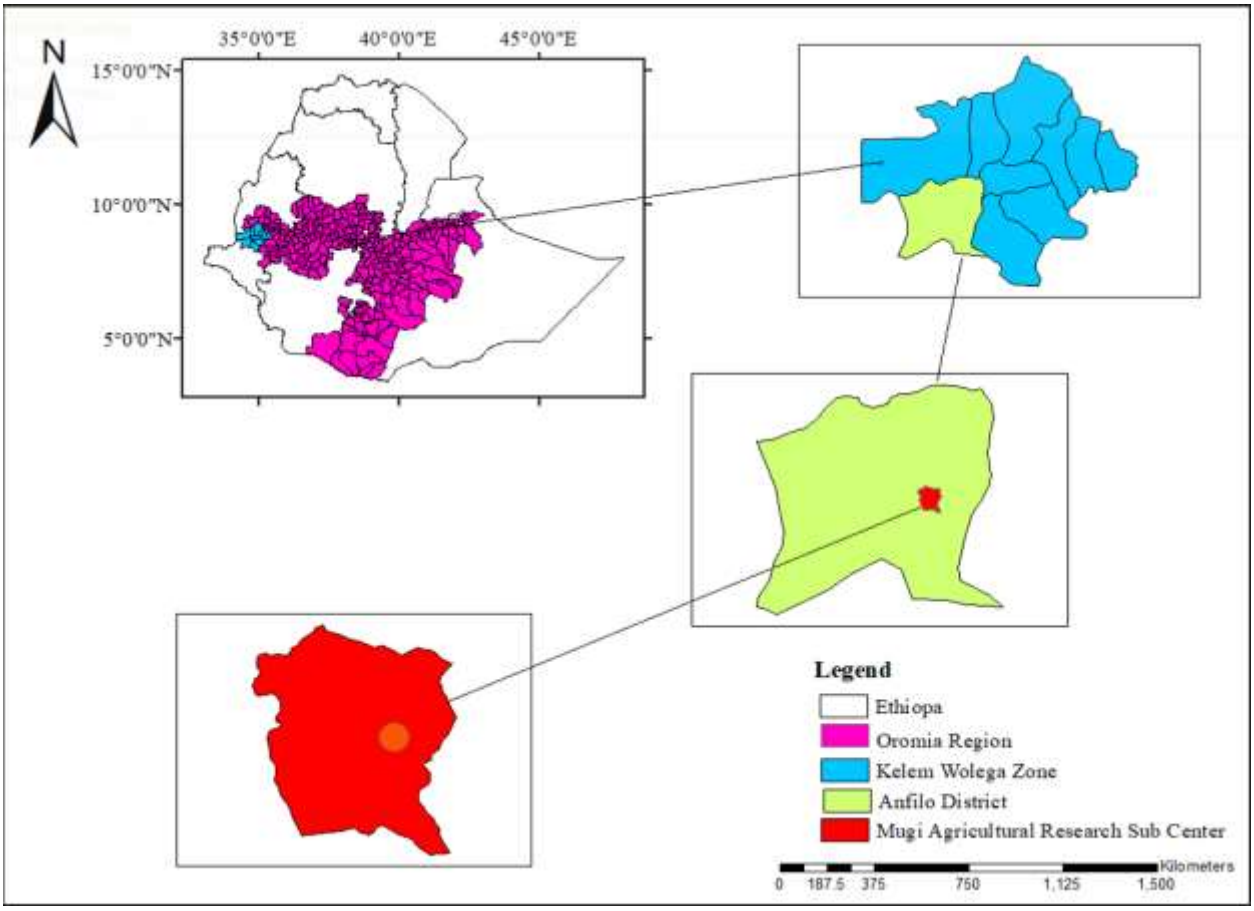

Fig 1: Map of the study area

Experimental materials and procedures

Fresh coffee husk was collected from the dry coffee processing site in Mugi town, Anfilo District. The compost was prepared by using 70% coffee husk, 10% Farmyard manure, 10%leguminous plant material and 10% top soil by volume following the procedure adopted by Solomon (2006). The prepared compost were air dried and applied with lime under the canopy of coffee by mixing thoroughly in the upper 15-20 cm soil depth at the start of rainy season. Moreover, the different lime rates as powdered lime having a calcium carbonate equivalent of 98% was used.

The lime requirement (LR) was obtained by multiplying exchangeable acidity with soil depth and bulk density (Kamprath, 1984).

$$LR, CaCO_3\ (kg/ha) = \frac{EA\ (cmol\ /kg\ of\ soil) * 10^4 m^2 * 0.15m * B.D\ (Mg/m^3) * 1000}{2000}$$

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Table 1. Initial Soil pH and exchangeable acidity of experimental field

Soil pH	**Exchangeable acidity**	**Bulk density**
4.97	2.48	1.2

Experimental treatments and design

The experiment was laid out in randomized complete block design (RCBD) and the treatment consists of combination of coffee husk compost, lime and NP fertilizer. The experiment consists of ten treatments combinations with three replications. The treatment combinations were shown in Table 2.

Table 1. Treatment combinations and their rates used for the study

Treatment number	Treatment description and combination	Actual amount applied			
		Lime(t/ha)	CHC(t/ha)	N(kg/ha)	P(kg/ha)
1	Control(no input)	0	0	0	0
2	Recommended NP	0	0	172	77
3	Recommended Lime	2.2	0	0	0
4	Recommended CHC	0	10	0	0
5	Recommended (NP + Lime)	2.2	0	172	77
6	Recommended (Lime + CHC)	2.2	10	0	0
7	Recommended NP + 50% Lime.	1.1	0	172	77
8	Recommended CHC + 50% Lime.	1.1	10	0	0
9	50% (CHC + NP)	0	5	86	38
10	50% (CHC + NP + Lime)	1.1	5	86	38

CHC= Coffee husk compost; N= Nitrogen fertilizer; P = Phosphorus fertilizer

Data Collection

Coffee yields and other agronomic parameters (Coffee yield, plant height, stem diameter, number of branches, number of bearing branches, canopy diameter) were taken from the two central rows per each plot from 12 coffee trees. Plant height was measured in meter from the ground level to the top of the plant at physiological maturity from central row of five randomly selected plants per each plot. Further, stem diameter (girth) was measured from middle of the base of plant from central row of five randomly selected plants per each plot by caliper.

Statistical analysis

The collected soil and plant data were summarized and subjected to ANOVA (analysis of variance) using SAS software (version 9.3) (SAS, 2011). For significantly different treatments, the means were separated using Least Significant Difference at $p = 0.05$.

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RESULTS AND DISCUSSIONS

Effects of integrated use of coffee husk compost, lime and NP fertilizer on coffee growth parameters

Plant Height of coffee

Mean height of coffee plants was highly significantly ($p < 0.01$) affected by integrated use of coffee husk compost, lime and NP fertilizer. Accordingly the maximum plant height (218.06cm) was recorded from the application of integrated use of 50% recommended (NP + coffee husk compost + lime), while the lowest plant height (172.2cm) was obtained from the control plot (Table 3). Coffee plant height recorded for integrated application of coffee husk compost, lime and NP fertilizer was statistically similar with full application of recommended lime and NP fertilizer, which shows the ameliorative effects of coffee husk compost in acidic soil for resource poor small holder farmers. Increases in plant height in response to combined application of coffee husk compost, lime and NP fertilizers might be attributed to release of major nutrients and reduced soil acidity. In agreement with this, Bikila et al. (2020) has reported that integrated use of coffee husk compost, lime and inorganic fertilizer performed better than just application of organic fertilizers, inorganic and lime alone on coffee seedling growth in acid soil of Haru, western Ethiopia. Similarly Nduka et al. (2015) also recorded significant increase in plant height and stem diameter on cashew seedling growth as a result of coffee husk application to acid soil.

Number of primary branches

Similar to coffee plant height, the number of primary branches per plant of coffee was significantly ($p < 0.01$) affected by integrated application of NP fertilizer, lime and coffee husk compost. Application of integrated use of 50% recommended (NP + coffee husk compost + lime) (86 kg ha^{-1} N and 38 kg ha^{-1}P fertilizer + 5 t ha^{-1} coffee husk compost + 1.1 t ha^{-1} lime) resulted in the highest number of branches per plant (50.4), followed by full recommended NP and lime (48.7), while the least number of branches per plant of coffee was recorded for the control plot (35.43) (Table 3). The increase in number of branches with application of integrated use of coffee husk compost, lime and NP fertilizer might be due to the ameliorative effects of lime and coffee husk compost with inorganic fertilizer which improves availability of major nutrients for the growth of coffee plants. In agreement with the present result, Gemechu et al. (2021) and Chemura (2014) has reported increases in number of branches per plant of coffee due to application of compost and inorganic fertilizer to soils.

Girth or stem diameter

Integrated application of lime, coffee husk compost and NP fertilizer on acidic soil, highly significantly ($p < 0.01$) affected Stem diameter or girth of coffee plants. Accordingly the maximum mean girth (54.36 mm) of coffee trees was recorded for integrated application of half recommended NP fertilizer, coffee husk compost and lime (86 kg ha^{-1} N and 38 kg ha^{-1} P fertilizer + 5 t ha^{-1} coffee husk compost + 1.1 ha^{-1} lime) followed by full recommended NP fertilizer with lime (53mm) while, the lowest mean girth (39.13 mm) was recorded for the unfertilized control plot. The maximum mean girth recorded and the significant effect obtained by the application of

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lime and coffee husk compost amendments on coffee plant growth could be because of more favorable chemical conditions of the soil made by those amendments such as reduced Aluminum toxicity and increased nutrient availability which ultimately enhanced coffee plant growth. The present result was in line with the findings of Bikila et al. (2020), who reported that there was a positive effect of combined application of lime and coffee husk compost on stem diameter of coffee seedlings in acid soil of western Ethiopia.

Table 3: Coffee growth parameters as affected by integrated use of coffee husk compost, lime and NP fertilizer Anfilo, western Ethiopia.

Treatment number	Treatment description	Growth parameters		
		Plant height(cm)	Branch numbers	Girth (mm)
1	Control(no input)	172.2f	35.43e	39.13e
2	Recommended NP	200.8cd	45.56c	48.53cd
3	Recommended Lime	182.96e	39.8d	41.96e
4	Recommended CHC	195.03d	42.2d	46.06d
5	Recommended (NP + Lime)	211.33ab	48.7ab	53.00ab
6	Recommended (Lime + CHC)	196.33d	41.6d	46.43d
7	Recommended NP + 50% Lime.	207.26bc	45.76bc	50.4bc
8	Recommended CHC + 50% Lime.	200.13cd	40.73d	46.6d
9	50% (CHC + NP)	206.63bc	45.43c	48.0cd
10	50% (CHC + NP + Lime)	218.06a	50.4a	54.36a
	LSD (0.05)	10.07**	3.05**	3.07**
	CV (%)	12.94	14.08	13.77

CHC=coffee husk compost **= highly significant at P ≤ 0.01.Mean values followed by the same letter(s) with in a column are not significantly different at p≤0.05.

Effects of integrated use of coffee husk compost, lime and NP fertilizer on coffee yield

Integrated application of coffee husk compost, lime and NP fertilizer on acidic coffee field, highly significantly affected ($p < 0.01$) coffee yield. Accordingly, the highest coffee yield (1928.08 kg ha^{-1}) was obtained from the integrated application of half recommended NP fertilizer, coffee husk compost and lime (86 kg ha^{-1} N and 38 kg ha^{-1} P fertilizer + 5 t ha^{-1} coffee husk compost + 1.1 ha^{-1} lime) followed by full recommended NP fertilizer with lime (1736.13 kg ha^{-1}) while, the lowest coffee yield (704.95 kg ha^{-1}) was recorded for the un amended control plot.

The highest coffee yield obtained from the integrated application of coffee husk compost and lime with NP fertilizer could be attributed to reduced soil acidity and increased availability nutrients that may enhanced growth of coffee and yield. In line with this, Gemechu et al. (2021) have reported that incorporation of coffee husk compost and NP fertilizers on highly weathered soil improved soil pH nutrient availability and soil moisture that favored optimum favored optimum coffee shoot and root growth and thus, enhanced nutrient use efficiency by the crop with ultimately increased coffee yield.

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Table 4: Integrated effects of coffee husk compost, lime and NP fertilizer on coffee yield at Anfilo, western Ethiopia.

Treatment number	Treatment description	Clean coffee yield (kg/ha)
1	Control(no input)	704.95[f]
2	Recommended NP	1395.32[c]
3	Recommended Lime	884.92[e]
4	Recommended CHC	1148.43[d]
5	Recommended (NP + Lime)	1736.13[b]
6	Recommended (Lime + CHC)	1171.36[d]
7	Recommended NP + 50% Lime.	1592.24[b]
8	Recommended CHC + 50% Lime.	1155.20[d]
9	50% (CHC + NP)	1332.49[c]
10	50% (CHC + NP + Lime)	1928.08[a]
LSD (0.05)		146.39**
CV (%)		12.54

CHC=coffee husk compost **= highly significant at P ≤ 0.01.Mean values followed by the same letter(s) with in a column are not significantly different at p≤0.05

CONCLUSIONS

The influence of integrated use of coffee husk compost and lime with NP fertilizer on growth and yield response of coffee were investigated on acid soil of Anfilo district, western Ethiopia. The experimental area before planting, soil examination revealed that it was severely acidic soil and needs amendments to ameliorate the acidity problem. Accordingly, findings of the study showed that, integrated application of coffee husk compost and lime with NP fertilizer significantly improved growth and yield of coffee. The highest clean coffee yield (1928.08 kg ha^{-1}) was obtained from the integrated application of half recommended NP fertilizer, coffee husk compost and lime (86 kg ha^{-1} N and 38 kg ha^{-1} P fertilizer + 5 t ha^{-1} coffee husk compost + 1.1 ha^{-1} lime) followed by full recommended NP fertilizer with lime (1736.13 kg ha^{-1}) while, the lowest coffee yield (704.95 kg ha^{-1}) was recorded for the un amended control plot.

The positive growth response and yield to integrated use of coffee husk compost and lime amendments with NP fertilizer than un amended plot control indicated that the soil of experimental field was strongly acidic, hence the level of many essential plant nutrients in these soils was fixed and lower which was readily available and supplied by lime and coffee husk compost amendments. Furthermore, this study confirmed that a promising potential of coffee husk compost amendment in combination with conventional lime to ameliorate soil acidity and improve coffee growth and yield since it is easily available organic material in coffee producing areas.

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