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Lime and Phosphorus Rates Response on Dry Matter Production and Partitioning of Hybrid Coffee (*Coffea arabica* L.) Seedlings Growth on Acidic Nitisol Soil

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Abstract

Coffee (*Coffea Arabica L.*)is indigenous to the tropical rain forests of Ethiopia in the South and Southwest where there was persistent usage since ancient times. Coffee soils in the south-western parts of Ethiopia canbe attributed to excessive accumulations of aluminum, iron or manganese which leads to deficiencies of phosphorus other nutrients. This low soil pH and nutrient deficiencies encountered in the soils of the study area are expected to decrease the growth and dry matter of coffee seedlings. Liming is more effective in combination with phosphorus fertilization or that the secondary effect of liming is higher phosphorus fertilizer availability to the coffee seedlings. Nursery experiment was conducted at Jimma Agricultural Research Center, south west Ethiopia to evaluate the response of lime and phosphorus rates on coffee seedlings dry matter production and partitioning. The experiment was laid out in a randomized complete block design with 3 replications. The treatments were arranged in factorial combinations of five levels of lime (0, 5, 10, 15 and 20 g) and four levels of phosphorus (0, 400, 600 and 800 mg) 2.5 kg^{-1}top soil. The statistical data was analyzed through SAS software and treatment means were compared at 5% probability using Duncan Multiple Range Test. The results revealed that the interactions of lime and P rates significantly increased dry matter production, partitioning and shoot to root ratio. The maximum dry matter production, partitioning and shoot to root ratio were recorded from the interaction of 10 g lime and 800 mgP rates 2.5 kg^{-1} top soil. Hence, combined application of 10 g lime and 800 mg P rate 2.5 kg^{-1}top provides the optimum dry matter production, partitioning and shoot to root ratio for the growth of coffee seedlings under nursery conditions.

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Keywords

Coffee seedlings, Dry matter, Phosphorus rate, Soil acidity

Introduction

In Ethiopia coffee Arabica coffee is an important export crop traded globally and is a major foreign exchange earner for the country. Ethiopia is the largest coffee producer in Africa and is the sixth producer in the world next to Brazil, Vietnam, Colombia, Indonesia and Honduras contributing to about 4.8% of the total world coffee production(ICO, 2018). *Coffea Arabica* is an indigenous to the tropical rain forests of Ethiopia in the South and Southwest where there was persistent usage since ancient times (DaMatta, 2004**;** Emana, 2015). Coffee can adapt to different soil types and the soil requirements for sustainable high yield of arabica should be of deep profile, over about 180 cm, moderately to heavy texture, good drainage and of high organic matter content(Cambrony, 1992; Paulos, 1994).It can then be inferred that the infertility of the coffee soils in the western, south-western, and southern parts of Ethiopia can be attributed to excessive accumulations of aluminum, iron and manganese causes for deficiencies available phosphorus and basic cations (Tekalign and Haque, 1991;Eyasu, 2017). In the high rainfall areas of western Ethiopia are strongly acidic, high in exchangeable aluminum throughout the profile, butlow in CEC, exchangeable bases, available phosphorus, and organic matter. Under these conditions, increased levels of lime and phosphorus application significantly correlated with many of the agronomic parameters, and that the interaction effect thereof was significant. In order to counteract the effect of soil acidity on crop growth, liming is a traditional practice often applied to soils to restore Ca and Mg availability for plants and adjust soil acidity (Cyamweshi *et al.*, 2013).Naidu *et al.*, (1990) observed the beneficial effect of liming in reduced micronutrient toxicity while increasing the availability of Ca, P, Mo and Mg in the soil. The soil is poor in plant available soil P because of high P-fixing capacity. Fertilizer experiments on some crops at the area have shown that P is the limiting nutrients to crop production with a significant yield increase and profitable return to the application of these nutrients(Paulos 1994). Thus, low soil pH is considered to be the main cause of yield reduction for all crops in general and acid sensitive crops in particular in the study area.

This low soil pH and nutrient deficiencies encountered in the soils of the study area are expected to decrease the growth and dry matter of coffee seedlings. Adding lime or other materials can raise the soil pH to the ideal range for coffee seedlings production create an environment for the healthy functioning of microbes, and increase levels of calcium or magnesium ions. Then both soil physical and chemical conditions and the proportion of available nutrients determine coffee seedling vegetative growth and its latter health and vigorous seedlings for transplanting to main field. Hence, there is now a new interest in using chemical fertilizers in combination with lime sources with the basic concept to maintain and increase soil fertility for increased sustained crop production by optimizing all possible sources in an integrated and judicious manner within a given ecological, social and economic setting. Liming is more effective in combination with phosphorus fertilization to enhance phosphorus fertilizer availability to the optimum growth of coffee seedlings (Cyamweshi *et al.,* 2013). Similar benefits of lime and P application on crop responses and improvements of soil properties have also been reported in highly acidic soils (Fageria and Baligar, 2008).This research activity was conducted to evaluate the response of lime and mineral phosphorus fertilizer on dry matter production and partitioning of hybrid coffee seedlings growth on acidic Nitisolssoilin case of Jimma southwest Ethiopia.

Materials and Methods

Descriptions of the study area

The study was conducted at Jimma Agricultural Research Center nursery site at south west Ethiopia. The center is geographically lies between 7^0 46' N, latitude 36^0 47' E longitudes at an altitude 1750 meter above sea level. The mean annual rain fall recorded 1532 mm and the min and maximum temperature are about 11.73^oc and 26.11^oc respectively. Eutric-Nitisolsare the dominant reference soil groups in the study areas (DeWispelaere *et al.,* 2015).

Experimental material, design and procedures

The experiment was laid out in a randomized complete block design with 3 replications. The treatments used were factorial combinations of five levels of lime (0, 5, 10, 15 and 20 g) and four levels of phosphorus (0, 400, 600 and 800 mg) 2.5 kg^{-1}top soil. Liming material calcium carbonate ($CaCO_3$) which contains 98% neutralizing values, fertilizers Triple Super Phosphate (46% P_2O_5) and urea (46 % N) were used. Hybrid coffee variety- *Gawe* used as a test crop. The different lime rates as powdered lime having a calcium carbonate equivalent of 98% were weighted and thoroughly mixed with 2.5 kg of the sieved soil.

Lime was applied one month before sowing for better incubation as described by Achalu *et al.,* (2012). Thereafter, the soil blended potting media was filled in black polythene bags of 16 cm wide and 22 cm long and each experimental unit which consist of 16 pots. The prepared seeds from the hybrid coffee variety (*Gawe*) were sown at the rate of two seeds per pot and thinned to one seedling after the germinated seeds attained a butterfly growth stage. Whereas, phosphorus was applied as triple super phosphate (46% P_2O_5) once when the seedlings attained a butterfly stage, while recommended rate of 540mg N was applied as urea (46% N) in three equal splits, i.e., when the seedlings attained butterfly stage, two and four pairs of true leaves. All the routine pre-and post-sowing nursery practices were applied according to the recommendation (Tesfaye *et al.*, 2005).

Data collections

The coffee seedlings were uprooted when attain at sixth pair of leaves. The stem, branches, leaves and roots were separated by cutting the plant with sharp clean knife. The vegetative parts were removed, washed, weighed and dried separately in the shade. All coffee seedlings parts leaf, stem and root were separately placed in labeled paper bag and dried oven at 70 ^{0}C for 24 hours to a constant weight and dry matter was measured for each samples using sensitive balance. The dry matter of roots, were determined by weighing the root materials separated from the aerial part of the plant on analytical balance. The mass of dry matter of the aerial part was obtained by the sum of the weight of the dry mass of leaves, stems and branches. The total dry matter was obtained by the sum of the dry matter arial part and the dry matter roots. The dry weight of each part was used to determine the dry matter partition to stem, leaves and roots and total dry matter (stem + leaves + roots dry matter). Shoot to root ratio was determined as (stem + leaf dry matter ÷ root dry matter) of the seedlings (Yacob *et al.*, 1995).

Statistical analysis

The relevant data was summarized using the General Linear Model of SAS 9.2 version. Treatment means were separated using Duncan multiple range test at 5% probability level for significantly different parameters.

Results and Discussions

Total dry matter production

Lime and P rates and their interactions significantly affected total dry matter production (Fig 1). However the maximum 0.837 g total dry matter was recorded from the interactions of 10 g lime and 800 mg P rate. While the lowest 0.293 g dry mater contents of coffee seedlings recorded from higher lime rates and P 20 g. The reduction in total dry matter content of coffee seedlings at higher lime rate attributed to a reduction in the solubility and availability of P to crops which might be caused by the formation of insoluble Ca-P compounds in the soil and reduced the availability of macro nutrients and P deficiency Fe, Mn, Zn and B deficiency (Fageria and Moreira, 2011; Habtamu 2015). Similarly, on control plots 0.413 g was recorded. On control plot the major constraints to seedlings growth through increasing in the concentration of H, Al and Mn and decreasing in basic cations of magnesium, calcium and potassium Moreover, it causes deficiency of P and molybdenum (Mo) through decreasing their solubility (Achalu, 2014).

Additions of 5 g and 10 g lime showed 0.437 and 0.580 g dry matter content respectively. But the further increments leads to reduce as the lime rate increased from 15 g and 20 g which were resulted to 0.347 and 0.293 g dry matter content respectively. In line with these work Anteneh (2015) reported that as the lime rate increased from the optimum level the total dry mater production decline contrary. As compared to plots which brought the highest recorded total dry matter, there was 47.22 % decrement of total dry mater observed. However, Kampareth (1984); Fageria and Baligar (2008); Achalu (2014) reported that heavier applications lime to the soil produced in the plant tissues an increase of calcium and a decrease, of nitrogen, phosphorus and potassium. Although soil analysis indicated that available phosphorus increased with lime applications, total phosphorus in plant tissues decreased with each increment of lime ions in the soil solution. An applications of P with the increasing rates boosted linearly the dry matter content of the coffee seedlings 400 mg P, 600 mg P and 800 mg P rates showed linearly increments 0.440, 0.533 and 0.657 g respectively (Fig1). Phosphorus was one of the most limiting and an important nutrient for coffee, because it causes an increase in root development and plant vigor to ensure the formation of seedlings with high total dry matter contents (Silva *et al.*, 2010; Felipe *et al.*, 2014; Habtamu, 2015).

Leaf dry mater production and partitioning

Dry matter production and partitioning was one of the parameters which determine the ability of coffee seedlings to produce and allocate the dry biomass in to their leaf, stem and root parts. Lime and P rates and their interactions significantly affected leaf dry matter production and partitioning. The maximum leaf dry matter production partitioning (Fig 2) were recorded from the combined application of 10 g lime and 800 mg P rate which gave 0.34 g dry matter and 50.70 % partitioning respectively.

The applications of lime rates were enhance coffee seedlings leaf dry matter production and partitioning. Whereas lime rates 5 and 10 g gave 0.17 g and 0.26 g dry matter and 40.91 and 40.68 % partitioning respectively. Further applications of lime 15 and 20 g contrary decreased to 0.13 g and 0.11 g dry matter and 37.14 and 29.73 % partitioning (Fig 2 and Table 1). Similarly, leaf dry matter production and partitioning was affected by P rates. Application of with increasing P rates enhances dry matter production and partitioning. Regarding to this 0.17, 0.24 and 0.32 g dry matter and 37.50, 40.00, and 41.27 % partitioning observed from 400 mg P, 600 mg P and 800 mg P treated plots respectively. Fageria and Baligar (2008) reported that an application of P with the increasing rates improves leaf dry matter production and partitioning.

Stem dry matter production and partitioning

Stem dry matter production and partitioning significantly affected by lime and P rates and their interactions (Fig 3 and Table 2). The maximum 0.27 g stem dry matter production and 30.99 % partitioning were recorded from the plot 10 g lime and 800 mg. Whereas 10 and 15 g lime rates applied plot showed 0.12 and 0.15 g stem dry matter and 27.27 and 23.94 % partitioning respectively.

Although an application of P rates treatments showed an increasing rate of stem dry mater production partitioning linearly with increasing applied P rates. Regarding to this 0.12, 0.13 and 0.15 g dry matter and 22.73, 30.00 and 30.16 % partitioning observed from 400 mg P, 600 mg P and 800 mg P treated plots respectively. This was confirmed with the works of Anteneh (2015) reported that applications of P with the increasing rates enhance stem dray matter production and partitioning.

Table.1 The interaction effect of lime and phosphorus rates on leaf dry matter production

Lime rates	Phosphorus rate (mg)			
(g)	0	400	600	800
0	0.16^{gih}	0.17^{gih}	0.24^{efd}	0.32^{ba}
5	0.17^{ih}	0.21^{egfh}	0.27^{egfh}	0.32^{ab}
10	0.26^{ecd}	0.27^{bcd}	0.32^{ba}	0.34^{a}
15	0.13^{ji}	0.15^{ji}	0.22^{egfd}	0.29^{bc}
20	0.11^{j}	0.15^{ji}	0.17^{gih}	0.20^{gfh}
CV % 12.40				

Different letters within a column and row represent significant differences at 5% level

Table.2 The interaction effects of lime and phosphorus rates on stem dry matter production and partition

Lime rates	Phosphorus rate (mg)			
(g)	0	400	600	800
0	0.10^{kl}	0.12^{hji}	0.13^{hg}	0.15^{fe}
5	0.12^{hji}	0.15^{fe}	0.16^{de}	0.17^{dc}
10	0.15^{fe}	0.17^{c}	0.20^{b}	0.27^{a}
15	0.10^{kl}	0.11^{kl}	0.11^{kji}	0.13^{hgi}
20	0.08^{m}	0.09^{l}	0.11^{kjl}	0.11^{kji}
CV % 5.78				

Different letters within a column and row represent significant differences at 5% level

Table.3 The interaction effect of lime and phosphorus rates on root dry matter production and partition

Lime rates	Phosphorus rate (mg)			
(g)	0	400	600	800
0	0.13^{ih}	0.15^{hg}	0.16^{feg}	0.20^{d}
5	0.15^{hg}	0.15^{fg}	0.17^{e}	0.21^{dc}
10	0.17^{fe}	0.22^{c}	0.24^{b}	0.27^{a}
15	0.12^{i}	0.11^{ij}	0.13^{ih}	0.15^{hg}
20	0.10^{j}	0.10^{j}	0.11^{ij}	0.13^{ih}
CV % 7.01				

Different letters within a column and row represent significant differences at 5% level

Fig.1 The interactions effects of lime and phosphorus rates on total dry matter productions

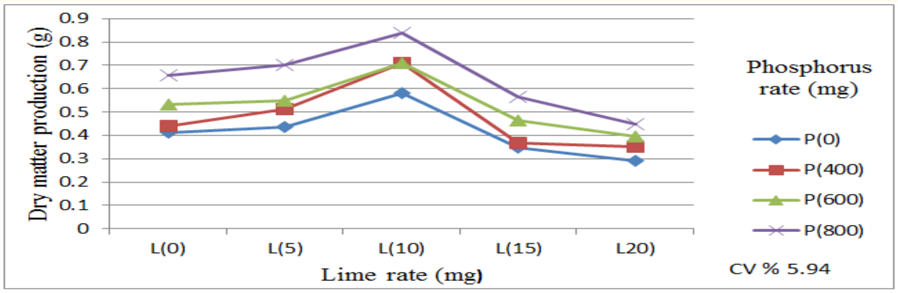


Fig.2 Effects of lime and phosphorus rates on leaf dry matter partitioning

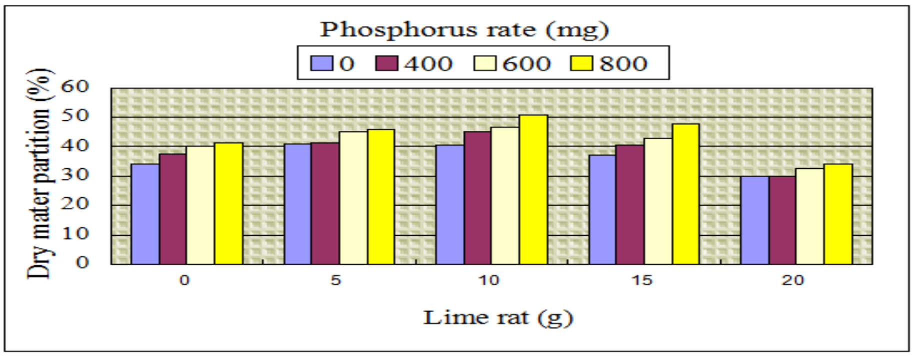


Fig.3 Effects of lime and phosphorus rates on Stem dry matter partitioning

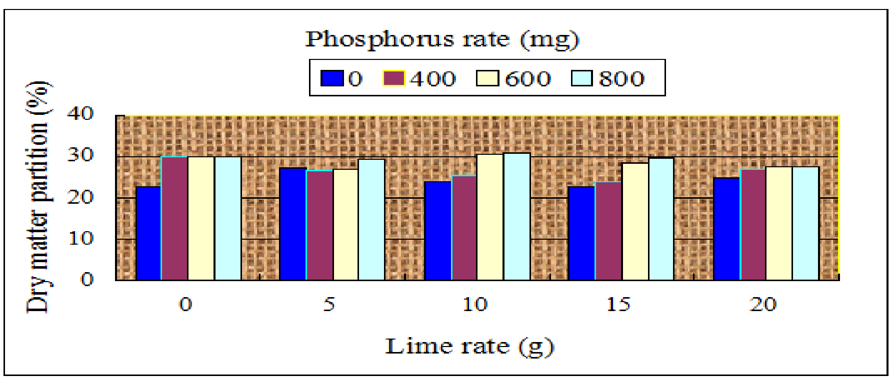


Fig.4 Effects of lime and phosphorus rates on root dry matter partitioning

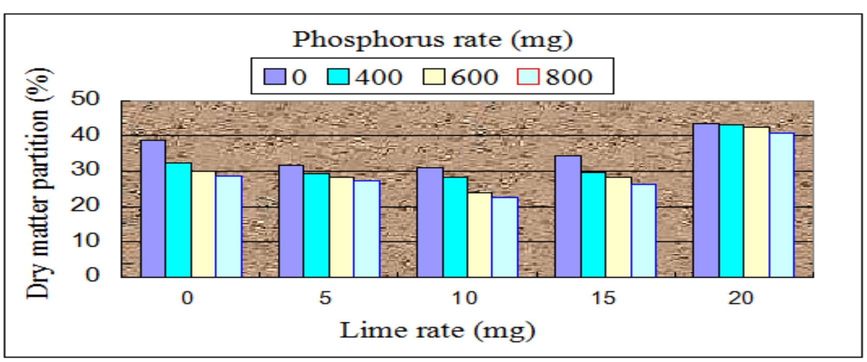
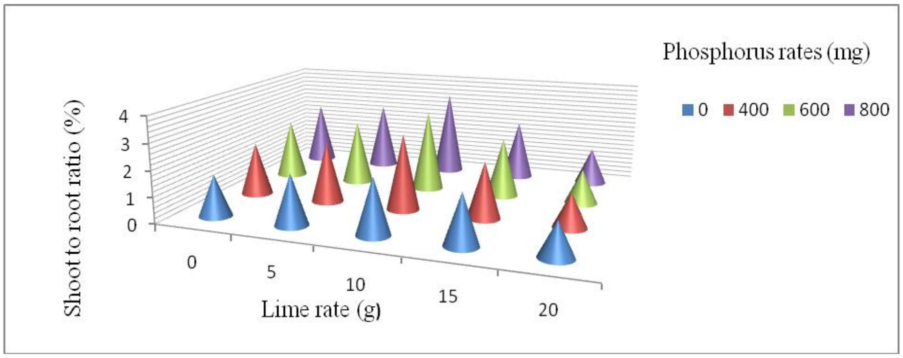


Fig.5 Effects of lime and phosphorus rates on shoot to root ratio



Root dry matter production and partitioning

Lime and P rates and their interactions showed statically significance difference among the treatments (Fig 4 and Table 3). The maximum 0.27 root dry matter production and 23.94 % Partitioning recorded from 20 g lime and 800 mg P rate respectively. However application of 5 and 10 g lime rates showed dramatically increased root dry mater production 0.15 and 0.17 g productions and decreased partitioning 31.82 to 30.90 % respectively. Further addition rates from 15 g to 20 g which gave 0.12 and 0.10 g production and increased 34.29 to 43.3% partitioning respectively.

Root dry matter partitioning was enhanced with various P rates. Although application of 400 mg P, 600 mg P and 800 mg P rates showed linearly increasing dry matter 0.15, 0.16 and 0.20 g productions and contrary decreasing 32.50, 30.00 and 28.57 % dry matter partitioning. Coffee root dry matter partition one of the most important parameters which showed the ability of the seedlings to distribute the dry matter part across to their root parts. (Anteneh 2015) reported that the increase in dry matter partitioned to roots with increasing lime rate could be attributed to the impaired chemical characteristics of the soil, such as increase in pH and decrease in available P. This finding agree with the findings of Taye *et al.,* (2012) who reported enhanced partitioning of the total, assimilate to roots of coffee seedlings under relatively nutrient deficient and poor physical media condition. This depicts that root is much stronger sink of the total assimilate under relatively nutrient stressed condition.

Shoot to root ratio

Lime and P rates and their interactions improved shoot to root ratio of coffee seedlings (Fig 5). The interaction lime and phosphorus treated plot showed the maximum rate of shoot to root ratio as compared to lime and P alone plots (Fig 5). Accordingly the maximum shoot to root ratio 3.40 followed by 3.18 and 2.94 observed from combined application of 10 g lime and 800 mg P; 10 g lime and 600 mg P and 10 g lime and 400 mg P rates respectively. Taye (1998) reported that, high quality coffee seedlings with balanced shoot to root ratio need to be produced under optimum soil environments.

The least 1.31 shoot to root ratio recorded from 20 g lime rates. Similar work to this reported by Ericsson and Ingestad (1988) at highest lime rates P was fixed with Ca^{+2} and limiting growth conditions occurred, while the roots share more of the total assimilates than the shoot and subsequently leading to a typical decrease in shoot to root dry matter ratio. Although lime applied treatments 5 g, 10 g showed 1.95 and 2.14 shoot to root ratio further applications 15 g and 20 g decreasing 1.92 and 1.31shoot to root ratio. The response of 400 mg P, 600 mg P and 800 mg P rates showed that there was linearly increment 2.08, 2.33 and 2.50 of shoot to root ratio (Fig 5).

Soil acidity is one of the major problems that significantly lower the productivity of many cultivated soils in south west Ethiopia especially in area of high rain fall. Soil acidity is characterized by low pH and the abundance of acidic cations (H, Al, Fe, and Mn) on system colloid soil solution. The low pH affects significantly the fixation and the availability of soil nutrients such as available phosphorous and basic cations. The abundance of acidic cations on system colloid soil solution can be toxic to crop growth and leads to reduced crop yield. Soil acidity can be amended by adding liming materials to the soil. Reductions in the dry matter production of shoots and roots and in the shoot/root ratio in the coffee seedlings, Al^{3+} accumulated in the roots and a small part of it was translocated to the aerial part. The research activity was conducted to evaluate the response of lime and phosphorus rates on dry matter production and partitioning of hybrid coffee seedlings under acidic nursery media at Jimma south west Ethiopia. The result revealed that the maximum dry matter production, portioning and shoot to root ratio were recorded from 10 g lime and 800 mg Phosphorus rates 2.5 Kg^{-1} soil This increment in dry matter of coffee seedlings with application of P fertilizer might be due to the adequate supply of P could be attributed to an increase the dry matter contents of the seedlings. This in turn increased photosynthetic area which demonstrates a strong correlation with dry matter accumulation and yield. Increased dry matter yield of coffee seedlings due to liming is attributed to the beneficial effect of ameliorating the soil, which increased the Ca-saturation and availability of major nutrients, especially phosphorus and other basic cations. In general 10 g lime and 800 mg phosphorus rates gave better dry matter production, partitioning and shoot to root ratio which contribute for vigorous and healthy coffee seedlings to transplant for the main filed.

References

Achalu Chimdi, 2014. Assessment of the Severity of Acid Saturations on Soils Collected from Cultivated Lands of East Wollega Zone, Ethiopia. *Science, Technology and Arts Research Journal*, 3(4): 42-48.

Achalu Chimdi, Heluf Gebrekidan, Kibebew Kibret and AbiTadesse, 2012, Response of barley to liming of acid soils collected from differentland use systems of Western Oromia, Ethiopia, Ethiopia. *Journal of Biodiversity and Environmental Sciences*, 2(7): 1-13.

Anteneh Netsere, 2015. Dry Matter Production and Partitioning in Arabica Coffee Seedling as Affected by Lime and Phosphorus Mineral Fertilizerat Jimma, Southwestern Ethiopia. *Journal of Biology, Agriculture and Healthcare*,13: 95–101.

Cambrony, H.R. 1992.Coffee growing. CTA/The Macamallian Press Ltd., New York, Tokyo119pp.

Cyamweshi, R.A., J.S. Tenywa, P. Ebanyat, M.M. Tenywa, A. Mukuralinda and A. Nduwumuremyi, 2013.Phosphate Sorption Characteristics of Andosols of the Volcanic Highlands of Central African Great Lakes Region. *Journal of Environmental Science and Engineering*,2: 89-96.

DaMatta, F., M. 2004. Ecophysiological constraints on the production of shaded and unshaded coffee: a review. *Field crop research*.86: 99-114.

DeWispelaere, L., V. Marcelino, A. Regassa, E. De Grave, M. Dumon, F. Mees and E.VanRanst, 2015. Revisiting nitic horizon properties of Nitisols in SW Ethiopia.*Geoderma*, 243:69-79.

Emana, B.T., 2015. Distribution assessment and pathogenicity test of coffee berry disease (*Colletotrichum kahawae*) in Hararghe, Ethiopia, 2: 038-042.

Ericcson, T. and T. Ingested, 1988. Nutrition and growth of birch seedlings at varied relative phosphorus addition rates. *Journal of Plant Physiology*, 72(2):227-235.

Eyasu Elias, 2017. Characteristics of *Nitisol* profiles as affected by land use type and slope class in some Ethiopian highlands. *Journal of Environ Syst Res.*, (6)20:1-15.

Fageria, N.K. and A. Moreira, 2011.The Role of Mineral Nutrition on Root Growth of Crop Plants. *Advances in agronomy*, 110(1):251-331.

Fageria, N.K. and V.C. Baligar, 2008. Ameliorating soil acidity of tropical Oxisols by liming for sustainable crop production, *Advances in agronomy*, 99:345-399.

Habtamu Admas, 2015. Reclamation of Phosphorus Fixation by Organic Matter in Acidic Soils.*Global journal of agricultural science*3(6): 271–78.

ICO (International coffee organization), 2018.Coffee market report in the international trade, challenges and opportunities facing the sector, pp.1-8.

Kamprath, E.J., 1984. Crop response to lime on soils in the tropics. *Soil acidity and liming*, (soilacidityandl), pp.349-368.

Naidu, R., R.W. Tillman, J.K. Syers and J.H. Kirkman, 1990. Lime-aluminium-phosphorus interactions and the growth of *Leucaena leucocephala*.I plant growth *Plant and Soil*, 126(1):9-17.

PaulosDubale, 1994. Mineral Fertilizer of Coffee in Ethiopia.Institute of Agricultural Research, Addis Ababa, Ethiopia. 105p.

Silva, L.D., P.E. Marchiori, C.P. Maciel, E.C. Machado and R.V. Ribeiro, 2010.Photosynthesis, water relations and growth of young coffee plants according to phosphorus availability. *Pesquisa Agropecuária Brasileira*, 45(9): 965-972.

TayeKufa 2012.Biomass production and distribution in seedlings of *Coffea Arabica* L. genotypes under contrasting nursery environments in southwestern Ethiopia Agricultural Sciences(3) 6:835-843.

Taye Kufa,1998. Response of arebica coffee (*Coffea arebica* L.) to various soil fertility management

M.Sc thesis, Alemeya university of Agriculture, pp.127.

Tekalign Mamo and I. Haque. 1991. Phosphorus status of some Ethiopian soils. III. Evaluationof some soil test methods for available phosphorus. *Tropical Agriculture (Trinidad)*, 68 :51-56.

Tesfaye Shimber, Alemseged Yilma, Taye Kufa, Endale Taye and Anteneh Netsere, 2005.Coffee seedlings management and production. Amharic version, Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia. 17pp.

Yacob Edjamo, Taye Kufa and Alemseged Yilma, 1995. Varietal and age impact on Arabica coffee leaf growth parameters at three locations. Pp. 38-51. In: Proceedings of the Third Conference of the Agronomy and Crop Physiology Society of Ethiopia, 29-30 May 1997, Institute of Agricultural Research, Addis Ababa, Ethiopia.

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