Agriculture, Forestry and Fisheries
2021; 10(1): 21-27
http://www.sciencepublishinggroup.com/j/aff
doi: 10.11648/j.aff.20211001.14
ISSN:2328-563X (Print); ISSN:2328-5648 (Online)

Effects of Lime on Phosphorus Availability and Nutrient Uptake of Hybrid Coffee (*Coffea arabica* L.) Seedlings Under Acidic Nursery Soil

Ewnetu Teshale[1, *], Taye Kufa[2], Alemayehu Regassa[3]

[1]Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center, Jimma, Ethiopia

[2]International Institute of Tropical Agriculture, Burundi Station, Bujumbura

[3]Department of Natural Resources Management, Jimma University, Jimma, Ethiopia

Email address:
ewnetu.tg@gmail.com (E. Teshale)
[*]Corresponding author

To cite this article:
Ewnetu Teshale, Taye Kufa, Alemayehu Regassa. Effects of Lime on Phosphorus Availability and Nutrient Uptake of Hybrid Coffee (*Coffea arabica* L.) Seedlings Under Acidic Nursery Soil. *Agriculture, Forestry and Fisheries*. Vol. 10, No. 1, 2021, pp. 21-27.
doi: 10.11648/j.aff.20211001.14

Received: December 8, 2020; **Accepted**: December 19, 2020; **Published**: March 10, 2021

Abstract: Coffee (*Coffea arabica* L.) is one of the major cash crops which were widely grown in west, south and south west parts of Ethiopia. There is wider genetic diversity in the country but the average clean coffee production is very low 0.7 ton/ha compared with other coffee producing countries. The low production was arises from erroneous management of the plant during the initial stage of establishment by using of improper nursery growing media and other field managements. The research was conducted at Jimma Agricultural Research Center nursery site in lata house to evaluate the effects of lime on the availability of phosphorus fertilizer and nutrient uptakes of coffee seedlings. The treatments consists five lime rates (0, 5, 10, 15 and 20 g) 2.5 kg^{-1} and four phosphorus mineral fertilizer rates (0, 400, 600 and 800 mg) 2.5 kg^{-1} of soil. The experiment was arranged in factorial randomized complete block design with three replications. Soil samples were taken before planting and after harvesting. Representative leaf samples were taken and both soil and leaf samples were analyzed. The result reviled that applications of 10g lime and 800 mg P rates improves the soil parameters and nutrient uptake of coffee seedlings under nursery conditions.

Keywords: Coffee, Nitisols, Phosphorus Rates, P Uptakes, Soil Acidity

1. Introduction

Ethiopia is the primary center of origin and diversity of Arabica coffee and production contributions ranks the leading in Africa and 6^{th} in the world [18]. Coffee is largely cultivated in the Southern, South Western, Western and Eastern parts of Ethiopia [12] with 700,447 ha of total land coverage and 469, 091 tons of production per annum [11]. However, the existence of wider genetic diversity of Arabica coffee and its importance in the country's economy, productivity of the crop is very low 0.7 ton ha^{-1} clean coffee as compared to other coffee producing countries [11-18]. Such low level of productivity of the crop stems from erroneous management of the plant during the initial stage of establishment in the field and the use of weak and whippy seedlings with undesirable shoot and root growth for field planting. This emanates mainly from using of improper nursery growing media which are not suitable for germination and seedling growth [3].

Nursery soil management is the first step in coffee seedling production for field planting [1]. However, nutrient availability during nursery period is one of the factors that determine successful production of high quality coffee seedlings. The most coffee production area of the country relies almost exclusively on Nitsols. The most recent survey puts the extent of Nitisols to cover about one million hectares that account for 31% of the agricultural lands in the Ethiopian highlands [14]. The soils are particularly extensive in the south-western and north-central highlands representing 64 and 25% of the agricultural landmass, respectively.

Nitisols are among the most productive agricultural soils along with Vertisols, Luvisols, and Planosols [14]. With having low P contents due to not only the inherent low available content but the high P fixation capacity of the soils [24-27]. Such soil type has a robust effect on P- uptake efficiency, under low P- in acidic soil conditions the growth and developments of plant performances highly affected [13]. One of the important nutrients for coffee is phosphorus, because it causes an increase in root development and plant vigor to ensure the formation of crops with high productivity and low rates of replanting [29] The acidic natures of *Nitisol* soils needs a little amendment of lime was an alternative nursery media for improved selection coffee cultivars of coffee seedling which healthy and vigorous seedlings for transplanting. This was primarily associated to the rise in soil pH and precipitation of the exchangeable Al^{3+} that fixes phosphorous and increase in solubility and availability of soil phosphorus to the seedlings [4]. The research works focused on evaluations of different lime rates on the availability of phosphorus and nutrient uptake of hybrid coffee seedling under nursery condition for vigorous and healthy growth.

2. Material and Methods

2.1. Description of the Study Site

The study was carried out at Jimma Agricultural Research Center nursery site. Located 70° 46' N, latitude and 36° 47' E longitudes with 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°C and 26.11°C respectively. The dominant soil types *Eutric Nitosol* or *Luvic Phaeozem* which was deep and well drained, medium-to-high in exchangeable, and physically and texturally suitable for the growth of coffee [27].

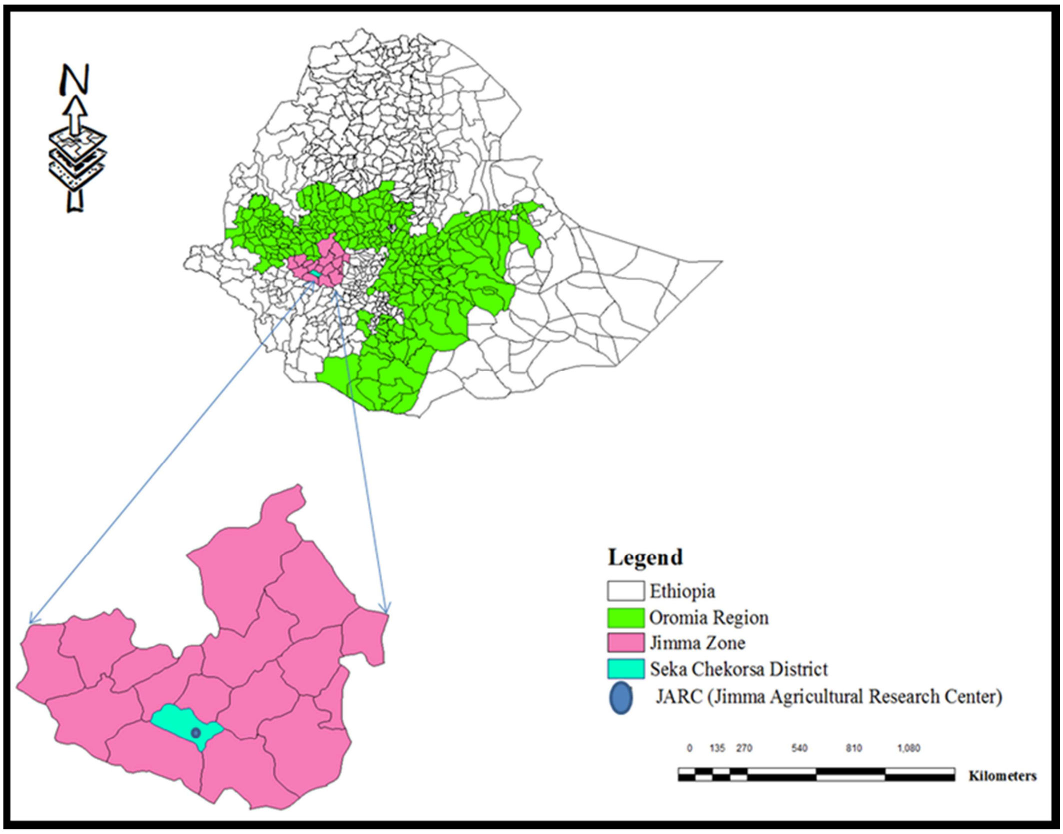

Figure 1. *Map of the study area.*

2.2. Treatment and Experimental Procedures

The experimental treatments consists five lime rates 0, 5, 10, 15 and 20 g 2.5 kg^{-1} and four phosphorus mineral fertilizer rates 0, 400, 600 and 800 mg per pot (2.5 kg^{-1}) of soil. The study was conducted in factorial experiment arranged in a randomized complete block design with three replications. While hybrid coffee (*Coffea arabica* L.) variety (*Gawe*) seeds were sown at the rate of two seeds per pot and thinned to one seedling after the germinated seeds attained a butterfly growth stage. N 540 mg 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. Different phosphorus rates were applied ones at sowing in the form of Triple Super Phosphate (46% P_2O_5). Lime $CaCO_3$ was applied one month before sowing for better incubation. The amount of lime applied at each was calculated on the basis of exchangeable acidity concentration of the soil and crop factor tolerant to soil acidity. (LR, $CaCO_3$ (kg/ha) = (C.F * Ex. Ac *Soil depth*Area*BD*1000)/ (2000 cmole). Where, LR = Lime requirement, BD = Bulk density, Ex. Ac =Exchangeable acidity, C.F = Crop factor tolerance to acidity.

Table 1. *Treatment arrangements.*

Treatment	Lime rate (g per pot)	Phosphorus rate (mg per pot)	Treatment description Lime (g) and P (mg) per pot
T_1	0	0	(0) Lime and (0) phosphorus
T_2	0	400	0) Lime and (400) phosphorus
T_3	0	600	0) Lime and (600) phosphorus
T_4	0	800	0) Lime and (800) phosphorus
T_5	5	0	(5) Lime and (0) phosphorus
T_6	5	400	(5) Lime and (400) phosphorus
T_7	5	600	(5) Lime and (600) phosphorus
T_8	5	800	(5) Lime and (800) phosphorus
T_9	10	0	(10) Lime and (0) phosphorus
T_{10}	10	400	(10) Lime and (400) phosphorus
T_{11}	10	600	(10) Lime and (600) phosphorus
T_{12}	10	800	(10) Lime and (800) phosphorus
T_{13}	15	0	(15) Lime and (0) phosphorus
T_{14}	15	400	(15) Lime and (400) phosphorus
T_{15}	15	600	(15) Lime and (600) phosphorus
T_{16}	15	800	(15) Lime and (800) phosphorus
T_{17}	20	0	(20) L and (0) p
T_{18}	20	400	(20) L and (400) p
T_{19}	20	600	(20) L and (600) p
T_{20}	20	800	(20) L and (800) p

2.3. Soil Laboratory Analysis

Soil particle size analysis was determined using the hydrometer method [7]. Soil bulk density was determined by the undisturbed core sampling method after drying the soil samples in an oven at 105°C to constant weights [6]. Soil pH (Soil reaction) was measured in a 1:2.5 (soil: water) ratio using a glass electrode pH meter [22]. Organic carbon was determined by Walkley and Black methods [32]. Total nitrogen was determined by the Kjeldahl digestion and distillation procedure as described by Van Reeuwijk [31]. Available phosphorus was determined by the readily acid-soluble forms of P were extracted with a HC1: NH_4F mixture (Bray's No. II method) as described by Bray and Kurtz [8]. Cation exchange capacity (CEC) was determined by the ammonium acetate (NH_4Ac) saturation method as described by Bouyoucos [7]. Exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+) Were determined after extracting the soil samples by ammonium acetate (1N NH_4Ac) at pH 7.0 Exchangeable Ca and Mg in the extracts was analyzed using atomic absorption spectrophotometer, while K^+ were analyzed by flame photometer [9]. Exchangeable acidity was determined as the sum of Al^{3+} + H^+. The soil sample extracted with unbuffered 1 *M* KC1, and the sum of Al + H was determined by titration [31]. Percentage base saturation (PBS) was calculated by dividing the sum of the charge equivalents of the base-forming cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) by the CEC of the soil and multiplying by 100.

2.4. Nutrient Uptake (N, P and K)

The nutrient uptake was calculated as the product of the nutrient concentration multiplies with dry matter yield [26]

$$\text{Uptake of NPK} = \frac{\%\ of\ N*P*K*Dry\ matter}{100}$$

2.5. Statistical Analysis

The collected data were analyzed with statistical analysis software (SAS) 9.3 version and Treatment means were separated using Duncan multiple range test at 5% probability level for significantly different parameters.

3. Result and Discussion

3.1. Initial Soil Properties of Nursery Media

The initial soil characters (Table 2) indicated that the soil pH a value of 4.86 was recorded, according to Tekalign [30] considered as strong acidic soil. Paulos [27] reported that coffee soils in south west part of the soil was highly weathered with having low pH and low content of available phosphorus. Exchangeable acidity, were recorded 2.69 cmol (+) kg^{-1}. High exchangeable acidity limits coffee seedling growth through increasing the solubility of Al^{3+} by reducing the availability of P through enhanced P fixation as insoluble compounds of aluminium phosphates [5]. low CEC 18 cmol (+) kg^{-1} and low contents of the basic cations such as Ca^{2+} and Mg^{2+} and K^+ soil nutrients were recorded. The main cause of acidity is the loss of exchangeable bases through leaching from the top soil and is replaced with Al^{3+} ions [10]. The Bray-II extractable available phosphorus was 7.50 mg kg^{-1}, which was far below the critical level for growth of coffee plant, which was described by Melke and Ittana [23] for some Ethiopian soils.

Table 2. *Initial physical and chemical properties of nursery soil.*

Soil properties	Values
Chemical properties	
pH (1:2.5 H_2O)	4.86
Organic Carbon (%)	0.68
Total Nitrogen (%)	0.11

Soil properties	Values
Available. P (mg kg-^{1})	7.50
Exchangeable basic cations (cmol (+) Kg^{-1} soil)	
Exch. Na^{+}	0.06
Exch. Ca^{2+}	4.06
Exch. Mg^{2+}	1.79
Exch. K^{+}	0.81
PBS	37.3
C.E.C.	18
Exch. acidity (cmol (+) kg-^{1})	2.69
Physical properties	
Bulk density	1.17
Clay (%)	31.5
Silt (%)	19.0
Sand (%)	46.5
Textural class	Sandy clay Loam

3.2. Effect of Lime and Phosphorus Rates on Soil pH (Soil Reaction), Exchangeable Acidity, Available Phosphorus and Percentage Base Saturation (PBS)

Soil pH and available P was significantly affected by the interaction of lime and P rates. (Figure 2 and 3) the maximum soil pH 5.99 recorded from 20 g lime rates. pH rate was increased as the increasing rates of lime (Figure 2). Once applied to the soil, lime reacts with hydrogen and Al ions then react with the carbonate (CO_3^{-2}) component of lime to form CO_2, H_2O and Al_2O_3, resulting decreased in acidity [33]. Similar works has been reported that liming has several benefits including, its ability to reduce the toxicity effects of some micro elements by lowering their concentrations and increased soil pH, Ca, Mg and P [31].

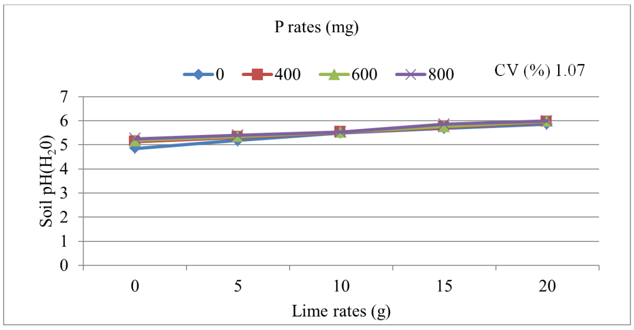

Figure 2. *Interaction effects of lime and P on Soil pH.*

Available P was significantly affected by the interactions of lime and P rates. The maximum 32.69 mg kg^{-1} available P was observed from the plot with combined applications 10 g lime and 800 mg P rate and increased by 410.78% as compared to control plots (Figure 3). an application of lime alleviated Al toxicity and improved soil P desorption capacity from soil fixed-P fraction of acid soils beside increased availability in soil Ca, Mg and N nutrients. According to Lelei [21], the raised soil pH after liming and application of phosphorus, enhanced the decomposition of organic matter and mineralization of N and P. lime at an appropriate rate brings several chemical and biological changes in the soils which are beneficial or helpful in improving crop yields on acid soils.

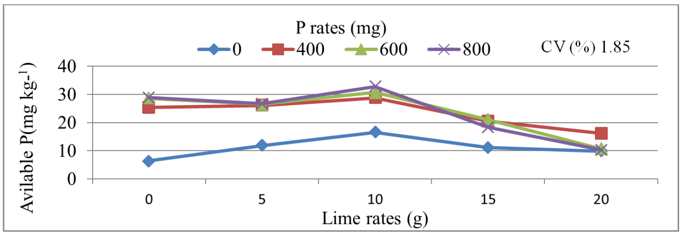

Figure 3. *Interaction effects of lime and P on soil available phosphorus.*

The highest exchangeable acidity was dramatically decreased as the rates of lime increased. The least exchangeable acidity 0.10 cmol (+) kg-^{1} followed by 0.12 and 0.13 were recorded from 20 g lime and 800 mg P, 20 g lime and 600 mg P and 15 g lime and 800 mg P rates which reduced by 96.01% as compared to the control plot (Figure 4). Several Studies have shown that lime reduces exchangeable acidity and Al toxicity and increases soil pH, available phosphorus, calcium and magnesium contents of the soil [20].

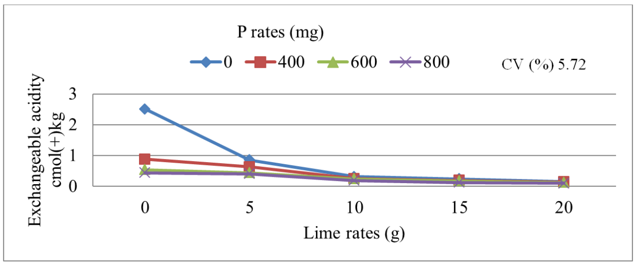

Figure 4. *Interaction effects of lime and P on exchangeable acidity.*

Percentage base saturation (PBS) was significantly ($P< 0.05$) affected by lime and P and their interactions (Figure 5). The highest 80.92% and the lowest 32.83% values of PBS were recorded by addition of 20 g lime and 800 mg P and control treatment respectively. This indicates that applications of lime enhance the level of basic cations and PBS on the soil. Similarly, Athanase [5] described that an amendment of lime was known to actively reduce levels of exchangeable Al within a soil as well as adding nutrients such as Ca, Mg and K and Na. Furthermore, lime amendments can also increase cation exchange capacity (CEC), base saturation (BS) and nutrient availability by raising soil pH.

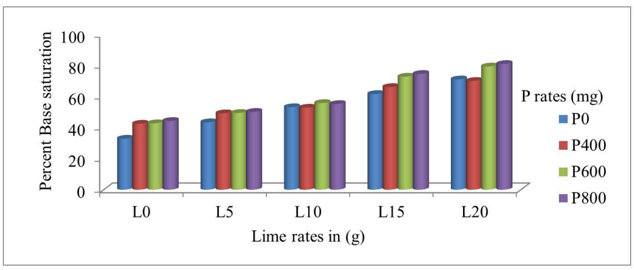

Figure 5. *Effects of lime and Phosphorus on percent base saturations.*

3.3. Effects Lime and Prates on Exchangeable Bases

The exchangeable calcium in the soil was significantly affected by lime and P rates and their interactions. The maximum 16.89 cmol (+) kg^{-1} rate of exchangeable calcium was recorded from 20 g lime and 800 mg P rates while the lowest exchangeable calcium 4.01 cmol (+) kg^{-1} was recorded from control plot (Table 3). Kebede and Dereje [19] reported that liming raises the soil pH by adding calcium and magnesium to soil and causes the aluminium and manganese to go from the soil solution back into solid (non-toxic) chemical forms. The highest value of Exchangeable magnesium 1.89 cmol (+) followed by 1.79 cmol (+) kg^{-1} was recorded from the combined applications of 10 g lime and 800 mg P and 15 g lime and 800 mg P rates. Contrary at the highest lime and P rate 20g lime and 400 mg P; 20 g lime and 600 mg P and 20g lime and 800 mg P rate the exchangeable magnesium 12.11-50.42% decreased as compared to the highest result of the treatments (Table 3). This might be due to over-liming effect, whereby Mg is lost from the topsoil as stated by Somani [28]. The maximum Exchangeable potassium rate of 1.49 cmol (+) kg^{-1} exchangeable K was recorded from combined applications of 10 g lime and 800 mg P rate (Table 3). According to Fageria and Baligar [15], liming acid soils increase soil pH and improve soil K with mineralization of soil from clay particles and enhance retention of K^{+} and thereby decrease K^{+} leaching. Liming increases K^{+} retention in soils by replacing Al^{3+} on the exchange sites with Ca^{2+}, allowing K^{+} to compete better for exchange sites and increasing the effective cation exchange capacity. Similarly, the work Kebede and Dereje [19] showed the significant difference between limed and control plot. The control plot shows the lowest value and deficiencies of potassium in soil. This is the result of insolubility of K^{+} at low pH, leaching easily by high rain fall and replacement by soluble H^{+} and Al^{3+} in water solution. Soil CEC was affected by the interaction of lime and P rates the maximum 24.56 cmol kg-1 was recorded from 20 g lime and 800 mg p rates and the lower 18.37 cmol (+) kg^{-1} recorded from control plots.

Table 3. *The interaction effects of lime and p rates on soil properties.*

Treatment	Total N	OC	Exchangeable			CEC
			K^{+}	Ca^{+2}	Mg^{+2}	
T1. (0) L and (0) p	0.114^{g}	1.38^{l}	0.83^{fg}	4.01^{p}	1.19^{i}	18.37^{m}
T2. (0) L and (400) p	0.120^{fg}	1.43^{k}	0.85^{efg}	5.86^{o}	1.62^{c}	19.31^{l}
T3. (0) L and (600) p	0.141^{fe}	1.43^{k}	0.85^{efg}	6.17^{n}	1.38^{ghf}	19.85^{k}
T4. (0) L and (800) p	0.193^{b}	1.39^{l}	0.86^{efg}	6.93^{m}	1.39^{ghf}	20.71^{j}
T5. (5) L and (0) p	0.138^{fe}	1.45^{k}	0.95^{e}	6.79^{m}	1.65^{c}	20.65^{j}
T6. (5) L and (400) p	0.168^{dc}	1.85^{gf}	0.86^{efg}	7.90^{l}	1.79^{ba}	21.78^{ih}
T7. (5) L and (600) p	0.164^{d}	1.83^{g}	0.87^{efg}	8.17^{k}	1.68^{bc}	22.09^{gh}
T8. (5) L and (800) p	0.158^{de}	1.86^{gf}	1.06^{d}	8.21^{k}	1.75^{bc}	21.82^{ih}
T9. (10) L and (0) p	0.167^{d}	1.52^{ji}	0.90^{ef}	9.22^{j}	1.65^{c}	21.40^{i}
T10. (10) L and (400) p	0.217^{a}	1.99^{cb}	1.19^{c}	9.25^{ji}	1.77^{bc}	22.52^{gf}
T11. (10) L and (600) p	0.216^{a}	2.00^{b}	1.33^{b}	9.48^{i}	1.73^{bc}	22.78^{ef}
T12. (10) L and (800) p	0.218^{a}	2.06^{a}	1.49^{a}	9.75^{h}	1.89^{a}	23.39^{d}
T13 (15) L and (0) p	0.123^{fg}	1.51^{j}	0.82^{fg}	11.54^{g}	1.47^{d}	22.13^{gh}
T14. (15) L and (400) p	0.193^{b}	1.98^{cb}	0.96^{ed}	12.46^{f}	1.45^{edf}	23.34^{d}
T15. (15) L and (600) p	0.193^{b}	1.95^{cd}	0.88^{efg}	13.93^{e}	1.44^{egdf}	23.09^{ed}
T16. (15) L and (800) p	0.192^{b}	1.84^{g}	0.83^{fg}	14.27^{d}	1.79^{ba}	23.88^{c}
T17. (20) L and (0) p	0.120^{fg}	1.55^{i}	0.83^{fg}	13.72^{e}	1.36^{gh}	22.64^{ef}
T18. (20) L and (400) p	0.191^{b}	1.75^{h}	0.81^{fg}	15.55^{c}	1.38^{ghf}	24.03^{bc}
T19. (20) L and (600) p	0.196^{ba}	1.89^{ef}	0.83^{fg}	16.21^{b}	1.37^{gh}	24.46^{ba}
T20. (20) L and (800) p	0.189^{bc}	1.92^{ed}	0.78^{g}	16.89^{a}	1.34^{h}	24.56^{a}
SEM ±	0.0013	0.0023	0.0065	0.0153	0.0044	0.0286
CV (%)	7.58	1.23	6.6.	1.33	2.43	1.21

3.4. Effects Lime and P rates on Coffee Seedling Leaf N, P and K Uptake

The combined application of lime and P fertilizer enhanced the N P and K phosphorus leaf up take of coffee seedlings. The interaction of 10 g lime and 800 mg P followed by 10 g lime and 600 mg P rates showed the maximum N nutrient uptake 13.735 and 11.328 mg $plant^{-1}$ and an increment by 336.03 and 259.61% as compared with control and other treatments respectively (Figure 6). Phosphorous uptakes of coffee seedlings highly affected by applications of lime and different P rates. The interaction 10 g lime and 800 mg P, followed by 10 g lime and 600 mg P rates showed the maximum P uptake 3.831and 3.689 mg $plant^{-1}$ and an increment by 314.16 and 298.81% as compared with control and other treatments (Figure 6). Gillman [16] reported that slight reduction in concentration of P is most likely due to the formation of insoluble compounds of Calcium phosphate and Phosphorus at such high soil pH which consequently could cause reduction in its uptake by the plants.

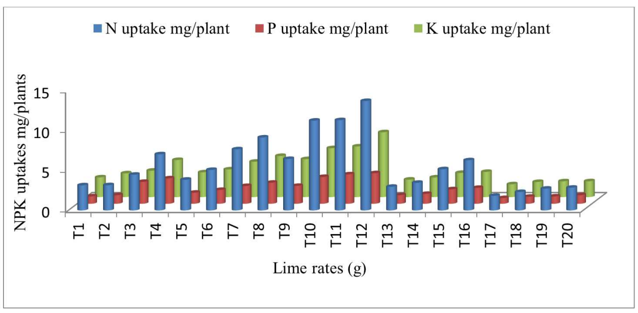

Figure 6. *Coffee seedlings leaf NPK uptakes affected by different lime and phosphorus rates.*

The potassium uptake by leaf of coffee seedling was influenced with combined application of different levels of lime and P rates (Figure 6). The maximum K^+ uptake 8.137 mg K $plant^{-1}$observed from the interaction plots 10 g lime and 800 mg P rats and increased by 229.30% as compared to control and other treatments. At lower pH soils usually excessive in soluble Al and Mn and deficient in P, Ca, Mg and Mo, that may cause their reduced uptake and lead to nutrient imbalances in plants [17].

4. Conclusion

The southern, west and south western parts of coffee production areas highly affected by soil acidity problems. This leads to limit for the optimum coffee seedlings growth, affects the soil nutrient availability and nutrient uptakes of the coffee seedlings. The research conducted revealed that an applications of 10 lime g and 800 mg phosphorus rates improves soil pH, and reduced the effects of exchangeable acidity and improved availability of phosphorus to the soil. Similarly leaf nutrient N, P and K uptakes improved as compared with control treatments. This research result plays a vital role especially for the farmers which grow coffee in acid soil affected areas. To conclude 10 g lime and 800 mg P is recommended to produce healthy and vigrious coffee seedlings for transplanting to the main field.

Acknowledgements

The authors highly acknowledged the Ethiopian Institute of Agricultural Research (EIAR) for the financial support

References

[1] Ade, A., Muliasari. A., Wachjar and Supijatno. 2015. The Growth of Arabica Coffee (Coffea arabica L.) Seedling on Combination of Inorganic-organic Fertilizers and Shading Level. Asian Journal of Applied Sciences, 3 (6): 2321-2893

[2] Anteneh, Netsere. (2015a). Recommendation on pre-sowing Arabica coffee seed management in Ethiopia. *Seed*, *5* (9).

[3] Anteneh Netsere, (2015b). Recommendation on Pre-Sowing Arabica Coffee Seed Management in Ethiopia. *Journal of Biology, Agriculture and Healthcare,* 5 (9): 99–104.

[4] Anteneh, N. (2015b). Dry Matter Production and Partitioning in Arabica Coffee Seedling as Affected by Lime and Phosphorus Mineral Fertilizer at Jimma, Southwestern Ethiopia. *Journal of Biology, Agriculture and Healthcare*, *13*, 95-101.

[5] Athanase, N., Vicky, R., Jayne, M. N., and Sylvestre, H. (2013). Soil acidification and lime quality: sources of soil acidity, its effects on plant nutrients, efficiency of lime and liming requirements. *Agricultural Advances*, *2* (9), 259-269.

[6] Black, C. A., Evans, D. D., White, J. L., Ensminger, L. E., & Clark, F. E. (1965). Methods of Soıl Analysıs. Part I. American Society of Agronomy. *Inc. Publisher, Madison, Winconsin, USA*.

[7] Bouyoucos, G. J. (1962). Hydrometer method improved for making particle size analyses of soils 1. *Agronomy journal*, *54* (5), 464-465.

[8] Bray, R. H., & Kurtz, L. T. (1945). Determination of total, organic, and available forms of phosphorus in soils. *Soil science*, *59* (1), 39-46.

[9] Chapman, H. D. (1965). Cation-exchange capacity. *Methods of Soil Analysis: Part 2 Chemical and Microbiological Properties*, *9*, 891-901.

[10] Chimdi, A. (2015). 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.

[11] CSA (Central Statistical Agency). (2017). Area and production of major crops in the Federal democratic republic of Ethiopia central statistical agency agricultural sample survey, 1: 1-117.

[12] Emana, B. T. (2015). Distribution assessment and pathogenicity test of coffee berry disease (Colletotrichum kahawae) in Hararghe, Ethiopia.

[13] Erel, R., Bérard, A., Capowiez, L., Doussan, C., Arnal, D., Souche, G.,... & Le Marié, C. (2017). Soil type determines how root and rhizosphere traits relate to phosphorus acquisition in field-grown maize genotypes. *Plant and soil*, *412* (1-2), 115-132.

[14] Eyasu, E. (2017). Characteristics of Nitisol profiles as affected by land use type and slope class in some Ethiopian highlands. *Environmental Systems Research*, *6* (1), 20.

[15] Fageria, N. K., & Baligar, V. C. (2008). Ameliorating soil acidity of tropical Oxisols by liming for sustainable crop production. *Advances in agronomy*, *99*, 345-399.

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

[17] Gillman, GP. (1984). Nutrient Availability in Acid Soils of the Tropics Following Clearing and Cultivation, pp. 39-57 In: Proceedings of international workshop on soils. 12-16 September 1983. Townsiville, Queensland Australia. CABI, Danish, pp. 35-46.

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

[19] Kebede, D and Dereje, T. (2017). Effects of liming on physicochemical properties and nutrient availability of acidic soils in Welmera Woreda, Central Highlands of Ethiopia. *Chemistry and Materials Research* 9 (9): 30–37.

[20] Kisinyo, P., Othieno, C., Gudu, S., Okalebo, J. R., Opala, P. A., Maghanga, J. K. and Nekesa, A. O. (2015). Effects of lime, phosphorus and rhizobia on Sesbania sesban performance in a Western Kenyan acid soil.

[21] Lelei, J. J. (1999). The effect of lime, manure, N and P fertilizers on nitrogen and phosphorus availability, microbial biomass and maize yield in an acid soil (Doctoral dissertation, M. Sc. Thesis, Egerton University, Njoro, Kenya).

[22] McLean, E. O. (1983). Soil pH and lime requirement. *Methods of soil analysis: Part 2 Chemical and microbiological properties*, *9*, 199-224.

[23] Melke, A., and Ittana, F. (2015). Nutritional requirement and management of Arabica coffee (Coffea arabica L.) in Ethiopia: National and global perspectives. *Journal of Experimental Agriculture International*, 400-418.

[24] Mesfin, A. (2007). Nature and management of acid soils in Ethiopia. *Addis Ababa, Ethiopia*, *99*.

[25] Muliasari, A. A., & Ade Wachjar, S. (2015). The Growth of Arabica Coffee (*Coffea arabica* L.) Seedling on Combination of Inorganic-organic Fertilizers and Shading Level. *Asian Journal of Applied Sciences*, *3* (6).

[26] Osonubi, O., Mulongoy, K., Awotoye, O. O., Atayese, M. O., & Okali, D. U. U. (1991). Effects of ectomycorrhizal and vesicular-arbuscular mycorrhizal fungi on drought tolerance of four leguminous woody seedlings. *Plant and soil*, *136* (1), 131-143.

[27] Paulos, D, (1994). Mineral Fertilizer of Coffee in Ethiopia. Institute of Agricultural Research, Addis Ababa, Ethiopia. 105p.

[28] Somani, LL. (1996). Crop production in acid soilsoils. Agrotech Publishing Academy, New Delhi 224p.

[29] Taye K. (1998). Response of arebica coffee (*Coffea arebica* L.) to various soil fertility management M. Sc thesis, Alemeya university of Agriculture, pp. 127.

[30] Tekalign T. (1991). Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. *International Livestock Research Center for Africa*, Addis Ababa

[31] Van Reeuwijk, LP. (1992). Procedures for Soil Analysis. 3rd Edition International Soil Reference and information entre Wageningen (ISRIC). The Netherlands P O. Box 353. 6700 AJ Wageningen.

[32] Walkley, A., & 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* (1), 29-38.

[33] White, J. R., Bell, M. J., & Marzies, N. W. (2006). Effect of subsoil acidity treatments on the chemical properties of a ferrosol. In *Proceeding agronomy Conference. Aust. 10th-15th sept.* 2006 pp 10-15.