

Effects of Lime and Phosphorus Rates on Growth of Hybrid Arabica Coffee Seedlings at Jimma, Southwest Ethiopia

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Abstract

Coffee growing soil of southwestern region parts of Ethiopia are classified as Nitisols with having a low pH and highly deficient in phosphorus. A nursery experiment was conducted at Jimma Agricultural Research Center, southwestern Ethiopia to evaluate the effects of lime and phosphorus rates on coffee seedling growth under nursery conditions. 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 the growth of both non-destructive parameters (plant height, girth, number of nodes, internode length, leaf number and leaf area) and Root growth parameters (taproot length, lateral root length, lateral root number, root volume, leaf stem and root fresh weight, of coffee seedlings. The maximum shoot and root extensions were obtained from the interaction of 10 g lime and 800 mg P rates 2.5 kg⁻¹ top soil. On the other hand, applications of P significantly ($P \leq 0.01$) affected soil and plant growth parameters. As P rate increased availability P boosted and plant growth were enhanced. Similarly, an application of lime significantly affected ($P \leq 0.01$) plant growth and enhance nutrient availability up to 10 g, though further applications adversely affect seedling growth and nutrient availability. Hence, combined application of 10 g lime and 800 mg P rate 2.5 kg⁻¹ top soil enhances the optimum growth of coffee seedlings under nursery conditions.

Keywords: Coffee nursery, Coffee seedlings, Exchangeable acidity, Lime rates

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1. Introduction

In Ethiopia currently about 40% of the total arable land was affected by soil acidity, out of this about 27.7 % is moderately acidic and 13.2% is strongly acidic (Adane, 2015). As a result, most of the soils have a pH range of 4.5 to 5.5 and contain low organic matter and also low nutrient availability (Achalu, 2014).

Ethiopia is one of the largest coffee producer in Africa and is the sixth largest coffee producer in the world next to Brazil, Vietnam, Colombia, Indonesia and Honduras, contributing about 4.1 percent of total world coffee production (ICO, 2018). Moreover, it has tremendous impact on economic, social and spiritual life of people of the country and, quarter of the population of the nation to depend directly or indirectly on coffee for its income generation (Girma *et al.*, 2008). According to CSA (2017), the estimated area of land covered by coffee in Ethiopia is about 700,474.69 hectares, whereas the estimated annual national production of clean coffee is about 469,091.12 tons and mainly produced in the southwestern and southeastern parts of the country. At present, Ethiopia has 40 improved (34 varieties and 6 hybrids) and released coffee berry disease (CBD) resistant varieties (Tadesse, 2017).

The bulk of coffee soils in the southwestern region are classified as *Nitisols*, which are highly weathered and originate from volcanic rock and these soils are deep and well drained having a low pH and highly acidic in nature, and have medium to high contents of most of the essential elements and highly deficient in phosphorus (Paulos, 1994; Smithson, 1999; Anteneh, 2015b). Despite there are about 200 million ha of *Nitisols* which affected by soil acidity problems at worldwide about one million hectares that account for 31% of the agricultural lands in the Ethiopian highlands (Eyasu, 2017).

Increased soil acidity causes solubilization of aluminum, which is the primary source of toxicity to plants at pH below 5.5, and deficiencies of P, Ca, Mg, Mo, N, K, and micronutrients (Habtamu, 2015). Therefore, in addition to Al³⁺ toxicity, low P availability to crops is also another factor limiting crop production on acid soils (Kabata, 2001; Abdena, 2013).

Top soil of *Nitisol* with lime and phosphorus fertilizer was an alternative nursery media for improved selection coffee cultivars of coffee seedling which enhances to produced higher dry matter, 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 (Anteneh and Heluf, 2007; Anteneh 2015c). The aim of this work was to evaluate the responses of lime and phosphorus for alleviating soil acidity and optimum hybrid coffee seedlings growth under nursery condition.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted at Jimma Agricultural Research Center (JARC) nursery site. The center is located in Jimma zone Oromiya Regional State, Southwest Ethiopia at a distance of 365 km from Addis Ababa and 12 km from Jimma Town. Geographically lies between $7^{\circ}46' N$, latitude $36^{\circ}47' E$ 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 $11.73^{\circ}C$ and $26.11^{\circ}C$ respectively. *Nitisols* are the dominant reference soil groups in the upper slopes and *Planosols* in the low lying plain areas (DeWispelaere *et al.*, 2015).

2.2. Experimental Materials

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 variety was released in year 2002 and recommended for medium altitude coffee growing areas (Desalegn, 2017). Among all coffee varieties, *Gawe* was the 2nd leading variety in terms of yield performance under research and on-farm field conditions with high quality standard (Tadesse, 2017). For this, ripe red cherries was handpicked at JARC and prepared properly following the standard procedures (Yacob *et al.*, 1996)

2.3. Experimental Procedures

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 540 mg 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 as described by Anteneh (2015b). All the routine pre-and post-sowing nursery practices were applied according to the recommendation (Tesfaye *et al.*, 2005).

2.4. Data collected

Four uniform seedlings in the inner part of each plot were selected when seedlings growth attained for transplanting (six pair of leave) used as representative sample to collect data as described below.

2.4.1. Shoot growth parameter

Plant height (cm): The length of newly developed shoots of the samples was measured from the base to the tip of the shoot using a ruler and the average of plot was taken from each treatment

Girth (mm): Girth of the stem was measured at the base near a medium surface using caliper

Number of leaves: Total number of seedling was counted

Number of node: Number of node per seedling was counted

Leaf area (cm²): Leaf length from petiole to the tip and leaf width at broadest part was measured. Then, intact leaf area per leaf was calculated using the protocol adapted by Yakob *et al.* (1998)

$$Y = K * L * B$$

Where, Y = estimated leaf area

K = constant specific to cultivars and canopy class (0.67)

L = Leaf length (cm)

B = maximum leaf breadth (cm)

Shoot fresh and dry weights (g):- After measuring leaf and stem fresh weights, the same shoot samples were kept in an oven drier (at the temperature of $70^{\circ}C$ to constant weight for 24 hrs. to record dry weights using a sensitive balance and shoot moisture content was calculated from each treatment

2.4.2. Root characteristics

The same four central seedlings were used to record root parameters. Root characteristics was recorded subsequent to the separation of medium from the roots to this end the polythene bags containing the seedlings was immersed in a bucket of water where roots was carefully separated. The roots were washed in clean water and the following root characteristics were recorded.

Root fresh weight (g): Roots was carefully detached and thoroughly washed to remove the soil then weight was

measured using sensitive balance

Tap root length (cm): The length between the collar region and the tip of the primary root was measured and the mean value was recorded by using ruler

Lateral root numbers and length: The numbers of lateral root were counted and length were measured by using ruler

Root volume (ml):- Measured by water displacement method using graduated cylinder half filled with water. The volume of water displaced due to the immersion of each sample was calculated and the average was taken as root volume

Root dry weights (g):- Root fresh weight was measured and immediately put in an oven drier (at the temperature of 70 °C to constant weight) for 24 hrs. Root weights were measured using a sensitive balance and the average was calculated from each treatment

2.4.3. Experimental design and Statistical Analysis

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 were used. 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 (Kamprath, 1984; Kebede and Dereje, 2017). The study was conducted in 5x4 factorial experiment arranged in a randomized complete block design with three replications. All the relevant data was summarized and subjected to analysis of variance (ANOVA) 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 (SAS institute, 2004).

Table 1. Treatment combination and descriptions

Treatment No	Treatment combinations (Lime and P rates 2.5 kg ⁻¹ soil)
1	0gm Lime and 0 mg Phosphorus (Control)
2	0gm Lime and 400 mg Phosphorus
3	0gm Lime and 600 mg Phosphorus
4	0 gm Lime and 800 mg Phosphorus
5	5gm Lime and 0 mg Phosphorus
6	5gm Lime and 400 mg Phosphorus
7	5 gm Lime and 600 mg Phosphorus
8	5gm Lime and 800 mg Phosphorus
9	10gm Lime and 0 mg Phosphorus
10	10 gm Lime and 400 mg Phosphorus
11	10 gm Lime and 600 mg Phosphorus
12	10 gm Lime and 800 mg Phosphorus
13	15 gm Lime and 0 mg Phosphorus
14	15 gm Lime and 400 mg Phosphorus
15	15 gm Lime and 600 mg Phosphorus
16	15 gm Lime and 800 mg Phosphorus
17	20 gm Lime and 0 mg Phosphorus
18	20 gm Lime and 400 mg Phosphorus
19	20 gm Lime and 600 mg Phosphorus
20	20 gm Lime and 800 mg Phosphorus

3. Result and Discussions

3.1. The Shoot Growth of Coffee Seedlings

Lime and phosphorus and their interactions had significant effects ($P \leq 0.01$) on coffee seedling height, girth and internode length (Table 2). The maximum seedling height 11.87 cm, girth 3.26 mm and internode length 1.61 cm recorded from the plots 10 g lime and 800 mg P rates respectively. A combination of lime and phosphorus fertilizer resulted to vigorous plant height than that with lime or P used independently (Table 2). The result was in agreement with Uzoho *et al.* (2010) which reported that lime and phosphorus promote plant growth through improved soil conditions such as increased soil pH, nutrient availability, soil organic matter, soil solution P concentration and decreased aluminum toxicity and micronutrient accumulation.

It is noted that the application of phosphorus resulted in a linear increase of the ratio stem height and stem diameter (girth). Treatment effectiveness on seedlings height, girth and internode length generally increased in the order control, lime, P fertilizer, P fertilizer + lime. This was due to the fact that, lime alleviated plants from Al toxicity, reduced P fixation and increase Ca and P availabilities described by The *et al.* (2006). In agreement with this result, Kisinyo *et al.* (20014) indicated that growth of plant enhanced in acidic soil with additions lime and P fertilizers.

Table 2. The interaction effects of lime and phosphorus rates on the shoot growth of hybrid coffee seedlings

No	Treatment	Plant height	Stem girth	Internode length
T ₁	Control	7.63 ^{kl}	2.46 ^{fg}	1.15 ^h
T ₂	0gm Lime and 400 mg phosphorus	9.80 ^{ef}	2.47 ^{fg}	0.98 ^{ji}
T ₃	0gm Lime and 600 mg phosphorus	10.97 ^{bcd}	2.77 ^d	1.32 ^{def}
T ₄	0 gm Lime and 800 mg phosphorus	11.37 ^{ba}	3.06 ^{bc}	1.41 ^{dc}
T ₅	5gm Lime and 0 mg phosphorus	8.97 ^{ih}	2.88 ^{dc}	1.17 ^{hg}
T ₆	5gm Lime and 400 mg phosphorus	9.33 ^{gh}	2.75 ^{de}	1.29 ^{ef}
T ₇	5 gm Lime and 600 mg phosphorus	10.47 ^{efd}	2.86 ^{dc}	1.38 ^{de}
T ₈	5gm Lime and 800 mg phosphorus	11.27 ^{ba}	3.15 ^{ba}	1.57 ^{ba}
T ₉	10gm Lime and 0 mg phosphorus	10.27 ^{ef}	3.11 ^{ba}	1.40 ^d
T ₁₀	10 gm Lime and 400 mg phosphorus	11.13 ^{bc}	2.92 ^{dc}	1.41 ^{dc}
T ₁₁	10 gm Lime and 600 mg phosphorus	11.60 ^{ba}	3.14 ^{ba}	1.50 ^{bc}
T ₁₂	10 gm Lime and 800 mg phosphorus	11.87 ^a	3.26 ^a	1.61 ^a
T ₁₃	15 gm Lime and 0 mg phosphorus	8.10 ^{kj}	1.88 ⁱ	1.03 ⁱ
T ₁₄	15 gm Lime and 400 mg phosphorus	9.30 ^{gh}	2.36 ^g	1.16 ^{hg}
T ₁₅	15 gm Lime and 600 mg phosphorus	10.03 ^{ef}	2.57 ^{fe}	1.26 ^{ef}
T ₁₆	15 gm Lime and 800 mg phosphorus	10.60 ^{ecd}	2.87 ^{dc}	1.35 ^{def}
T ₁₇	20 gm Lime and 0 mg phosphorus	7.20 ^l	1.69 ^j	0.82 ^k
T ₁₈	20 gm Lime and 400 mg phosphorus	7.73 ^{kl}	2.01 ^{ih}	0.87 ^k
T ₁₉	20 gm Lime and 600 mg phosphorus	8.20 ^{lk}	2.17 ^h	0.91 ^{jk}
T ₂₀	20 gm Lime and 800 mg phosphorus	8.50 ^{ij}	2.50 ^{fg}	1.02 ⁱ
	SEM ±	0.037	0.012	0.006
	CV (%)	3.48	4.21	4.27

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

Lime and phosphorus and their interactions had significant effects ($P \leq 0.01$) on coffee seedling number of nodes, leaf number and leaf area (Figures 1, 2 and 3). The maximum seedlings number of nodes 5.63, leaf number 11.42 and leaf area 13.62 cm² were recorded from the plots 10 g lime and 800 mg P rates respectively. Although additions of lime up to 10 g, improved number of nodes 5.42, leaf number 11.00 and leaf area 10.63 cm² and respectively (Fig 1, 2 and 3). However the increasing rates of lime from 15 to 20 g seedling number of nodes, leaf number and leaf area decreased dramatically (Fig 1, 2 and 3).

This is due to that increased amount of exchangeable calcium that contributed to the rising of soil pH, reduce micro nutrients needed in small amount by the plant such as iron and manganese, and also declined the availability of p nutrient (Kebede and Dereje, 2017).

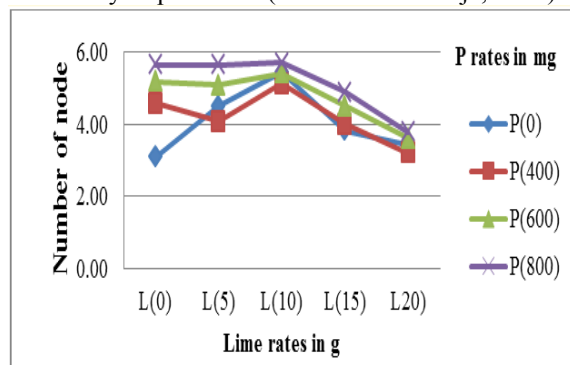


Fig 1 The interaction effects of lime and P rates on node numbers of hybrid coffee seedlings

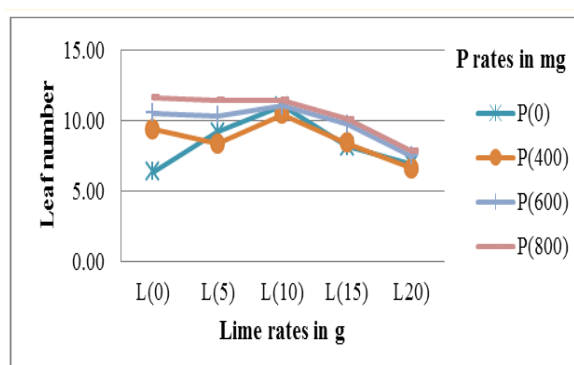


Fig 2 The interaction effects of lime and P rates on leaf number of hybrid coffee seedlings

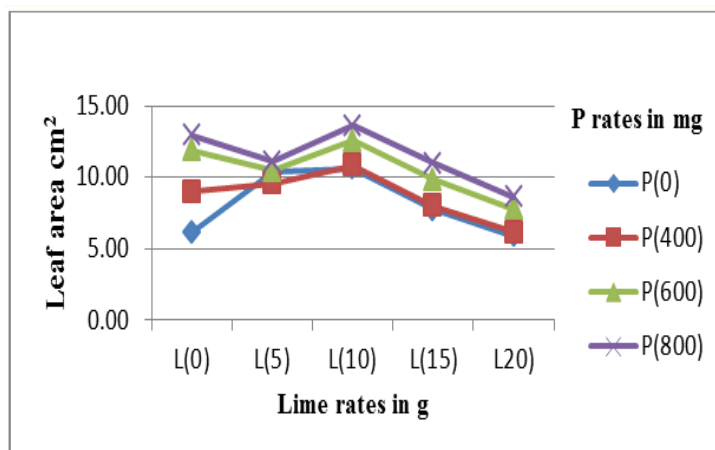


Fig 3 The interaction effects of lime and P rates on leaf area of hybrid coffee seedlings

3.2. The Root growth of coffee seedlings

The root growth parameters of coffee seedling significantly ($P \leq 0.01$) affected with the application of lime and phosphorus and their interaction (Table 3). The maximum Tap root length 23.73 cm, lateral length 9.58 cm, lateral root number 54.07 and root volume 0.97ml recorded from 10g lime and 800 mg P rate. While the lowest recorded from 20 g lime and control plot (Table 3). This could be due to at lower pH, increased the levels of hydrogen (H^+) ions occur to a great extent and Al^{3+} ions in the soil solution react in water (hydrolysis) and the reaction resulted in the release of H^+ and hydroxyl Al ions into the soil solution by which the H^+ ions released that lower the pH of the soil solution, making it very accessible to plants and caused toxicity. Even though this made to coffee seedling growth highly affected and reduced root growth decreases the absorption of nutrients and water and, consequently, the plant showed stunted growth (Ramos and Flores, 2008; Achalu, 2012; Habtamu, 2015). Similarly, at the highest lime rate treated plot there was high amount of calcium contents that made reduce the availability of phosphorus and micro nutrients and also the calcium was toxic to seedling and displaced Mg and K from the soil solution to the exchange site.

According to Asmare *et al.* (2015) an increasing rate response to applied P with increased rates of added lime have been attributed to either an improved rate of P supply by the soil or an improved ability of the plant to absorb P when Al toxicity has been eliminated. However, as increasing level of lime from 15 g lime to 20 g, the length of tap root dramatically decreased to 16.08 cm, lateral length 4.29 cm, lateral root number 37.46 and root volume 0.46ml, respectively (Table 3).

However, an application of phosphorus showed an improved growth rate of the roots parameters (Table 3). The result revealed that the root growth increased proportionally with increasing the level of phosphorus rate 400 mg P, 600 mg P and 800 mg P rates It has been reported that coffee seedlings root growth parameters such as tap root length, lateral root length and lateral root number significantly increased with the increasing rates of phosphorus (Anteneh, 2015c).

Table 3. The interaction effects of lime and phosphorus rates on root growth of hybrid coffee seedlings

No	Treatment	Tap root Length	Lateral root Length	Lateral root Number	Root Volume
T ₁	Control	17.26 ^g	5.46 ^h	38.06 ⁱ	0.56 ^{hg}
T ₂	0gm Lime and 400 mg phosphorus	17.02 ^g	6.10 ^h	40.07 ^{hi}	0.52 ^{hi}
T ₃	0gm Lime and 600 mg phosphorus	18.90 ^f	6.39 ^{gf}	41.26 ^{hegf}	0.66 ^d
T ₄	0 gm Lime and 800 mg phosphorus	20.38 ^d	7.51 ^{ed}	42.62 ^{edf}	0.73 ^c
T ₅	5gm Lime and 0 mg phosphorus	18.31 ^f	6.07 ^g	40.22 ^{hg}	0.59 ^{egf}
T ₆	5gm Lime and 400 mg phosphorus	17.36 ^g	7.57 ^{ed}	40.64 ^{hegf}	0.57 ^{hgf}
T ₇	5 gm Lime and 600 mg phosphorus	21.52 ^{cb}	8.03 ^{cd}	44.16 ^{cd}	0.73 ^c
T ₈	5gm Lime and 800 mg phosphorus	22.00 ^b	8.55 ^{cb}	45.83 ^{cb}	0.83 ^b
T ₉	10gm Lime and 0 mg phosphorus	20.00 ^{cd}	6.57 ^{gf}	41.97 ^{hegdf}	0.63 ^{edf}
T ₁₀	10 gm Lime and 400 mg phosphorus	20.90 ^{cd}	7.63 ^{ed}	43.10 ^{ed}	0.76 ^c
T ₁₁	10 gm Lime and 600 mg phosphorus	22.29 ^b	8.87 ^b	46.97 ^b	0.93 ^a
T ₁₂	10 gm Lime and 800 mg phosphorus	23.73 ^a	9.58 ^a	54.07 ^a	0.97 ^a
T ₁₃	15 gm Lime and 0 mg phosphorus	16.03 ^h	4.80 ^{ij}	36.31 ^{jk}	0.47 ^{ji}
T ₁₄	15 gm Lime and 400 mg phosphorus	17.15 ^g	5.32 ^{ih}	37.49 ^j	0.43 ^j
T ₁₅	15 gm Lime and 600 mg phosphorus	18.73 ^f	7.01 ^{ef}	40.78 ^{hegf}	0.53 ^{hg}
T ₁₆	15 gm Lime and 800 mg phosphorus	19.16 ^{ef}	7.43 ^{ed}	42.62 ^{edf}	0.64 ^{ed}
T ₁₇	20 gm Lime and 0 mg phosphorus	15.01 ⁱ	3.63 ^l	34.39 ^k	0.35 ^k
T ₁₈	20 gm Lime and 400 mg phosphorus	14.46 ⁱ	3.52 ^l	34.47 ^k	0.41 ^j
T ₁₉	20 gm Lime and 600 mg phosphorus	15.27 ^{ih}	3.77 ^{kl}	36.59 ^{jk}	0.44 ^j
T ₂₀	20 gm Lime and 800 mg phosphorus	16.08 ^h	4.29 ^{kj}	37.46 ^j	0.46 ^{ji}
	SEM ±	0.06	0.04	0.13	0.004
	CV (%)	2.49	4.28	2.76	5.59

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

3.3. Fresh weight of coffee seedlings

Lime and P rates and its interaction significantly ($P \leq 0.01$) affected coffee seedlings leaf, stem and root fresh weights. The maximum leaf 1.42 g, stem 0.47g and root 1.04 g fresh weight recorded from the treatment 10 g lime and 800 mg P treated plots (Table 4). While the lowest result were recorded from control and highest lime rate.

Fageria and Moreira (2011); Felipe *et al.* (2014); Anteneh (2015c); Kaio *et al.* (2015) reported that application of lime and phosphorus at the optimum rates gave the maximum fresh shoot and root biomass than lime untreated plot.

Asmare (2015) reported that the maximum fresh shoot biomass was observed with the application of mineral P and lime which increased by 118% compared to the control treatment. This may be due to the lime increasing the pH, reducing the level of exchangeable acidity and Al and creating a favorable environment for root growth.

An application of limes improved leaf, stem and root fresh up to 15 g (Table 4). Although, further application of lime rate 15 g and 20 g reduced the leaf 0.56 g, stem 0.32 g and root 0.37 g fresh weight respectively. This was also reported by Antneh (2015b) and Kaio *et al.* (2015) generally leaf, stem and root fresh weight the lowest was receded from the control plot followed by the highest rate lime and p treated plot. On the other hand application of 400 mg, 600 mg and 800 mg P rates linearly increased root fresh weight of coffee seedlings. Whereas mineral P is an immediate source of water soluble P from the TSP and is important for coffee seedling growth which absorbs P starting from seedling stage. In early stages of development, seedlings absorb P faster from the dissolving fertilizer than from the soil and hence a high proportion of the total P absorbed by young plants is derived from the fertilizer application which helps to develop appropriate root growth.

Table 4. Combined effects of lime and phosphorus on fresh weight of coffee seedlings

No	Treatment	Leaf fresh Weight (g)	Stem fresh weight (g)	Root fresh weight(g)
T ₁	Control	0.73 ^{ih}	0.31 ^l	0.52 ^{ih}
T ₂	0gm Lime and 400 mg phosphorus	0.55 ^{jk}	0.39 ^{hij}	0.55 ^{gh}
T ₃	0gm Lime and 600 mg phosphorus	0.97 ^{gfe}	0.42 ^{hg}	0.64 ^f
T ₄	0 gm Lime and 800 mg phosphorus	1.21 ^{bc}	0.45 ^{fg}	0.72 ^d
T ₅	5gm Lime and 0 mg phosphorus	0.65 ^{ji}	0.38 ^{ij}	0.52 ^{ih}
T ₆	5gm Lime and 400 mg phosphorus	0.82 ^{gh}	0.48 ^{fe}	0.53 ^{ih}
T ₇	5 gm Lime and 600 mg phosphorus	0.83 ^{gfh}	0.51 ^{de}	0.70 ^{ed}
T ₈	5gm Lime and 800 mg phosphorus	1.33 ^{ba}	0.54 ^{dc}	0.79 ^c
T ₉	10gm Lime and 0 mg phosphorus	0.99 ^{def}	0.46 ^f	0.61 ^{gf}
T ₁₀	10 gm Lime and 400 mg phosphorus	1.11 ^{dce}	0.56 ^c	0.70 ^{ed}
T ₁₁	10 gm Lime and 600 mg phosphorus	0.96 ^{gfe}	0.63 ^b	0.94 ^b
T ₁₂	10 gm Lime and 800 mg phosphorus	1.42 ^a	0.74 ^a	1.04 ^a
T ₁₃	15 gm Lime and 0 mg phosphorus	0.51 ^{jk}	0.32 ^{lk}	0.48 ^{ij}
T ₁₄	15 gm Lime and 400 mg phosphorus	0.62 ^{jik}	0.31 ^{lk}	0.44 ^{kj}
T ₁₅	15 gm Lime and 600 mg phosphorus	0.82 ^{gfh}	0.36 ^j	0.54 ^h
T ₁₆	15 gm Lime and 800 mg phosphorus	1.14 ^{dc}	0.41 ^{hi}	0.66 ^{ef}
T ₁₇	20 gm Lime and 0 mg phosphorus	0.48 ^k	0.23 ^m	0.36 ^m
T ₁₈	20 gm Lime and 400 mg phosphorus	0.56 ^{jk}	0.32 ^{lk}	0.37 ^{lm}
T ₁₉	20 gm Lime and 600 mg phosphorus	0.65 ^{ji}	0.35 ^{kj}	0.39 ^{klm}
T ₂₀	20 gm Lime and 800 mg phosphorus	0.73 ^{ih}	0.38 ^{ij}	0.42 ^{kl}
	SEM ±	0.011	0.003	0.004
	CV (%)	11.28	5.96	5.92

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

3.4. The dry weights of shoot and root of coffee seedlings

The maximum leaf, stem and root dry weight affected by lime and P rates the highest leaf 1.42 g stem 0.74 g and root 0.27 g dry weight were recorded from 10 g lime and 800 mg P rates. While the lowest leaf 0.11g, stem 0.08g and root 0.10 were recorded from 20 g lime treated plots (Fig 4, 5 and 6).

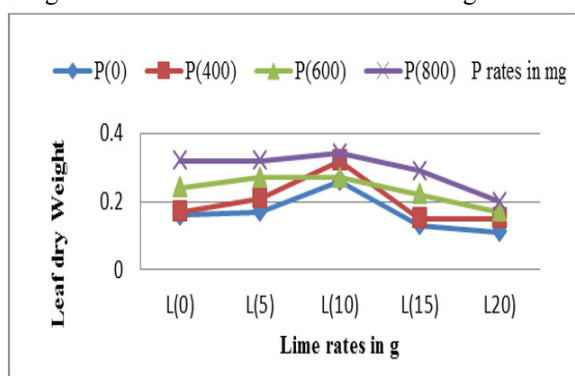


Fig 4 The interaction effects of lime and P rates on Leaf dry weight of hybrid coffee

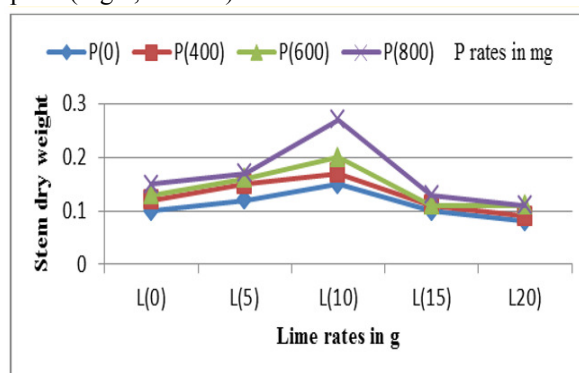


Fig 5 The interaction effects of lime and P rates on Stem dry weight of hybrid coffee

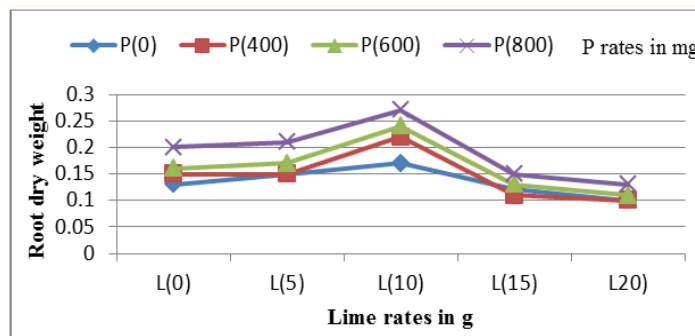


Fig 6 The interaction effects of lime and P rates on Root dry weight of hybrid coffee seedlings

3.5. Shoot to root ratio

The results on (Fig 7) showed that shoot to root ratio of hybrid coffee seedlings affected by the interaction lime and phosphorus rates. Whereas the maximum rate 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. Controversially the least shoot to root ratio 1.31 recorded from 20 g lime rates. Similar work to this reported by Ericsson and Ingestad (1988); Anteneh (2015c) 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.

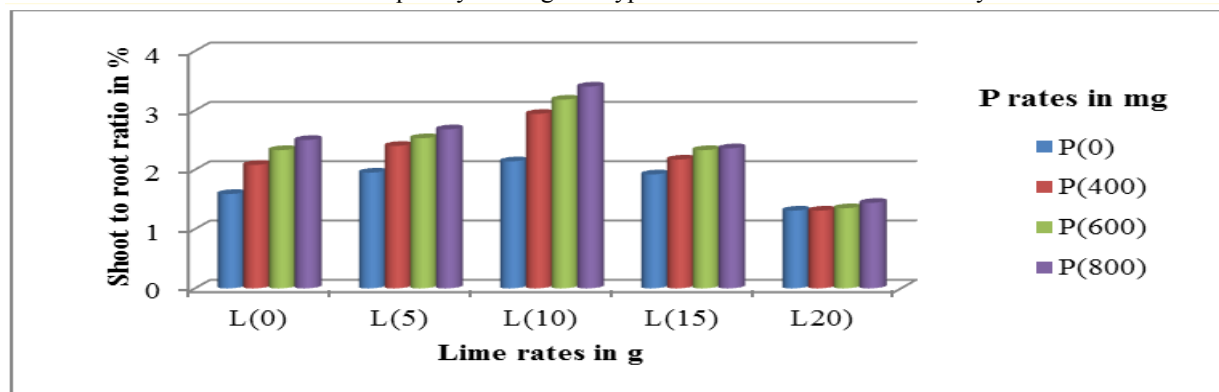


Fig 7 The effects of lime and P rates on Shoot to Root Ratio of coffee seedlings

4. Conclusion

Lime and phosphorus rates and their interactions were enhanced shoot and root growth performances of hybrid coffee seedlings. The interaction of 10 g lime and 800 mg P rate showed significant effects on both destructive and non-destructive growth parameters of coffee seedlings.

The most shoot and root extension seedling growth parameters were significantly increased with the addition of 10 g lime and 800 mg P rate as compared to control and other treatments. Similarly, destructive parameters such as, tap root length, lateral length, lateral root number and root volume although showed highly significant difference among the treatments. Generally, the combined applications of 10 g lime and 800 mg phosphorus rates eliminates the impacts of soil acidity problem and improves the growth parameters of hybrid coffee Seedlings at nursery stages.

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