LIME AND PHOSPHORUS EFFECTS ON SOIL ACIDITY AND MALT BARLEY PHOSPHORUS USE EFFICIENCY IN WELMERA DISTRICT, CENTRAL HIGHLANDS OF ETHIOPIA
#9389

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ABSTRACT

In Ethiopia, about 43% of total arable land affected by soil acidity. Furthermore, phosphorus (P) deficiency is a major constraint to increase crop yields. Efforts to ameliorate the deleterious effects of soil acidity must therefore be accompanied by measures to increase P availability in soils. Therefore, appropriate rate of lime and P fertilizer is an important strategy for improving crop growth in acidic soils. Accordingly, an experiment was undertaken to study lime and P effects on soil acidity and phosphorus use efficiency in 2018 in Welmera district, Oromia National Regional State in central highlands of Ethiopia. Acidic fields that have not been previously reclaimed with lime since last five years were selected, soil sampled and analyzed. Six rate of lime (0, 1.56, 2.34, 3.12, 3.9 and 4.68 t ha^{-1}) and three rates of P (0, 16.5 and 33 kg ha^{-1}) arranged in factorial randomized block design in three replications. The soil pH increased, and exchangeable acidity reduced after amending the soil with lime. Lime and P fertilizer applied have greatly contributed for the soil chemical acidity Improvement and better improvement of phosphorus use efficiency; it is recommended that, application of 2.34 t lime ha^{-1} with 16.5 kg P ha^{-1} fertilizer is good combination in Welmera District.

Keywords: Acid soil, soil pH, yield, exchangeable acidity.

INTRODUCTION

Soil acidity is contributing to crop yield reduction in the country in general, and that of barley production that is expanding in scope and magnitude. About 43% the total arable land affected by soil acidity across different regions of Ethiopia (Behailu, 2015). Acidity related soil fertility problems are major production constraints reducing the productivity of the major crops grown in the country (IFPRI, 2010). Low soil pH severely affects nutrient solubility and particularly enhances phosphorus sorption and precipitation with Al and Fe (Takow *et al.,* 1991 and Hue, 1992). Soil P deficiency is another major constraint to increase yields of barley and wheat in tropical and subtropical regions (Stangel and von Uexhull, 1990). To maintain production levels, P must be added to the soil plant system as mineral fertilizer to replenish what is removed with harvested crop parts (Vlek *et al.*, 1997). However, under acidic conditions applied phosphorus reacts with Fe and Al oxides/hydroxides to form insoluble phosphates, which can’t be accessed by plants (Kamprath, 1984).

Liming of acid soils can increase soil pH, P availability and alleviate Al toxicity to plants and thus maintain a suitable environment for growth of a variety of crops (Lollato *et al.*, 2013; Geremew *et al.*, 2015; Mamedov *et al.*, 2016; Getachew *et al.,* 2017; Geremew *et al*., 2020c). Efforts to ameliorate the deleterious effects of soil acidity must therefore be accompanied by measures to increase available P in soils. Appropriate rate of lime and P fertilizer are therefore an important strategy for improving malty barley productivity on acid soils. Furthermore, there is scarce research information available on the effect of lime and P fertilizer on malt barley P use efficiency. Therefore, the objective was to study lime and P effects on soil acidity and PUE at Welmera District, Central Highland of Ethiopia.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted in 2018 production year in Oromia National Regional State in Welmera District of Holeta Agricultural Research Center (HARC), Robgebeya (RG) and Watabacha Minjaro (WM), found 40, 52 and 25 km, respectively, Northwest of Addis Ababa on the main road to Ambo.

Soil Sampling and analysis

Fields that have not been previously reclaimed with lime since last five years were selected. Soil samples were collected at depth of 0-15 cm at randomly marked sampling points and composited to (0.5 kg), similarly, were collected on plot bases at harvesting and air-dried, ground, and sieved. The soil was analysed following standard procedures for; pH (Van Reeuwijk, 1992), organic carbon Walkley and Black (1934), the total nitrogen (TN) Kjeldahl method (Bremner and Mulvaney, 1982). Available P using the standard Bray-II (Bray and Kurtz, 1945), Exchangeable bases (Ca, Mg and K) and CEC (Okalebo *et al.*, 2002). Exchangeable acidity (Ac) and exchangeable Aluminum (exAl) Rowell (1994) method.

Experimental design, treatments, and experiment setup

The treatments comprise six rates of lime (0, 1.56, 2.34, 3.12, 3.9 and 4.68 t ha^{-1}), the lime rates set were based on Geremew *et al*. (2020 a). Three rates of P (0, 16.5 and 33 kg ha^{-1}) combined in factorial RCBD with three replications. The lime source used was $CaCO_3$; with the purity 95.5% relative neutralizing value 85.6. The plot size was 2 by 2.5 m^2 having 10 rows with 20 cm between rows. The lime was applied 30 days before sowing by broadcasting uniformly on the plots; P was applied by banding at planting and malt barley variety IBON143/3, developed at HARC from ICARDA germplasm and released in 2012 used.

Plant sampling and analysis

Data collection on yield was undertaken as method set by Anderson *et al*. (2002). The sampled malt barley grain and straw were chopped, ground, and then dried until constant weight was attained to determine P contents of the total biomass. For phosphorus analysis, dried and grounded parts of the plants were digested at a temperature of 480^0 C. Finally, phosphorus use efficiency (PUE) was determined as described by Fageria *et al*. (1997).

Data analysis

Collected data were subjected to analysis of variance (ANOVA) using Statistical Analysis Software (SAS, 2003). The difference among significant treatment means were tested using least significant difference (LSD) at 5% level of significance. Before combined analyses test of homogeneity of error variance and normality was checked.

RESULTS AND DISCUSSIONS

The pre plant analysis result indicated that soil reaction was strongly acidic at HARC (4.95) and RG (4.66) and very strongly acidic at WM (4.49) as per soil acidity rate set by Tekalign *et al.* (1991). The concentration of exAl was at toxic level to plants mean value 1.66

cmol$_{(+)}$kg^{-1} soil. The soil OC was very low, 1.69% and TN was moderate, 0.19% (Tekalign *et al.*, 1991), while AP was low, 7.49 mg kg^{-1} as rated by Jones (2003). Soil CEC at all sites was moderate, 19.4 cmol$_{(+)}$kg^{-1}soil according to Hazelton and Murphy (2007).

Exchangeable Ca was moderate at all sites mean value 5.03 cmol$_{(+)}$kg^{-1} soil, while Mg was moderate at HARC (2.27 cmol$_{(+)}$kg^{-1}) and RG (1.91 cmol$_{(+)}$kg^{-1} soil) and low at WM (0.91 cmol$_{(+)}$kg^{-1} soil). Exchangeable K content was high with mean value of (1.32 cmol$_{(+)}$kg^{-1} soil) according to rating by FAO (2006). Generally, the analysis result indicates that OC and available P contents of soils of all the experimental sites were low and the soil reaction acidic.

Selected soil chemical properties after harvesting

The results of soil analysis after crop harvest are depicted in Fig. 1 and 2. The exchangeable acidity (Ac) and exAl after harvesting. The pH of the soil and AP of the soil increased with application of lime at all sites. Contrary to this the soil Ac and Al decreased with increased application of lime. The lowest Ac and exAl were recorded for plots treated with lime at the rate of 4.68 t ha^{-1} at all sites after harvesting. The exchangeable Al recorded was comparable with lime applied at the rates of 3.12 and 3.9 at RG. Increased application of lime and P fertilizer contributed for increased AP in all the study area, but application of P fertilizer at the rates of 33 kg ha^{-1} resulted in the highest AP after harvesting at HARC, RG and WM but was comparable to 16.5 kg ha^{-1} P applied. (Fig. 2).

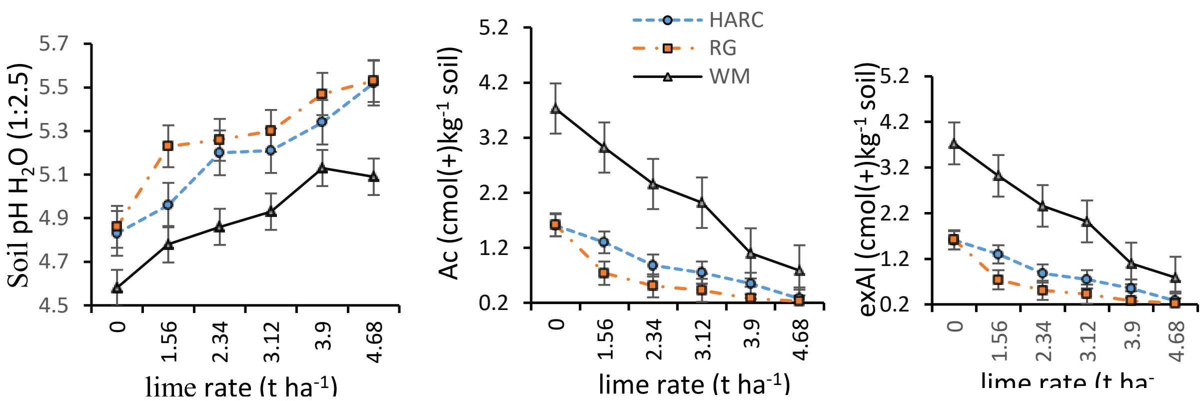

Fig. 1. Soil reaction and exchangeable acidity as affected by application of lime exchangeable Al.

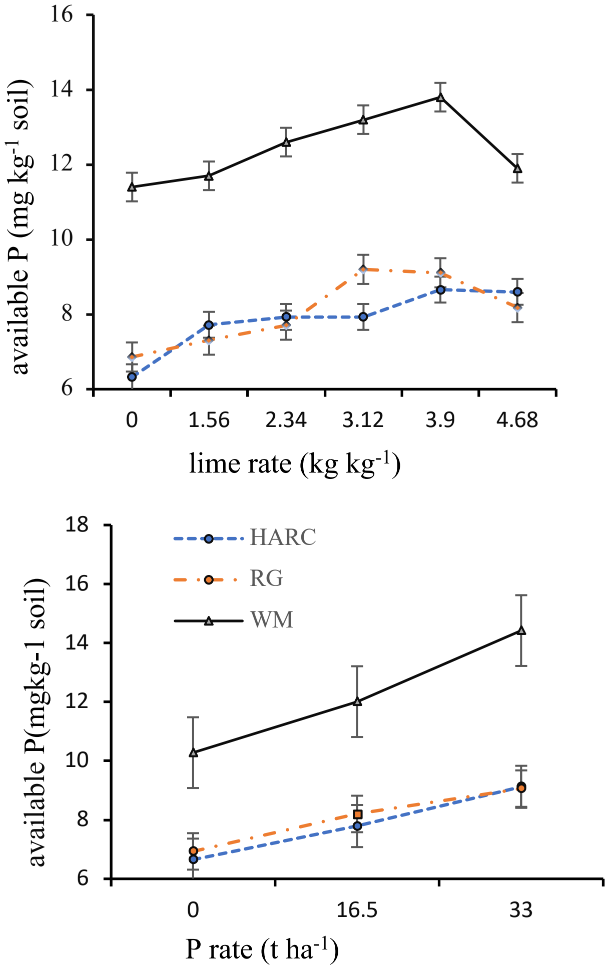

Fig. 2. Soil available phosphorus as affected by application of lime. HARC-Holeta Agricultural Research Center, RG-Robgebeya, WM-Watabacha Minjaro, Ac-Exchangeable Acidity, exAl- Exchangeable aluminum.

Soil reaction increased with increased application of lime whereas the exchangeable acidity and aluminum deceased. This indicates that applied lime has neutralized the acidity and increased pH, lowered the Ac and exAl. Getachew *et al.* (2017) found that amelioration of soil acidity with lime amendment which facilitates detoxification of Al and Mn activity. Detoxification of Al can be achieved by increasing soil pH which in turn certainly results in decrease of Al solubility thereby minimizes its toxic effect on plants (Geremew et al., 2020b). Peter (2017) also reported that application of lime significantly reduced the Ac compared to plots that were not treated by lime.

Phosphorus use efficiency

The phosphorus use efficiency increased with increased rate of lime up to 2.34/16.5 and 3.9/16.5 (t ha^{-1} by kg ha^{-1}) at HARC and RG, respectively. At WM, independent application of lime and P fertilizer affected phosphorus use efficiency of malt barley. Statistically superior PUE were recorded on plots treated with lime and P fertilizer at the rates of 2.34 t ha^{-1} and 16.5 kg ha^{-1}, respectively compared to the higher rates of P fertilizer (Table 1).

Table 1. Phosphorus use efficiency of malt barley as affected by the interaction of lime by phosphorus.

	Lime rate (t ha^{-1})												Lsd	Mean
	---0---		**---1.56---**		**---2.34---**		**---3.12---**		**---3.9---**		**---4.68---**			
	Phosphorus rate (kg ha^{-1})													
	16.5	33	16.5	33	16.5	33	16.5	33	16.5	33	16.5	33		
HARC	13.8^{cd}	23.4^{bc}	21.3^{bc}	22.1^{bc}	51.7^{a}	37.61^{ab}	37.6^{ab}	25.5^{bc}	36.0^{ab}	34.4^{abc}	52.3^{a}	33.6^{abc}	20.7	22
RG	7.5^{ef}	12.4^{def}	11.8^{def}	19.4^{cde}	29.6^{abc}	17.7^{cde}	38.5^{ab}	11.16^{def}	43.3^{a}	12.9^{def}	42.1^{a}	26.0^{bcd}	15.3	15

Means with the same letter in the same row are not significantly ($p \leq 0.05$) different from each other. HARC-Holeta Agricultural Research Center, RG-Robgebeya, Lsd-List significant difference.

The P use efficiency (PUE) of malt barley per unit of P application was decreasing but increasing with increased application of lime (Table 1). Lower PUE was recorded at higher P rates under all lime rates applied at all sites. Similarly, Rahim *et al.* (2010); Shabnam and Iqbal (2016) noted that elevated P application has significantly reduced the phosphorus use efficiency of crops; which is attributed to reductions in P utilization efficiency of the plant as reported by Sandana and Pinochet (2014). Furthermore, Bolland (1992) indicated that when plants are exposed to stress, P uptake is reduced, and phosphorus use efficiency increased.

CONCLUSIONS

Application of lime improved soil acidity status of the soil. The pH of the soils increased, while Ac and exAl decreased with liming. Lime and P fertilizer applied have greatly contributed for improvement of soil acidity and phosphorus use efficiency of malt barley and recommended that, 2.34 t ha^{-1} lime by 16.5 kg ha^{-1} P fertilizer are good combination in Welmera District.

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