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Response Wheat (Triticum aestivum L.) to Liming of Acid Soils under Different Land Use Systems of Loma Woreda, Dawuro Zone, Southern Ethiopia

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Abstract
Soil acidity problem is among soil degradation constraints to improve crop production and productivity in high rainfall regions of Ethiopia in general and in study area in particular. A greenhouse pot experiment was undertaken to evaluate wheat crop response to the applications of different rates of agricultural lime in acidic soils under different land uses (forest, grazing and cultivated) of the study area. The experiment employed 3×6 factorial combination of three land use types and six rates (0, 2, 4, 6, 8 and 10 t ha^{-1}) of agricultural lime as treatments in a completely randomized design with three replications. The interaction of different land use types and applied lime rates very highly significantly ($P \leq 0.01$) influenced plant height, grain yield, total dry biomass weight, and harvest index however, insignificantly ($P \leq 0.05$) influenced days to 50% crop emergence, grain filling and physiological maturity, number of tillers and effective tillers each per plant, thousand kernel weight and P uptake. The responses of wheat to different lime rates and the yield advantages obtained differed from one land use type to another. Applications of lime, organic and inorganic fertilizers and crop rotation especially in the cultivated lands may enhance the productivity of the soils and the yield advantage of the crops.
Keywords: Loma *woreda,* Wheat, Soil acidity, Lime rate, Land use types.

INTRODUCTION

Wheat (*Triticum aestivum* L.) was among the first of the domesticated food crops and it has been the basic staple food for most of the world for more than 10,000 years. According to the FAO (2012), about 650 million tons (t) of wheat was produced from 217 million hectares (ha) in 2010 with a productivity level of about 3 t ha^{-1}. In Ethiopia, wheat is largely grown in the highlands of the country. The major wheat producing areas in Ethiopia are located in Arsi, Bale, Shewa, Ilubabor, Western Hararghe, Sidama, Tigray, Northern Gonder and Gojam Zones (Bekele *et al*., 2000**)**. National average productivity of wheat was 21.1 q ha^{-1} (ECSA, 2012/13) which is relatively low due to the use of unimproved varieties, poor weed management practices, the prevalence of aggressive and virulent crop pathogens, depletion of soil nutrients, low level of chemical fertilizer usage, and the unavailability of other modern crop management inputs (Hoveland, 1980).

In southern region, Alisols, Nitisols and Fluvisols are among dominant acidic soils. Hossana, Soddo, Chencha, and Hagereselam are some of the reported areas that are severely affected by soil acidity in the region. A number of adverse effects such as loss of crop diversity, decline in the yield of existing crops, lack of response to ammonium phosphate and urea fertilizers, and complete failure of crop yield were reported by (Wassie and Shiferaw, 2009). Research results showed that on Alisols of Chencha, barley, wheat and other crops yields are too low or zero even under application of optimum rate of NP fertilizers (Wassie and Shiferaw, 2011). Liming is an effective and widespread practice for improving crop production on acid soils (Fageria and Baligar, 2003). Usually, liming acidic soils improve soil physical and chemical properties and biological activities (Fageria and Baligar, 2005). Yields of the major cereal crops, particularly barley, are as low as 0.5 Mg ha^{-1} partly as a result of soil acidity. Improving the soil pH by applying lime, N, and P has increased yields by threefold (Desta, 1987).

For Dawuro Zone, Southern Ethiopia, wheat is one of the major cereal crops produced for the purposes of both consumption and marketing. The wheat variety kekeba is a nationally released variety, which is currently under production. It was introduced to the proposed study areas lately and has got good acceptance and yield performance as compared to other high yielding varieties of wheat. However, the response of this variety to different levels of liming has not been experimentally worked for the study area in particular. Loma *Woreda*, Dawuro Zone, has severe yield reduction problems: one reason for reduction is said to be soil acidity problem. Soil acidity may arise from crop residue removal, leaching of basic ions (Ca^{+2}, Mg^{+2}, K^{+}, Na^{+}) since the area experiences a high annual rainfall and poor soil management practices especially in cultivated fields. Hence, the overall objective of this study was to evaluate wheat crop response to the applications of different rates of liming material in acidic soils under different land use types of the study area under greenhouse conditions.

MATERIALS AND METHODS

Description of the Study Area

Location, Climate and Soil

The study was conducted in Loma *Woreda*, Dawuro Zone of Southern Ethiopia. Geographically, the study area lies between 6°54′29.96" to 6°55′16.78″ N and 37°13'49.10″ to 37°14'18.05" E. It is at about 500 km south west of Addis Ababa, the capital of Ethiopia (Figure 1).

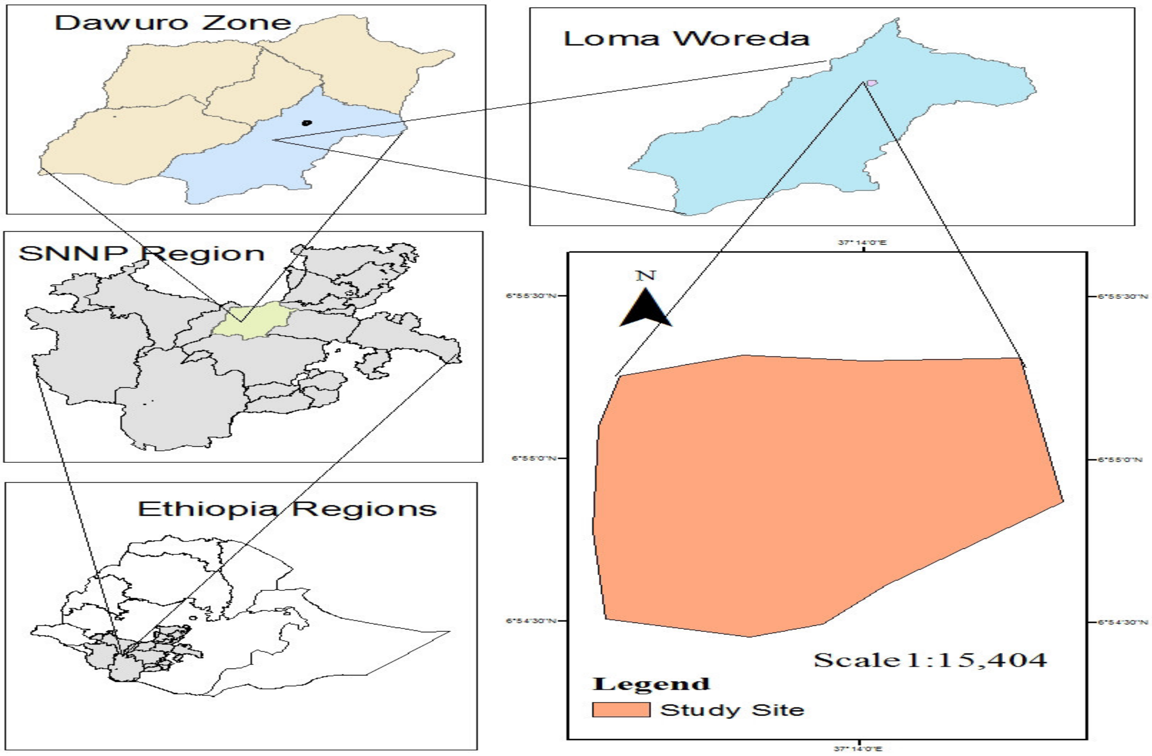

Figure 1. Location map of the study area.

The study area lies between 2286 and 2516 masl receiving a total annual rainfall range from 1355.4 to 2565.6 mm with mean monthly temperature varying from 11.7 to 23.5°C. The rainfall is a bimodal type: the short rainy season is between March and May, and the long between June and September (Figure 2). According to Tefera *et al.* (1999), the geology of the study area is abundant with rhyolites and trachy basalts mainly overlying in the Precambrian basement and tertiary volcanism. Most of the area is mountainous, having well drained and moderately weathered brown soil (Nitisols) and Orthic Acrisols (BoPED, 1998).

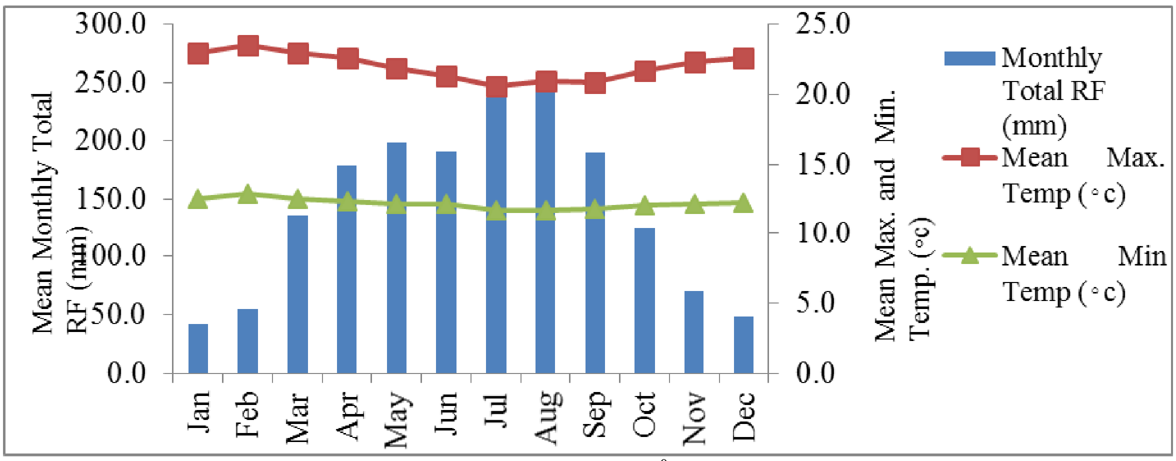

Figure 2. Mean monthly minimum and maximum temperatures (^{0}C) and mean monthly total rainfall (mm) of the study area recorded for the year from1999-2010.
Source: National Meteorological Agency; Gessachare station.

Land Uses and Farming Systems

Cultivated land uses are areas cultivated for annual crops production having very few scattered trees deliberately left as traditional agro-forestry trees. The problem of cultivated lands on the study areas are being on steeper slopes and losing their depth and fertility due mismanagement. The grazing land uses include areas comprising of private lands with little or no vegetations which are used for livestock grazing and brewing purpose. Forest land use considered in the study are areas covered with long and dense trees with dense indigenous natural forest. It is under constant pressure due to the expansion of agricultural lands. The natural vegetation is shrunk near the bottom of high mountains, course of rivers and around the churches.

The farming systems of the area are predominantly subsistence farming based on mixed crop-livestock production. Tillage practices involve a simple oxen-plough that cultivates the soils to a shallow depth. The dominant crops grown in the study area include legume crops (faba bean, lentil and field peas), cereal crops (wheat, rye, barley, maize), perennial crops such as Enset (*Ensete ventricosum* L.*),* coffee, different agro-forestry tree species and eucalyptus plantations and root crops (potatoes and taro) and others. The scattered trees in the cultivated lands are preserved from the original forest during clearance, which are indicator of previously existing forest in that area (LWADO, 2013).

Site Selection and Soil Sampling for Laboratory Analysis

A preliminary survey and field observation was carried out in order to have general information about the land forms, land uses, topography and vegetation cover of the study site. Accordingly, three major representative land use types (forest, grazing and cultivated lands) from the study area, which are adjacent to each other, were identified based on their history and occurrence at different landscape positions. Undisturbed core and disturbed composite surface (0-20 cm) soil samples were collected randomly from three sites of each land use system and subjected to analysis of selected soil physico-chemical properties. Eighteen to twenty three sub-samples were collected and mixed thoroughly to make composite samples according to the variations in the field. The undisturbed soil samples were used to determine bulk density; while the disturbed composite soil samples were analyzed for particle size distribution, pH-H_2O, organic carbon, total N, available P, exchangeable acidity, exchangeable bases, and cation exchange capacity. Analysis of soil samples was carried out at the Haramaya University Soil Chemistry Laboratory.

Soil Sample Collection and Preparation for Pot Experiment

A composite surface (0-20 cm depth) soil samples were collected from each land use types (forest, grazing and cultivated lands) of the study site. Fifty four polyethylene pots filled with 2 kg acidic soils per pot was prepared for establishment of a greenhouse pot experiment. Agricultural lime was collected from the Dire Dawa National Cement Factory S.C, Ethiopia. Its calcium carbonate equivalent as determined by the acid neutralization method was 91.5%.

Table 1. Selected physico-chemical properties of the experimental soils.

Soil properties	Land use types		
	Forest	Grazing	Cultivated
Sand (%)	24.33	25.67	31.67
Silt (%)	33.78	35.00	34.56
Clay (%)	41.89	39.33	33.77
Bulk density (g cm^{-3})	1.07	1.36	1.15
pH-H_2O (1:2.5)	5.11	4.86	4.60
Organic matter (%)	7.33	4.21	1.72
Available Phosphorus (ppm)	10.18	6.95	5.22
Exchangeable Ca ($cmol_{(+)}$ kg^{-1})	5.82	5.22	2.66
Exchangeable Mg ($cmol_{(+)}$ kg^{-1})	4.26	3.30	1.42
Exchangeable K ($cmol_{(+)}$ kg^{-1})	0.51	0.38	0.20
Exchangeable Na ($cmol_{(+)}$ kg^{-1})	0.45	0.34	0.19
Cation exchange capacity ($cmol_{(+)}$ kg^{-1})	29.76	26.40	18.16
Percent Base Saturation (%)	37.26	35.07	24.63
Percent Acid Saturation (%)	26.51	42.98	68.92

Experimental Design and Planting

To evaluate the responses of wheat to lime rates of acidic soils from three different land use types, a green house pot experiment involving 2 kg of surface (0-20 cm) soil was conducted. Six lime rates (0, 2, 4, 6, 8 and 10 tons ha^{-1}) were mixed thoroughly on a dry and clean tray, potted and the pots were placed in a green house. After one month of incubation with regular watering as required, all the pots were planted.

The study involved 3×6 factorial combination of three land use types (forest, grazing and cultivated lands), and six rates (0, 2, 4, 6, 8 and 10 tons ha^{-1}) of agricultural lime as treatments. The experiment was then laid down in a completely randomized design (CRD) with three replications. The test crop that was used is wheat (variety kekeba). Twelve (12) seeds of the test crop per pot were planted in a greenhouse at the Haramaya University and thinned to 6 seedlings per pot at 14 days after seedling emergence.

Crop Data Recording

Days to 50% crop emergence, grain filling and physiological maturity were recorded when 50% of the plants reached their respective phenological stages. Numbers of tillers per plant in replicates was determined from three randomly selected plants of all pots at late tillering stages, whereas plant height of three randomly selected plants in each pot was measured using a ruler from the base to the tip of the owns at the late heading stage. Yield components were determined from randomly selected representative samples in replicates per net pot. Number of tillers and number of effective tillers each per plant, grain yield and total above ground dry biomass, 1000 kernel weight and harvest index were determined. Harvest index was obtained as the ratio of the grain yield per pot to the total above ground dry biomass including the grain yield. Grain yield per pot was determined after carefully separating the grain from the straw and cleaning and adjusting to 12.5% seed moisture content using a hand seed moisture tester instrument. Plant P uptake was analyzed from an extract obtained through calcinations (wet digestion) of the tissue samples which were dried and ground to pass a standard mesh size. Finally, it was quantified using spectrophotometer at 460 nm wavelength after adding molybdate and metavandate for color development as described by Woldeyesus *et al.* (2004).

Data Analysis

Data recorded were subjected to analysis of variance (General Linear Model (GLM) procedure) using SAS software version 9.1 (SAS Institute, 2004) to test differences in treatment combinations for crop parameters. For statistically different crop parameters, means of treatment combinations were separated using the Duncan's Multiple Range Test (DMRT) comparison at $p \leq 0.01$ or $p \leq 0.05$.

RESULTS AND DISCUSSION

Days to 50% Crop Emergence, Grain filling and Physiological Maturity

About 91.67% emergence was achieved regardless of the land use types and applied lime, and seedlings from all pots, reached 50% emergence after 4 days. The interaction effects of lime rates and land use types were insignificant on number of days to 50% crop emergence, but statistically significant *($P \leq 0.01$)* differences have been observed due to the main effects of applied lime rates (Table 2). Plants in the pots applied with high rates (6, 8 and 10 t ha^{-1}) of lime emerged early than those that were not treated with lime (0 t ha^{-1}) and treated with lowest rate (2 t ha^{-1}) of lime in pot with soils from all considered land use types (Table 4).

Research finding by Mekonnen *et al.* (2014) in acidic soils of Gozamin *Woreda*, North-Western Ethiopia, indicated wheat emergence between 5 and 7 days of planting and days to emergence were significantly affected by 2.2 t ha^{-1} lime. The same authors reported that lime hastened early emergence of wheat. Once the germination process is set, seedling emergence might take less than a week, depending on soil temperature, moisture availability and seeding depth (Quinones, 1997).

It was also observed that the number of days to 50% grain filling was significantly ($p \leq 0.01$) influenced by the main effects of land use types and lime rates (Table 2 and 4), however the interaction effects of land use types and lime rates showed no significant effects. Plants in the pots amended with highest lime rate required relatively less days to reach to 50% of grain filling compared those that were un-amended and applied with lowest lime rate irrespective of land use types. Compared to other land use types, plants in the pots with soils from cultivated lands required highest numbers of days to reach to 50% grain filling (Table 5).

Similarly, significant differences ($p \leq 0.05$) due to the main effects of lime application and land use types were observed in the pots with respect to plant maturity (Table 2 and 4), but no significant differences were observed due to the interaction effects. Plants treated with lime, particularly at the highest rates of lime (8 and 10 t ha^{-1}) required relatively less days to reach to 50% physiological maturity compared to the plants without lime in all land use types. Lime applications at the rates of 8 and 10 t ha^{-1} had significantly *($P \leq 0.01$)* hastened days to 50% physiological maturity (Table 4). According to the finding of this study, compared to other land use types plants in the pots with soils from forest land use types required less numbers of days to reach to 50% physiological maturity which became yellow and matured early (Table 5).

Table 2. Mean square estimates for crop phenological and yield parameters of wheat on different land use types

Crop parameters	Mean squares for sources of variation				
	LUT (2)	LR (5)	LUT*LR (10)	EMS (34)	CV (%)
PH (cm)	1301.48^{***}	65.70^{***}	0.64^{*}	0.28	1.00
DE	0.17^{ns}	1.78^{***}	0.07^{ns}	0.05	5.43
DGF	11.68^{***}	7.45^{***}	0.12^{ns}	0.35	0.82
DPM	28.13^{***}	13.09^{***}	0.23^{ns}	0.57	0.81
NT	2.46^{***}	11.48^{***}	0.10^{ns}	0.15	10.39
NET	0.07^{ns}	5.98^{***}	0.05^{ns}	0.07	11.58
GY(g pot^{-1})	4.26^{***}	1.18^{***}	0.005^{*}	NS	1.31
TDBY (g pot^{-1})	44.13^{***}	2.42^{***}	0.03^{**}	NS	0.61
TKW (g)	16.31^{***}	1.71^{***}	0.09^{ns}	0.13	1.68
HI (%)	10.36^{***}	26.17^{***}	0.04^{ns}	0.09	1.30
P-uptake(mg pot^{-1})	22.90^{***}	2.86^{***}	0.01^{ns}	0.02	2.19

LR = Lime Rate (t ha^{-1}), LUT = Land Use Type, EMS = Error Mean Square, CV = Coefficient Variation; PH = Plant Height(cm), DE = Days to 50% Emergence, DGF = Days to 50% Grain Filling, DPM = Days to 50% Physiological Maturity, NT = Number of Tillers per plant, NET = Number of Effective Tillers per plant, GY = Grain Yield (g pot^{-1}), TDBM = Total Dry Above Ground Biomass Yield (g pot^{-1}), TKW = Thousand Kernel Weight (g) and HI = Harvest Index (%), P-uptake = Phosphorous uptake (mg pot^{-1}); Number in parentheses = Degree of Freedom; * = significant at* $p \le 0.05$, *** and *** = highly significant at* $p \le 0.01$ *and ns = non significant at* $p \le 0.05$

In line with this reports, Osunduwa *et al.,* (2013) also found that liming reduces P sorption capacity of acidic soil thereby increasing P availabilities of native soil and fertilizer, consequently enhancing early maturity. Liming reduces Al concentration thus increase the availability of certain nutrient thereby improving plant growth. Total root length of plant was restricted at lower pH, and thus the un-amended soil showed reduced root length as compared with lime-amended soil (Harling *et al.,* 2011; Achalu *et al*., 2012).

Plant Height

Analysis of Variance (ANOVA) revealed that the interaction effects of lime rates and land use types were significant *($P \le 0.05$)* on plant height (Table 2). The plants in the control pots were shorter than the treated ones on soils from all land use types. A maximum of 64.51 cm mean plant height was recorded on soils of forest land at lime rate of 8 t ha^{-1}. However, the highest mean plant height was recorded on soils of grazing and cultivated land at 10 t ha^{-1} lime rate (Table 3). There was continuous and significant increase of plant height in response to the increase in applied lime rate depending on the land use types.

The significant wheat plant height increment in response to the increasing lime rates on acidic soils of all land use types over the control is because of the lime's ability to neutralize acidic soil toxicity effect and increase soil nutrient availability by enhancing mineralization. Liming might have reduced the detrimental effect of soil acidity on plant growth due to high concentration of H^+ and Al^{3+} ions in these acid soils in all land use systems. Activities of exchangeable basic (Ca^{2+}, Mg^{2+} and K^+) cations; orthophosphate (H_2PO_4), nitrate (NO_3^-) and sulfate (SO_4^{2-}) anions with soil organic matter content and their availability to plant roots might be hampered by acidifying ions (Thomas and Hargrove, 1984; Abreha *et al.,* 2013).

Table 3. Interaction effects of lime rate and land use types on the plant height of wheat

Lime Rate (t ha^{-1})	Land Use Types		
	Forest Land	Grazing Land	Cultivated Land
	Plant Height(cm)		
0	56.00^{d}	48.76^{g}	40.46^{j}
2	61.86^{c}	54.14^{f}	45.10^{i}
4	62.82^{b}	54.41^{ef}	45.89^{hi}
6	63.74^{a}	55.03^{de}	46.39^{h}
8	64.51^{a}	55.29^{de}	46.60^{h}
10	64.25^{a}	55.44^{d}	46.71^{h}

*Interaction means across all columns and rows followed by the same letter are not significantly different at P≤0. 01.

Number of Tillers and Number of Effective Tillers each per plant

As it is observed from ANOVA, the interaction effects of land use types and lime rates are not statistically significant *($p \le 0.05$)* on number of tillers per plant, however the applied lime and land use types have showed significant effect (Table 4 and 5). Plants in the pots that were not amended with lime produced lowest numbers of tillers per plant than the amended ones. The plants in pots with soils which received the lime rate of 8 and 10 t ha^{-1} produced highest numbers of tillers per plant. Compared to the other considered land use types pots with soils from cultivated land use type produced relatively lowest number of tillers per plant (Table 5).

Table 4. Effects of lime rates on phenological parameters of wheat

LR (t ha^{-1})	PH (cm)	DE	NT	NET	DGF	DPM
0	48.41^{d}	5.00^{a}	1.78^{d}	1.00^{e}	73.33^{a}	95.00^{a}
2	53.71^{c}	4.78^{a}	3.22^{c}	1.78^{d}	73.11^{ab}	94.56^{ab}
4	54.37^{b}	4.22^{b}	4.00^{b}	2.11^{c}	72.67^{bc}	93.89^{b}
6	55.05^{a}	4.00^{b}	4.44^{a}	2.89^{a}	72.11^{cd}	93.11^{c}
8	55.38^{a}	4.00^{b}	4.67^{a}	3.00^{a}	71.56^{de}	92.33^{d}
10	55.55^{a}	4.00^{b}	4.67^{a}	3.00^{a}	71.00^{e}	92.00^{d}
LSD (5%)	0.51	0.22	0.37	0.25	0.73	0.82

*Means followed by the same letter in the column are not significantly different at *$p \leq 0.05$;* PH = Plant Height (cm), DE = Days to 50% Emergence, DGF = Days to 50% Grain Filling, DPM = Days to 50% Physiological Maturity, NT = Number of Tillers per plant, NET = Number of Effective Tillers per plant, LSD = Least Significant Difference

Similarly, it was observed that the numbers of effective tillers per plant were not significantly influenced by the interaction of different land use systems and lime rates. However, the application of lime significantly ($p \leq 0.05$) influenced the numbers of effective tillers per plant in soils from all land use systems (Table 4). Relatively the highest numbers of effective tillers per plant were produced in pots with soils which received highest rate of lime (8 and 10 t ha^{-1}) while the lowest numbers of effective tillers per plant were observed in un-amended pots with soils from all considered land use systems (Table 4). The increase in tillers and effective tillers each per plant due to the increased rate of applied lime may be partly attributed to increase in soil pH, available P, K and Ca; and reduce in the adverse effects of Al on root growths of the crop, thus promoting plant tillering.

Table 5. Effects of land use types on phenological parameters of wheat

LUT	PH(cm)	DE	NT	NET	DGF	DPM
FL	62.20^{a}	4.38	4.11^{a}	2.23	71.50^{c}	92.01^{b}
GL	53.85^{b}	4.38	3.89^{a}	2.33	72.28^{b}	94.00^{a}
CL	45.19^{c}	4.22	3.38^{b}	2.22	73.11^{a}	94.39^{a}
LSD (5%)	0.36	0.15	0.26	0.18	0.51	0.58

*Means with the same letter are not significantly different at $p \leq 0.05$; PH = Plant Height (cm), DE = Days to 50% Emergence, DGF = Days to 50% Grain Filling, DPM = Days to 50% Physiological Maturity, NT = Number of Tillers per plant, NET = Number of Effective Tillers per plant, LSD = Least Significant Difference.

Grain Yield

In present study, the interaction between lime rate and land use types was significant ($p \leq 0.05$) on the grain yield (Table 2). The highest mean grain yield of 4.31 g pot^{-1} was obtained from forest land with the application of 8.0 t ha^{-1} lime however, the grain yield of 3.75 and 3.28 g pot^{-1} were the highest, respectively, on soils of grazing and cultivated land both at the lime rate of 10 t ha^{-1} (Table 6). The mean grain yield advantage obtained were varied in all considered land use types when the mean maximum grain yield gained from all land use types were compared with those on respective controls. A mean grain yield advantage of 1.04 g pot^{-1} was gained on soils of forest land; while the mean grain yield advantages were 1.01 and 0.84 g pot^{-1} respectively, on soils of grazing and cultivated lands.

As it is revealed in this study, the increased grain yields obtained on soils from all land use types amended with different lime rates when compared to their respective controls are mainly associated with reduction of concentration of exchangeable acidity and enhancement of exchangeable bases, CEC and available P. Achalu *et al*. (2012); and Shiferaw and Anteneh (2014) have reported increase in barley yield as a result of increased pH and reduced exchangeable aluminum and in part due to improved nutrients recovery as a result of lime application. Sole application of 3.7 t ha^{-1} lime has also been reported to have increased wheat grain yield by twice of the control treatment (Guangdi *et al.,* 2009).

Total Dry Biomass Yield

The interaction effects of lime rates and land use types have demonstrated highly significant *($P \leq 0.01$)* effects on the wheat total dry biomass yield (Table 2). The lowest total dry biomass yield was recorded in the control treatment of soils from all the considered land use types (Table 6). The mean highest total dry biomass yield (16.81 g pot^{-1}) was recorded on forest land with 8.0 t ha^{-1} lime which is not significantly different from those mean total dry biomass yield (16.66 and 16.76 g pot^{-1}) recorded with 6 and 10 t ha^{-1} lime rate, respectively. The average maximum total dry biomass obtained on forest land has a yield advantage over the control by 1.49 g pot^{-1}. A 1.59 and 1.08 g pot^{-1} average total dry biomass yield advantages, respectively, on soils of grazing and cultivated lands were achieved when the maximum records and the control were compared in each case.

Table 6. Interaction effect of lime rate and land use types on the yield parameters of wheat

Lime Rate (t ha^{-1})	Land Use Types		
	Forest Land	**Grazing Land**	**Cultivated Land**
	Grain Yield (g pot^{-1})		
0	3.27^{i}	2.74^{l}	2.44^{m}
2	4.03^{d}	3.52^{g}	3.05^{k}
4	4.14^{c}	3.59^{gh}	3.16^{j}
6	4.22^{bc}	3.64^{fg}	3.22^{ij}
8	4.31^{a}	3.71^{ef}	3.26^{i}
10	4.27^{ab}	3.75^{e}	3.28^{i}
	Total Dry Biomass Yield (g pot^{-1})		
0	15.32^{d}	13.47^{hi}	12.49^{j}
2	16.43^{c}	14.75^{g}	13.32^{i}
4	16.55^{bc}	14.84^{fg}	13.42^{hi}
6	16.66^{ab}	14.91^{ef}	13.47^{hi}
8	16.81^{a}	14.98^{ef}	13.52^{h}
10	16.76^{a}	15.06^{e}	13.57^{h}
	Harvest Index		
0	21.34^{k}	20.33^{l}	19.57^{m}
2	24.55^{def}	23.87^{hi}	22.90^{j}
4	25.05^{bcd}	24.18^{fgh}	23.59^{i}
6	25.35^{abc}	24.46^{efg}	23.95^{ghi}
8	25.68^{a}	24.77^{de}	24.12^{fgh}
10	25.47^{ab}	24.90^{cde}	24.22^{fgh}

*Interaction means across all columns and rows for each yield components followed by the same letter are not significantly different at *P≤0. 01*

The relatively higher yield advantage obtained from forest land use might partly be due to higher organic matter content, which complexes phytotoxic monomeric Al in soil solution by both soluble humic material and aliphatic organic acids, whilst a reduction in exchangeable and soluble Al may occur through either increased pH or complexation of Al in the solid phase by newly accumulated organic matter.

The increase in the agronomic yield of wheat due to liming of acidic soils of different land use types of the study area as indicated in this study may be due to the reduction in acidic ions (H^+ and Al^{3+}) and reduction in nutrient deficiency of Ca^{2+} and P. There is possibility of increasing the crop yield by improving soil acidity through the application of lime, N and P fertilizers (Oluwatoyinbo, 2005). According to the same author, the increase in crop yield through the application of lime may be attributed to the neutralization of Al, supply of Ca and increasing availability of some plant nutrients like P.

Thousand Kernel Weight

The main effects of land use systems and lime rates have showed significant (p≤0.05) influences on thousand kernel weight (Table 7 and 8) while the interaction effects of land use types and lime rates were insignificant (p<0.05) (Table 2). The mean thousand kernel weight in soils from forest land is higher by about 5.19 and 9.08% as compared to that of soils from grazing and cultivated land, respectively. The maximum mean thousand kernel weight recorded with the applied lime rate of 10 t ha^{-1} was 22.11 (g pot^{-1}) which is not significantly different from those recorded at rates of 6 (21.98 g pot^{-1}) and 8 (21.89 g pot^{-1}) t ha^{-1} (Table 8).

Table 7. Effects of land use types on yield and yield components of wheat

LUT	GY (g pot^{-1})	TDBY (g pot^{-1})	TKW (g)	HI (%)	P-uptake (mg pot^{-1})
FL	4.04^{a}	16.42^{a}	22.70^{a}	24.57^{a}	6.59^{a}
GL	3.49^{b}	14.67^{b}	21.58^{b}	23.75^{b}	5.63^{b}
CL	3.07^{c}	13.30^{c}	20.81^{c}	23.06^{c}	4.35^{c}
LSD (0.05)	0.03	0.06	0.24	0.19	0.07

*Means with the same letter within a column are not significantly different at p≤0.05; LUT = Land Use Types, FL = Forest Land, GL = Grazing Land, CL = Cultivated Land, GY = Grain Yield (g pot^{-1}), TDBM = Total Dry above Ground Biomass Yield (g pot^{-1}), TKW =Thousand Kernel Weight (g) and HI = Harvest Index (%), P-uptake = Phosphorous uptake (mg pot^{-1}), LSD = Least Significant Difference

Harvest Index

In the present study, soils from all land use types that were not treated with lime produced the lowest harvest index. The maximum harvest index 25.68 of the wheat was obtained from soils of forest land with the application of 8 t ha^{-1} lime; however, it was 24.90 and 24.22 on soils of cultivated and grazing land, respectively, with the application of 10 t ha^{-1} (Table 8). The maximum final grain yield obtained under each land use type of the applied lime rate might be an important contributing factor for high wheat harvest index at 8 t ha^{-1} lime rate for forest land use. It was 10 t ha^{-1} for cultivated and grazing land use types. However, the pattern of increment in harvest index with the applied lime rates were not uniform and varies from one land use type to the other.

The increase in percent harvest index gained on soils from all land use types amended with different lime rates as compared to respective non treated ones is highly attributed to reduction of concentration of exchangeable acidity and increment of exchangeable bases, and available P of the soils. In line with this, the study conducted by Achalu *et al.* (2012) indicated that the increased harvest index obtained on soils from all land use types treated with different lime rate as compared to respective non amended ones is highly likely associated with reduction of concentration of exchangeable acidity and enhancement of exchangeable bases, CEC and available P of the soils.

Table 8. Effects of lime rate on yield and yield components of wheat

LR (t ha^{-1})	GY (g pot^{-1})	TDBY (g pot^{-1})	TKW (g)	HI	P-uptake (mg pot^{-1})
0	2.81^{e}	13.76^{d}	20.91^{c}	20.41^{d}	4.56^{e}
2	3.53^{d}	14.83^{c}	21.50^{b}	23.77^{c}	5.23^{d}
4	3.63^{c}	14.94^{b}	21.78^{ab}	24.27^{b}	5.50^{c}
6	3.69^{b}	15.01^{b}	21.89^{a}	24.58^{a}	5.78^{b}
8	3.76^{a}	15.10^{a}	21.98^{a}	24.85^{a}	5.99^{a}
10	3.77^{a}	15.13^{a}	22.11^{a}	24.86^{a}	6.08^{a}
LSD (5%)	0.04	0.08	0.34	0.26	0.11

*Means with the same letter are not significantly different at $p \leq 0.05$; LR = Lime Rate, GY = Grain Yield (g pot^{-1}), TDBM = Total Dry above Ground Biomass Yield (g pot^{-1}), TKW = Thousand Kernel Weight (g) and HI = Harvest Index (%), P-uptake = Phosphorous uptake (mg pot^{-1}), LSD = Least Significant Difference

P uptake

In present study, soils from forest land showed higher mean plant P uptake and highly responded to liming than that of soils from grazing and cultivated land. Liming enhanced plant P uptake as it is seen by the highest 6.08 mg pot^{-1} from wheat crop harvested from 10.0 t ha^{-1} lime applications (Table 8). The mean plant P uptakes were decreased by about 15 and 34%, respectively, on soils of grazing and cultivated land uses when compared to that of forest land use (Table 7). The mean percentage increment of plant P uptake when the maximum plant P uptake due to liming was compared with the one recorded with control was about 33% (Table 8).

The lower plant P uptake in cultivated and grazing land compared to forest land may be due to their higher acidity. As soils become more acidic, essential nutrients like P become less soluble and available to plants. Another reason may be soil compaction due to trampling of animals and tillage practices which reduces aeration and pore space in the plant root zone, which in turn reduces plant growth and its P uptake. The wheat yield and P uptake increment due to liming is likely due to the increases in soil pH, reduction in the ion toxicity of H^{+}, Al^{3+} or Mn^{2+} and reduction in nutrient deficiency (Ca, P, or Mo) as well as due to indirect effect of better physical condition of the soil (Haynes, 1984; Kettering *et al*., 2005; Abreha *et al.,* 2013).

CONCLUSION AND RECOMMENDATIONS

Large areas of forest lands in Ethiopia in general and particularly in the study area had been converted to grazing and cultivated lands due to high population pressure. Practices like deforestation, overgrazing and intensive cultivation of soils with low inputs in the present study area may have resulted in disturbances, differences and even deteriorations of soil properties among the considered land use types.

The results from the greenhouse pot experiments revealed that the application of different rates of agricultural lime improved wheat phenological and yield components. The responses of wheat with different lime rates and the yield advantages obtained differed from one land use type to another. Application of lime, organic fertilizer sources and crop rotation especially in the cultivated lands may enhance the productivity of the soils and the yield advantage of the crops. However, it is difficult to make definite and concrete conclusions based on the findings of a green house pot experiment. In order to generate optimum lime rate recommendations for wheat production and to validate the findings from the trials of green house pot experiments, field trials on different soil types, crop species and locations are essential on soils of the study areas and on locations of similar agro-ecology.

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