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Evaluation of Different Agricultural Limes for Bread Wheat and Fababean Production in Acid Soil of West Shewa Zone, Ethiopia

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Abstract: The application of lime is believed to enhance soil health status through improving soil pH, base saturation and reduces Al and Mn toxicities. Liming effects depend on the source, composition, purity and fineness of the lime. The performance of three liming materials and one control treatment was evaluated in a field trial, further evaluation and validation was done at three districts on different farmers' sites during 2023 main cropping season. The liming materials included calcitic lime, hydrated lime, and quick lime. The treatments laid out in randomized complete block design. The results of the study showed that all tested lime materials (calcitic lime, hydrated lime, and quick lime) improved yield and agronomic performance of wheat, barley and fababean in comparably. This implies that hydrated limes can serve as an alternative agricultural lime to ameliorate soil acidity. Hence, these liming materials can be used as agricultural lime material and the result is confirmed through validation across locations on different testing crops (wheat, barley and Faba bean). So, it is recommended that liming materials which can be easily accessed for the farmers is recommended because of there is no significant difference among liming material tested.

Keywords: Lime, lime type, soil acidity, soil pH, Agricultural lime.

Research Paper

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INTRODUCTION

Soil acidity is one of the most serious challenges to agricultural production worldwide, in general and developing countries, in particular. It has become a serious threat to crop production in most highlands of Ethiopia, including the central part of the country. Currently, it is estimated that about 43% of the total arable lands is affected by soil acidity, of which about 28.1% are dominated by strongly acidic soils (pH 4.1-5.5) (Ethiosis, ATA, 2014). Soil acidity limits or reduces crop production primarily by impairing root growth, thereby reducing nutrient and water uptake (Marschner, 1995). Moreover, low pH or soil acidity converts available soil nutrients in to unavailable forms. The effect of soil acidity has caused mineral stress and infertility in the soil which can be attributed to excess aluminium (Al) iron or manganese on the one hand, and to deficiencies of major crop nutrients. Because of these adverse effects, the decline in the yield of existing crops, lack of response to ammonium phosphate and urea fertilizers, and complete crop failure have been observed (Temesgen *et al.*, 2017).

Liming is a long-established practice to ameliorate acidic soils and many liming-induced changes are well understood. Adding lime increases soil pH, reduces soil acidity, adds calcium (Ca) and/or magnesium (Mg), and reduces the solubility of Al and Mn in the soil and increases both P uptake in high P fixing soil and plant rooting system. Liming influences all elements in soils and as such there are numerous simultaneous changes to soil processes which in turn affect the plant nutrient uptake (Getachew *et al.*, 2017; Geremew *et al.*, 2022). However, quality of liming material is very important characteristics in correcting soil acidity. The efficiency of liming material is determined by its acid neutralizing potential, fineness factors of the various particle size fractions, effective neutralizing value (ENV) and its effective calcium carbonate equivalence (ECCE) (Synder and Leep 2007). Type of liming materials, fineness of the lime, application rate, time of application and degree of mixing, soil pH and others. An agricultural liming material, is a material containing calcium (Ca) and/or magnesium (Mg) compounds capable of neutralizing soil acidity. These materials include: limestone (both calcitic and dolomitic), burnt lime, slaked lime, marl, and various by-products. Liming materials are carbonates, oxides, or hydroxides of Ca and/or Mg.

Duration of lime application for the soil activity is a function of crop need and soil pH. Lime works better when applied as early as possible before planting of crop to allow it to react with soil colloids and to bring about significant changes in soil chemical properties (Alley, 1981). In acid soils of different mineralogy, significant chemical changes can take place 4–6 weeks after applying liming materials so long as soil has sufficient moisture (Conyers, 2003). Hence, to obtain desirable results, it is necessary to apply lime during the effective time of lime application with appropriate lime type for better yield and improvement of soil chemical properties. Lime (CaCO3 or its equivalent) is widely known as the effective ameliorant for correcting soil acidity (Anetor and Ezekie, 2007). Although not permanent, the direct effect of lime lasts longer than any other amendment (Fageria and Baligar, 2008), such as organic materials (Osundwa *et al*., 2013).

A variety of liming materials are available in Ethiopia. Hence, they may differ with neutralizing power, fineness, nutrients and/or other elements associated with the liming materials. Therefore, this experiment was conducted to evaluate and then validate the effect of different liming materials on yield of wheat, food barley and faba bean grown on acid soils of west shewa zone Ethiopia.

MATERIALS AND METHODS

Description of the Study Area

The study was carried out at different woredas of the west Shewa zone (Jibat, toke kutaye, Chaliya, and Liban jawi woredas) during 2021 and 2023 main cropping season. The capital city of West Shewa (Ambo) is located 114 km away from Addis Ababa of the Oromia Regional National State. And toke kutaye, and Liban jawi woredas are found at a distance of 11 and 50 km from Ambo town respectively.

Experimental Design, Procedure and Treatment Set up

The treatments consisted of two factors lime type and time of applications arranged in a randomized complete block de-sign with three replications for mother trial and the best four selective treatments (control, calcite at four weeks, hydrated at two weeks and quick at one week) application time before planting were validated for further confirmation of the result. For all lime materials, the amount of lime to be applied was calculated on the basis of the exchangeable acidity or acid saturation of the experimental soil, bulk density and 15 cm plough depth (equation below).

$$LR,\frac{CaCo3kg}{ha} = \frac{Cmol\frac{EA}{Kg}\,of\ soil * 0.15m * 10{,}000m^2 * BD\left(\frac{g}{cm^3}\right) * 1000 * crop\ factor}{2000}$$

Equation ----------- 1

Where: BD = bulk density, EA = exchangeable acidity (exch. H^+ + Al^{3+}), LR= lime requirements, 0.15m= plow depth/depth of lime incorporation.

It was assumed that one mole of exchangeable acidity would be neutralized by an equivalent mole of CaCO3 (adopted from Kamprath, 1984). The lime rates were adjusted to their respective 100 % calcium carbonate equivalence. The whole doses of lime of the respective plot treatment were broadcasted uniformly by hand and mixed in the top 15 cm soil layer, calcite at four weeks, hydrated at two weeks and quick at one week before sowing, to mix lime with soil properly. A land with average pH of 4.5 was selected for the study and land preparation took place well in advance before sowing test crops, as lime need certain incubation period to bring change in physicochemical properties of the soil. The size of each plot was 3 x 4 m (12 m^2) and the spacing between replication and plots were 1.5 and 1 m, respectively. The experimental field was prepared following the conventional farmers' practices. The field was oxen ploughed three times before sowing. The seed bed was prepared by ploughing and harrowing using oxen and then leveled manually. Both the recommended Phosphorus and nitrogen fertilizer were applied uniformly for all treatments. Phosphorus fertilizer was applied at planting and mixed with the soil, whereas nitrogen was applied twice in a split form. All agronomic practices such as hoeing and weeding, were undertaken uniformly to all plots by hand.

Table 1: Treatment and Description for mother trials

Treatment	Different liming materials with time of Lime applied
Treatment 1	Hydrated/Ca (OH)3/ four weeks
Treatment 2	Hydrated/Ca (OH)3/ six weeks
Treatment 3	Dolomite/CaMg (CO3)/ six weeks
Treatment 4	Calcite/CaCO3/ four weeks
Treatment 5	Dolomite/CaMg (CO3)/ four weeks
Treatment 6	Hydrated/Ca (OH)3/ at planting
Treatment 7	Quick lime/CaO/ at planting
Treatment 8	Calcite/CaCO3/ six weeks
Treatment 9	Quick lime/CaO/ six weeks
Treatment 10	Quick lime/CaO/ two weeks
Treatment 11	Quick lime/CaO/ four weeks
Treatment 12	Dolomite/CaMg (CO3)/ at planting
Treatment 13	Hydrated/Ca (OH)3/ two weeks

Treatment	Different liming materials with time of Lime applied
Treatment 14	Dolomite/CaMg (CO3)/ two weeks
Treatment 15	Calcite/CaCO3/ at planting
Treatment 16	Calcite/CaCO3/ two weeks

Table 2: Treatment and Description for baby trials

Different lime materials		Time of Lime applied
Treatment 1	Control (No lime)	-
Treatment 2	Hydrated/Ca (OH)3/	Two weeks before planting
Treatment 3	Calcite/CaCO3/	Four weeks before planting
Treatment 4	Quick lime/CaO/	One week before planting

Data Collection and Measurements

Growth, Yield, and Yield Data Collections

Plant height (cm): to evaluate the effect of the treatments on wheat development, five plants per plot were randomly selected before harvest and their heights were measured using a tape measure, and the mean height of the five plants was recorded as plant height in cm. Grain yield (kg/ha): was measured by harvesting the crop from the net plot area of the middle five rows. The moisture content of the grain was adjusted to 12.5% and then the weight was converted to kg $ha^{-}1$. Above-ground dry-biomass (t ha^{-1}): the total above-ground biomass of the middle five rows of the net plot area was determined by harvesting close to the soil surface at physiological maturity by sun-drying to gain a constant weight. Finally, the biomass yield of the selected middle five rows was converted to per hectare and expressed in t ha. Spike length (cm): to evaluate the effect of the treatments, five plants per plot were randomly selected before harvest and their spike length was measured using a tape measure the mean length of the five plants' spikes was recorded as spike length in cm.

The number of seeds per spike was counted from five randomly selected plants from five middle rows at harvest maturity and expressed as an average of each plant.

Data Analysis

Analysis of variance (ANOVA) was done using statistical analysis software (SAS, 2004) and means were compared using least significant difference (LSD).

RESULTS AND DISCUSSIONS

After the experiment of evaluating liming material and time of application on wheat, faba bean and barley, further evaluation and validation was done at three districts (Toke kutaye, Liban jawi and Chalia) across farmers' sites during 2023 main cropping season. Mother trial experiment was conducted at Jibat and Chaliya on farmers' field and baby trial was conducted at three districts of west shewa (Toke kutaye, Liban Jawi and Chaliya). The research results from mother trial were further evaluated, validated and widely demonstrated for wider use in acid prone areas of west shewa zone during 2023 of main cropping season.

Both agronomic and yield parameters (plant height, spike length, biomass, grain yield, pod/plant, and seed per plant) showed significant difference among lime materials and time of applications. Hydrated, quick and calcite lime gave better grain yield (5214.5, 5024.9 and 4640.9) respectively for wheat and this result gave more than 50% of yield advantage over the control (Table 3). Similarly, the highest above ground biomass yield by 11741.7 and 11658.3, kg ha^{-1} was recorded from quick and sliked lime. On the other hand, the lowest above ground biomass yield by 7058.3 kg ha^{-1} was obtained from the control plot (Table 3). Above ground biomass yield advantage of 40% and 39.5% were obtained due to application of Quick and hydrated respectively when compared to the control. The highest plant height of (98.00cm) was recorded from Quick lime which was statically at par with Hydrated (98.5cm) and Calcite lime (96.42 cm) while the lowest plant height was recorded from Recommended fertilizer alone (80.5cm) (Table 3).similarly, the tallest spike length of (8.875cm) was recorded from Quick lime which was statically at par with Hydrated (8.85cm) and Calcite lime (8.55 cm) while the shortest spike length was recorded from control treatment (6.10cm).

Table 3: Growth, yield, and yield parameters of wheat affected by d/t liming materials and time of application across locations of west Shewa zone.

Quick -1 week with Recc. fertilizer	5024.9[a]	11741.7[a]	98.00[a]	8.85[a]	58.40[a]
Hydrated-2 weeks with Recc. fertilizer	5214.5[a]	11658.3[a]	98.50[a]	8.875[a]	55.25[a]
Calcite -1 month with Recc. fertilizer	4640.9[a]	10166.7[b]	96.40[a]	8.55[a]	53.60[a]
Recc. fertilizer alone (no lime)	2612.1[b]	7058.3[c]	80.50[b]	6.10[b]	41.25[b]
Mean	4373.07	10156.25	93.35	8.09	52.12
LSD	954.09	1359.7	11.50	0.929	8.93
CV	13.63	8.36	7.70	7.17	10.71

Were, LSD: Least significant Different; CV: Coefficient variation; GY: grain yield; pH: plant height; DBM: Dry biomass; SL: Spike length; SPS: seed per spike

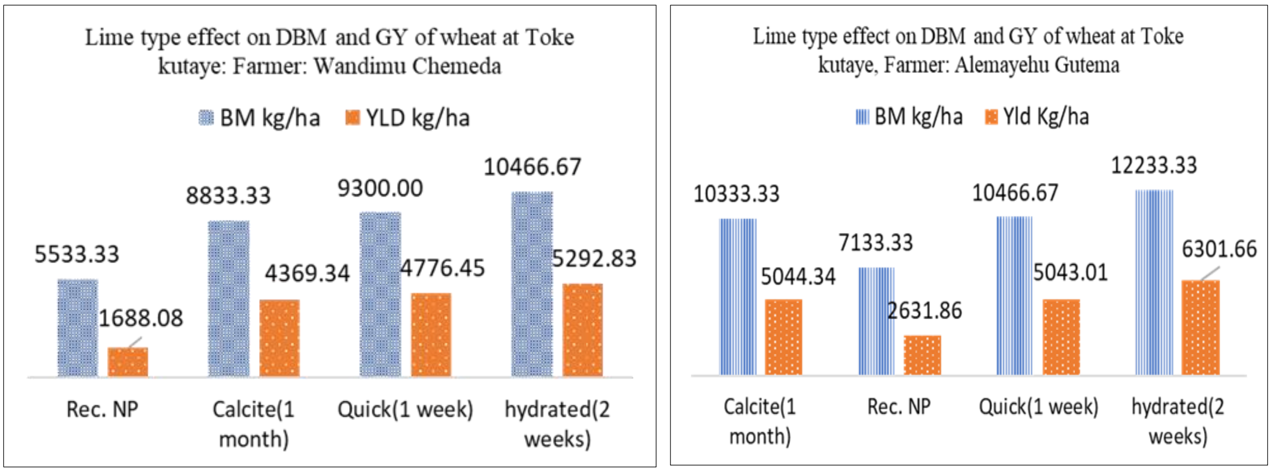

Fig. 1: Effect of lime type on wheat yield and dry biomass at Toke Kutaye at two farmer field separately

At Toke kutaye on two different farmer site all lime materials show no difference on yield and Above ground for wheat except when compared with the control treatment that has no lime, but hydrated lime numerically gave better grain and dry biomass yield than control and other liming materials treatment. Numerically the highest grain yield 5292.83 and 6301.66 kg ha-1 was recorded from Quick lime application one week before planting at site one and site two respectively, While, the lowest grain yield 1688.08 and 2631.86 kg ha-1 was recorded from control plot at site one and two respectively, which is with application of recommended site-specific fertilizer alone (Fig 2).

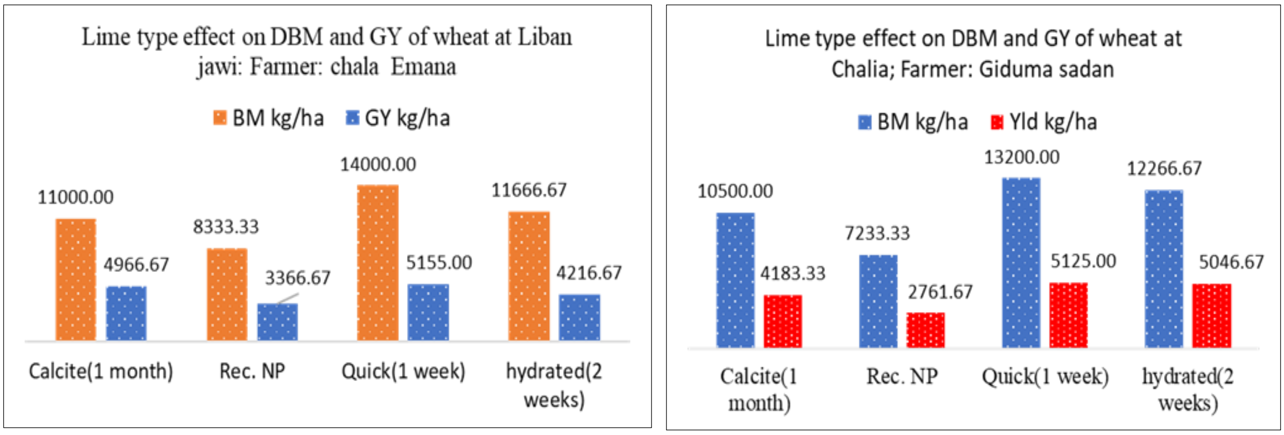

Fig. 2: Effect of lime type on wheat yield and dry biomass at Chaliya and Liban jawi district on two farmer field separately

At Chaliya and Liban Jawi site also there is no difference among all lime materials on yield and above ground for wheat except when compared with the control treatment that has no lime, but Quick lime numerically gave better grain and dry biomass yield than control and other liming materials treatment (Fig.2). Numerically, the highest above ground biomass 12.23 and 10.46 t ha-1 was recorded from application of hydrated lime two weeks before planting at first site and second site respectively. On the contrary, the lowest above ground biomass 7.1 and 5.5 t ha-1 was obtained at first site and second site respectively from the control treatment that has no lime (Fig.2). The result showed that the above ground biomass was increased due to higher number of seed per plant, plant height and grain yield when treated with lime. And these liming materials containing carbonates, oxides or hydroxide which used to raise soil pH, and in addition, neutralizes toxic elements in the soil. Application of both liming materials improve plant nutrient availability to the crop helps in the synthesis of carbohydrates, which are required for the formation of protoplasm, thus resulting in higher cell division and cell elongation. Thus, an increase in biomass yield might have been on account of overall improvement in the vegetative growth of the plant due to the application of liming materials. The results are similar with the results of Kisinyo *et al.*, (2016) who reported that a growth of plant is increased on acid soil in response to the application of different agricultural lime.

Similarly, at Liban jawi and toke kutaye different liming material was evaluated and validated using faba bean as test crop and also to maintain the crop rotation pattern; and from the result of the study some parameters (seed/plant, pod/plant, dry biomass, grain yield, and Plant height) showed significant ($P<0.05$) difference, (Table 5). The highest grain yield of (1848.9 kg/ha) was recorded from Calcite lime which was statically at par with Quick lime (1889.4 kg/ha) and Hydrated (1840.8 kg/ha) while the lowest grain yield was recorded from Recommended fertilizer alone (965.3 kg) (Table 5). Similarly, the highest Dry Biomass of (4691.7 kg/ha), pod/plant (15.40) and seed/plant (31.2) were recorded from Calcite lime respectively which was statically at par with Quick and hydrated lime, while the lowest Dry Biomass of (3100 kg/ha), pod/plant (7.5) and seed/pod (17.3) was recorded from Recommended fertilizer alone respectively. There were no statistically significant differences between the lime sources. Liming materials, improved ability of the plant to absorb P, when Al toxicity has been eliminated, and enhanced the vegetative growth of faba bean, which resulted in increased dry biomass yield. Temesgen *et al.*, (2017) reported that barley above ground biomass was reduced in control plots by 38.2% compared with lime treated plots. The authors also reported that the highest dry biomass of barley was recorded on lime amended soil with 2.2 t ha^{-1} than application of phosphorus fertilizer alone.

Table 4: Mean value of growth, yield, and yield parameter of Faba bean affected by different liming materials and time of applications in west shewa zone

Treatments	GY kg/ha	DBM kg/ha	PH (cm)	Pod/plant	Seed/plant
CaCO3(1 month)	1848.9a	4691.7a	135.10a	15.40a	31.20a
Ca0(1 week)	1889.4a	4654.2a	126.00a	12.70a	30.70a
Ca (OH)3(2 weeks)	1840.8a	4620.8a	124.30a	14.40a	27.20a
Control (Rec.NP)	965.3b	3100.0b	97.10a	7.50b	17.30b
Mean	1636.11	4266.66	120.62	12.50	26.60
LSD	781.48	1195	NS	5.13	9.03
CV	15.00	8.80	11.47	12.89	10.67

Were, LSD: Least significant Different; CV: Coefficient variation; GY: grain yield; PH: plant height; DBM: dry biomass

The field experiment as mother trial was conducted by acid soil program of the Ambo Agri. Research Center to examine the influence of lime type and time of application on wheat productivity. The result from the study showed that the plot treated with slaked lime and quick lime recorded the highest average wheat grain yield of 3551 kg/ha and above ground dry biomass of 9.3 $tons^{-1}$ha respectively. While, the yield obtained from untreated control treatment of 2612 kg/ha. In general, the analyzed data of an experiment conducted at both locations for both tested crops showed no significant ($P<0.05$) yield difference among lime materials, except when compared with the control treatment that has no lime. The probable reasons why yield difference was not significant among different lime materials might be due to nearly comparable mineralogical makeup of the lime materials, which is useful indication to use any of the lime materials by crop growers.

Table 5: Mean yield, dry biomass and plant height of wheat as affected by different lime materials

Treatment	DBM ton/ha	PHT (cm)	GY (kg/ha)
Hydrated/Ca (OH)3/ four weeks	9.3033a	83.67a	3304.7abc
Hydrated/Ca (OH)3/ six weeks	9.14a	77.07abcd	3551a
Dolomite/CaMg (CO3)/ six weeks	8.93a	80.67abc	3498.1a
Calcite/CaCO3/ four weeks	8.68ab	82.27ab	3441ab
Dolomite/CaMg (CO3)/ four weeks	8.66ab	81.93ab	3473.7a
Hydrated/Ca (OH)3/ at planting	8.52ab	81.8ab	3520.1a
Quick lime/CaO/ at planting	8.41abc	78.47abcd	3380.1abc
Calcite/CaCO3/ six weeks	8.16a-d	76bcd	3258.5abc
Quick lime/CaO/ six weeks	8.14a-d	79.53abcd	3228.7abc
Quick lime/CaO/ two weeks	7.81a-d	76.53bcd	2988.8abcd
Quick lime/CaO/ four weeks	7.55a-e	78.8abcd	2995.3abcd
Dolomite/CaMg (CO3)/ at planting	7.36a-e	73.33d	2901.4abcd
Hydrated/Ca (OH)3/ two weeks	6.87b-e	76.35bcd	2594.7cd
Dolomite/CaMg (CO3)/ two weeks	6.55cde	74.67cd	2658bcd
Calcite/CaCO3/ at planting	6.23de	76.33bcd	2390d
Calcite/CaCO3/ two weeks	5.77e	74.87cd	2310.6d
CV	12.73053	4.370732	13.41226
Mean	7.852708	78.1541	3074.132
Level of significant	**	*	**

Were, LSD: Least significant Different; CV: Coefficient variation; DBM: Dry biomass; PHT: plant height; GY: Grain yield

Response of Food Barley to the Treatment at Jibat

A field experiment was conducted at Jibat during 2020 cropping seasons to examine the influence of lime type and time of application on barley productivity. The result from the study showed that the plot treated with Dolomite lime and quick lime recorded the highest grain yield of 5.69 tons^{-1}ha and 5.5 tons^{-1}ha respectively. While the plot received the calcite lime recorded 2.9 tons^{-1}ha grain yield which is lowest (Fig.3).

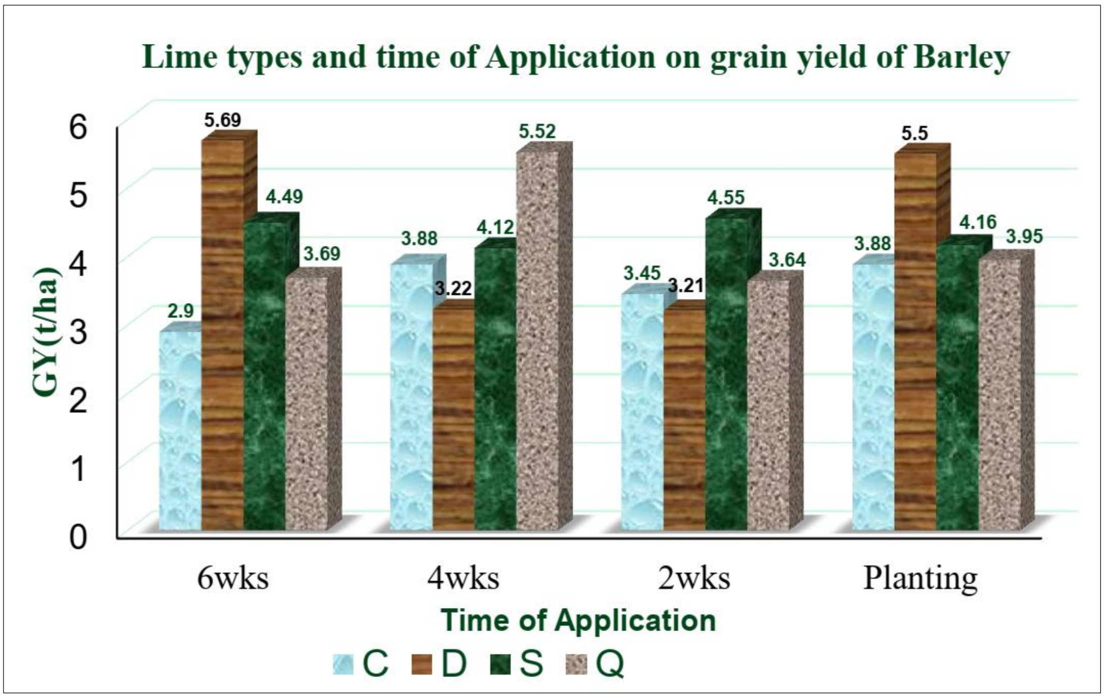

Fig. 3: Effect of lime type and time of application on grain yield of barley at Jibat
Were, **C:** Calcite lime; **D:** Dolomite lime; **S:** Slaked Lime; **Q:** Quick lime

Conflict of Interest: Author declares that there are no conflicts of interest.

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CONCLUSION AND RECOMMENDATION

Soil acidity is one of the major yield-limiting factors for crop production worldwide, particularly on highly weathered and leached tropical soils. Agricultural limestone has been used to correct soil acidity and there is evidence that lime can increase the pH of acid soils and improve soil fertility by improving nutrients availability for crop production. The results of the study showed that lime materials studied at different locations i.e. Toke kutaye, Liban jawi and Chaliya was equally improved both yield of food barley, faba bean and wheat. All tested lime materials (calcitic lime, hydrated lime, and quick lime) improved yield and agronomic performance of wheat, barley and faba bean in comparably. Hence, these liming materials can be used as agricultural lime material and the result is confirmed through validation across locations on different testing crops (wheat, barley and Faba bean). So, it is recommended that liming materials which can be easily accessed for the farmers is recommended because of there is no significant difference among liming material tested.

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