OPEN ACCESS

Middle East Research Journal of Agriculture and Food Science
ISSN: 2789-7729 (Print) & ISSN: 2958-2105 (Online)
Frequency: Bi-Monthly
DOI: 10.36348/merjafs.2024.v04i03.001

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Studies on the Effects of Liming Acidic Soil on Improving Soil Physicochemical Properties and Yield of Crops: A Review

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Abstract: Soil acidity is a major constraint to crop production globally by potentially limiting agricultural productivity and causing environmental challenges, especially in temperate and tropical regions of the world where there is high precipitation. The review article summarizes the works of literature and gathers information on the effects of liming on soil's physicochemical properties and the yield of crops. Soil acidity is caused by natural ways, such as the high amount of precipitation that exceeds evapotranspiration that leaches appreciable amounts of exchangeable bases from the soil surface, weathering, and decomposition of organic matter and by human interference (by the use of nitrogen fertilizer mainly ammonia and urea fertilizers). Application of lime improved soil pH and neutralize the effect of toxic elements. Liming directly improves some physicochemical properties of the soil, such as aggregates, density, and porosity as physical properties and reduction of exchangeable acidity, Al saturation, micronutrients (Cu, Fe, Mn, and Zn) in the soil solutions, from exchange complex to the levels required and increasing soil pH, exchangeable cations (Na^+, K^+, Ca^{+2}, and Mg^{+2}) as chemical properties. Soil aggregation, density, and porosity of soil undergo changes with the application of lime. The long-term lime application resulted in increased soil chemical properties. Lime application contributed to increased crop productivity and crop quality. The effects of liming can be explained by the flocculation and cementing action of Calcium ions in the short term. In the long term, increases in productivity induced by liming, result in increasing soil pH, available phosphorus, cation exchange capacity, basic cations, microbial activity, organic carbon, total nitrogen, and decreasing leaching of nutrients, exchangeable aluminum, and acidity, all favoring the physical and chemical properties of the soil.

Keywords: Lime, Soil Physical Properties, Improvement of Yield, Soil Acidity.

Review Paper

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How to cite this paper:
Bezuayehu Tola Abdi (2024). Studies on the Effects of Liming Acidic Soil on Improving Soil Physicochemical Properties and Yield of Crops: A Review. *Middle East Res J. Agri Food Sci.*, *4*(3): 95-103.

Article History:
| Submit: 24.03.2024 |
| Accepted: 26.04.2024 |
| Published: 07.05.2024 |

1. INTRODUCTION

Soil acidity is one of the most serious challenges to agricultural production worldwide in general, and in developing countries in particular (Temesgen *et al*., 2017). Globally, about 30% of the ice-free land, comprising a large proportion of agricultural land, is affected by soil acidity which is potentially limiting agricultural productivity and causing environmental challenges (Gurmessa, 2021). It is mostly distributed in developing countries, where population growth is fast and demands for food and fiber are increasing. In Ethiopia around 40.9% of the total land and 28% of the arable land area is acidic, of which 27.7% is moderate to weakly acidic with a pH of 5.5–6.7, and the remaining 13.2% is strong to moderately acidic with a pH of < 5.5 (Mesfin, 2007). The highlands of Ethiopia (areas >1500 m above sea level) are the most affected region by soil acidity. The cause of soil acidity is a high amount of precipitation that exceeds evapotranspiration that leaches appreciable amounts of exchangeable bases from the soil surface. As a result, most of the soils have a pH range of 4.5 to 5.5, contain low organic matter (<20 g $kg^{-1,}$) and low nutrient availability (Temesgen *et al*., 2011). Increased soil acidity causes solubilization of Al, 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 (Mesfin, 2007).

Theoretically, soil acidity is quantified on the basis of hydrogen (H^+) and aluminum (Al^{3+}) concentrations in soils. For crop production, however, soil acidity is a complex of numerous factors involving nutrient/element deficiencies and toxicities, low activities of beneficial microorganisms, and reduced plant root growth which limits absorption of nutrients and water (Fageria and Baligar, 2003). However, Al^{3+} toxicity is one of the major limiting factors for crop production on acid soils by inhibiting root cell division and elongation, reducing water and nutrient uptake (Wang *et al*., 2006), poor nodulation or mycorrhizal infections (Delhaize *et al*., 2007), consequently leading to poor plant growth and yield of crops. Liming is a management practice to reduce soil acidity and therefore one of the soil fertility management practices (AGRA, 2009). When lime is added to acid soils that contain high Al^{3+} and H^+ concentrations, it dissociates into Ca^{2+} and OH^- ions. The hydroxyl ions will react with hydrogen and Al^{3+} ions forming Al^{3+} hydroxide and water; thereby increasing soil pH in the soil solution. Soil pH increased significantly from 5.03 in the plots without lime to 6.72 at the lime rate of 3750 kg $CaCO_3ha^{-1}$ (Adane, 2014).

Many factors are responsible for the low productivity, which include inherent poor soil fertility (Bationo *et al*., 2006), the continuous decline of soil fertility (Kimani *et al*., 2004), poor management practices, and low agricultural input use (Njeru, 2009). The prevalence of acidity is associated with nitrogen, phosphorus deficiency in the soil, aluminum toxicity, low extractable bases (Ca, Mg, K, and Na), and reduced microbial activity which therefore results in low crop yield and land productivity (Crawford *et al*., 2012). Soil acidity affects the growth of crops because acidic soil contains toxic levels of aluminum and manganese and is characterized by deficiency of essential plant nutrients such as P, N, K, Ca, Mg, and Mo when the soil pH falls below 5.5; and the plant root system is affected by high Al concentrations because of Al interferes with the uptake, transport, and utilization of essential plant nutrients such as P, K, Ca, Mg, and water, as well as enzyme activity in the roots (Lofton *et al*., 2010). The degree of toxicity depends upon how high the concentration of soluble or exchangeable Al^{3+} is and how low the pH is (Crawford *et al*., 2008).

Soil acidity can also reduce the availability of phosphorous by forming insoluble compounds when combined with Fe and Al oxide at pH < 5.0 (Kim, 2010). Thus, due to the increased acidity of the soil, inorganic phosphorous applied to the soil becomes fixed or immobilized (Tinker and Nye, 2000). Therefore, acid soils possess toxic concentrations of Al^{3+} and Mn^{2+}, deficient concentrations of P, and low availability of bases, which together cause a reduction in crop yield (Schroder *et al*., 2010). The presence of Al in plant tissues interferes with Ca and Mg uptake from soil, as well as damaging the chloroplast and mitochondrial membrane (Meriño-Gergichevich *et al*., 2010).

Lime has been known as an effective ameliorant to reduce soil acidity and decrease exchangeable Al as well as Al saturation (Achalu *et al*., 2012). The application of lime is the most commonly used management practice to increase soil pH and improve crop production in acidic soils (Li et al. 2019). Moreover, the application of lime tends to raise the soil pH by displacement of H^+, Fe^{2+}, Al^{3+}, $Mn^{4+,}$ and Cu^{2+} ions from the soil adsorption site (Onwonga *et al*., 2010). More than increasing soil pH, it also supplies significant amounts of Ca and Mg, depending on the type. Indirect effects of lime include increased availability of P, Mo and B, and more favorable conditions for microbially mediated reactions such as nitrogen fixation and nitrification, and in some cases improved soil structure (Crawford *et al*., 2008). Therefore, the objective of this paper is to review the effect of lime on soil's chemical and physical properties and the yield of crops.

2. LITERATURE REVIEWS AND DISCUSSIONS

2.1 Effect of Lime on Chemical Properties of Soil

2.1.1 Increase of Soil pH and Decrease of Exchangeable Acidity

Limes are materials containing carbonates, oxides or hydroxides required to apply on acidic soil to raise soil pH and neutralize toxic elements in the soil. According to Abdissa *et al*., (2018) showed that the highest increment of pH from 4.83 at the control to 6.05 and reduction of exchangeable Al from 1.70 to 0.09 cmol kg^{-1} were obtained from the combined application of lime at 4 t ha^{-1}. Sultana *et al*., (2009) also observed the application rates of lime levels to soil progressively increased soil pH and increased availability of P, Ca, and Mg in soils. The application of lime significantly ($P<0.05$) increased soil pH and Al^{3+} was markedly reduced a negligible level at Holetta (Temesgen *et al*., 2017). They further stated application of lime at the rate of 0.55, 1.1, 1.65 and 2.2 t ha^{-1} increased soil pH by 0.48, 0.71, 0.85 and 1.1 units, and decreased Al^{3+} by 0.88, 1.11, 1.20 and 1.19 mill equivalents per 100 g of soil respectively, which means with successive increase in the amounts of lime, soil pH values increased with a corresponding decrease in exchangeable Al^{3+} of the soil (Temesgen *et al*., 2017).

Exchangeable acidity in soils consists of aluminum or iron, as well as any exchangeable H that may be present in the exchange sites. It is almost entirely due to Al^{3+} ions. This is because only Al^{3+} is a common exchangeable cation in moderately to strongly acidic soils (Bohn *et al*., 2002). Detoxification of Al can be achieved by increasing soil pH through application of agricultural lime which in turn certainly results in decrease in Al solubility thereby minimizes its toxic effect on plants. Achalu *et al*., (2012) reported that application of lime at the rate of 10-ton ha^{-1} decreased the soil exchangeable acidity from 2.80 cmol (+) kg in the control to 0.26 cmol (+) kg with a decrement in exchangeable acidity of about 90.7%. Asmare *et al*., (2015) reported that the highest lime rate (11.2-ton ha^{-1}) significantly increased the pH from 4.89 to 6.03 and reduced the exchangeable acidity from 2.22 to 0.14 cmolc kg^{-1} and exchangeable Al from 1.28 to 0.07 cmolc kg^{-1}. Temesgen *et al*., (2017) also reported that application of lime and its residual effect highly decreased exchangeable acidity (from the initial level of 1.32 to 0.1 cmol/kg) and Al^{+3} as the level of applied lime rates increased. This decrease may be ascribed to the increased replacement of Al by Ca in the exchange site and by the subsequent precipitation of Al as Al $(OH)_3$, as the soil was limed (Havlin LJ, 2016).

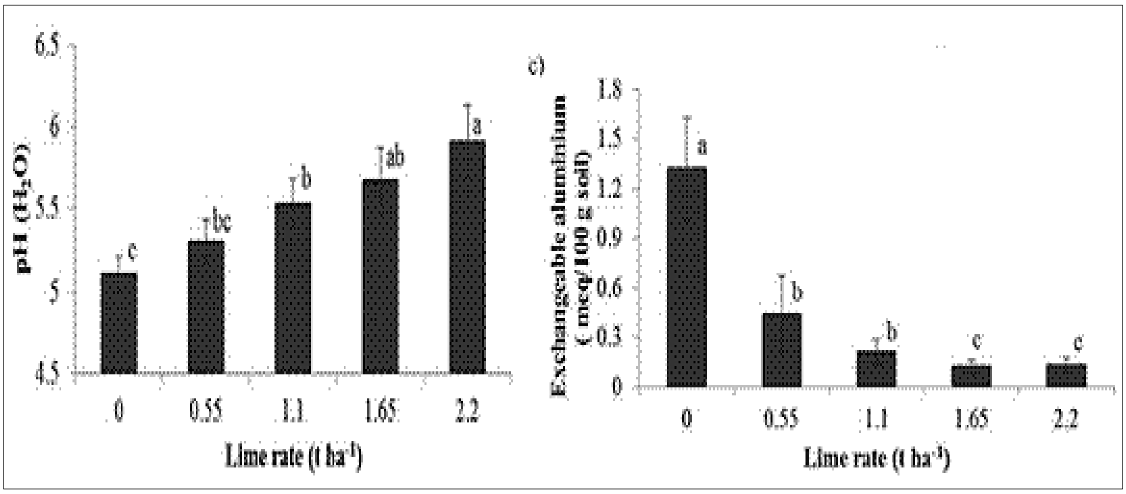

Figure 1: Mean variation of the pH and Exchangeable aluminum of soils after application of lime.
Source: Temesgen *et al*., (2017)

2.1.2 Increase of Available Phosphorus in the Soil Solution

Phosphorus is commonly bound to iron and aluminum oxides and hydroxides through chemical precipitation or physical adsorption (Kochian *et al*., 2004). The major portion (80-90%) of mineral P fertilizers applied to the soil cannot be absorbed by plants due to adsorption to Fe oxides/hydroxides, Al hydroxides, and due to chemical precipitation. As a result of adsorption, precipitation, and conversion to organic forms, only 10-30% of the applied phosphate mineral fertilizer can be recovered by the crop grown after fertilization (Syers *et al*., 2008). Liming of acidic soils could increase soil pH, which enhances the release of phosphate ions fixed by Al and Fe ions into the soil solution. The increase of available P as a result of lime application is due to improving soil acidity, and hence, increased availability of P (Kisinyo, 2016). Achalu *et al*., (2012) reported that the deficiency of P could be corrected through liming of acid soil to increase the pH to more than 6. They stated that lime contributed to the release of some amount of fixed P to the soil, which will be available for the crop. Therefore, agricultural liming materials added to soil are a profitable soil additive and they hydrolyze Al and Fe ions that precipitate with P. Hence, the precipitated phosphate ion is released into the soil solution thereby rendering the phosphate ion available for plant uptake. Liming and thus raising the pH of acidic soil generally provides more favorable environments for microbial activities and possibly results in net mineralization of soil organic phosphorus (Paradelo *et al*., 2015). Liming can increase phosphate availability by stimulating the mineralization of soil organic phosphorus (Adane, 2014).

Table 1: Showing improvement for some of the soil chemical properties as affected by different rates of agricultural lime from field experiment at Holeta

Lime kgha^{-1}	**PH**	**CEC (cmol (+) kg^{-1})**	**AL**	**EA (cmol (+) kg^{-1}**	**Ava. P (mgkg^{-1})**
0	5.03^d	19.18^d	0.68^a	0.97a	5.36^b
1250	5.64^c	25.21^c	0.56^b	0.75b	6.70^a
2500	6.14^b	31.49^b	0.33^c	0.51c	7.04^a
3750	6.72^a	33.34^a	0.24^c	0.36c	6.67^a
LSD (5%)	0.014	0.738	0.13	0.21	0.94
CV (%)	3.01	6.24	8.12	6.43	2.04

Means in a column with the same letter(s) are not significantly different from each other at P = 0.05%
Source: Adane (2014)

2.1.3 Increase of Exchangeable Bases and Cation Exchange Capacity

The removal of base cations, especially Ca and Mg, by leaching and erosion results in their replacement by acidic cations like H, Al, and Fe on exchange sites and in the soil solution (Johnston, 2004). Exchangeable bases (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). Highly weathered tropical soils such as Oxisols have very low levels of exchangeable Ca and crops grown on such soils exhibit Ca deficiency when exchangeable Ca is <1 cmol kg^{-1}. The application of limestone (calcium carbonate) and or dolomitic lime (Ca and Mg bicarbonate) increases soil exchangeable Ca and

Mg respectively. With the neutralization of part of the soil acidity by lime application, negative charges of the soil exchange complex are released, (Achalu *et al*., 2012) and then occupied by basic cations.

The soils' exchangeable Ca^{2+} ion and CEC showed increments with the increase of applied lime rates and soil pH (Achalu *et al*., 2012). This direct relationship between pH, exchangeable Ca^{2+}, and CEC with the increase of the lime rates is attributed to the applied lime which enhances the concentration of Ca^{2+} and thereby increases the soil pH due to the dissociation of agricultural lime and replacement of H^+ and Al^{3+} from the soil solution and soil exchange complex. Similarly, the direct relationship of CEC with soil pH may be attributed to the presence of pH-dependent negative charges which can increase with increasing soil pH due to applied agricultural lime (Tolossa, 2019).

The cation exchange capacity (CEC) of soil represents the total quantity of negative charge available to attract cations in the soil solution. High CEC values are usually associated with humus compared to those exhibited by the inorganic clays, especially kaolinite and Fe, Al oxides (Brady and Weil, 2002). Liming acidic soils indirectly increases the effective cation exchange capacity (ECEC) of soils that contain organic matter or variably charged clay minerals (Bohn *et al*., 2002). Adane (2014) found the highest (33.34 cmol($^+$) kg^{-1}) and the lowest (19.18 cmol($^+$) kg^{-1}) values of CEC were observed under the highest lime treated and the control (Table 1).

2.2 Effects of Liming on Soil Physical Properties

2.2.1Effects of Liming on Soil Aggregates

Application of lime at the rate of 1600 kg ha^{-1} gave non-significant ($P>0.05$) sand and silt content of the soil for either 0-15cm or 15-30 cm soil depth, whereas the clay fraction of the soil increased with an increase in profile depth (Ubi *et al*., 2017). Liming might affect the soil structure in positive or negative ways (Bronick and Lal, 2005). Liming performed in order to correct soil acidity can alter the mechanisms of flocculation, formation, and stabilization of macro and micro aggregates (Bronick and Lal, 2005; six *et al*., 2004). The aggregates are components of soil structure, and the aggregation process is the result of the approximation and cementation of organic and mineral particles in soil. The flocculation and subsequent particle aggregation occur within a few hours after limestone application (Babu and Poulose, 2018). The Ca^{2+} acts as a binding agent between the organic and mineral fractions of soil, favoring the association and strengthening the links between mineral and organic particles, favoring the aggregate formation (Gliński *et al*., 2011). A high correlation between levels of total organic carbon and Ca^{2+} (Briedis *et al*., 2012), as elucidated in Figure 2.

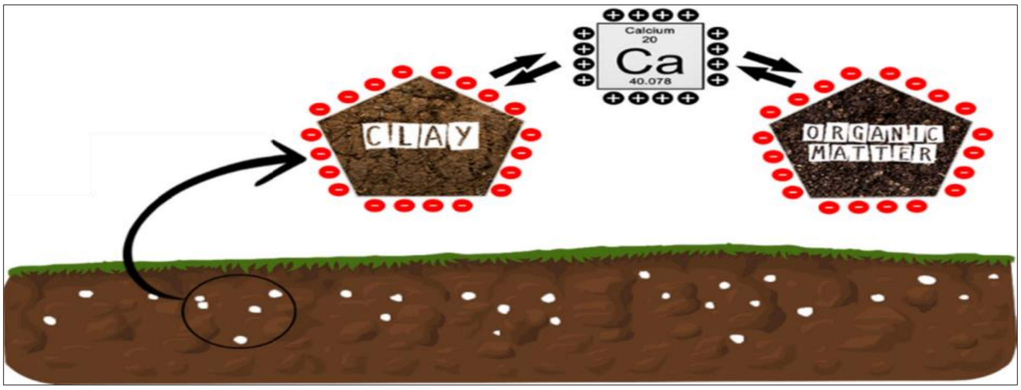

Figure 2: Importance of calcium increase and its action as a binding agent in the aggregate formation
Source: Junior *et al*., (2020)

According to Briedis *et al*., (2012), the Ca^{2+} derived by liming surface presents a correlation with the contents of total organic carbon and acts as a cation bridge between the surfaces of clay particles and carbon organic soil. The surface liming under a no-till system improves soil aggregation by increasing the average aggregate diameter in the layer (0-0.01 m), but without the same effect on the layer (0.02-0.1 m) (Ferreira *et al*., 2019). Carmeis *et al*., (2018) the superficial liming in the no-till system increased the amount of soil macroaggregates at a depth of 0-0.4 m, but the effect magnitude varied according to the applied limestone dose and soil depth. Further, the increase in average aggregate diameter shows a positive correlation according to the increase in applied limestone doses. In addition to the direct effect of calcium on soil aggregation, the correction of acidity can have indirect effects on soil properties since the production of area and root Phytomass of the crops increases the content of soil organic matter and microbial activity. These factors favor soil aggregation (Corrêa *et al*., 2009). Changes in soil aggregation due to liming, in turn, modify other physical properties of soil, such as density and porosity.

2.2.2 Effects of Liming on Soil Density and Porosity

Soil density is defined as the relationship between the mass of a soil sample dried at 105 ºC and the sum of volumes occupied by particles and pores (Hardie *et al.*, 2014). Depending on the physical and chemical changes resulting from limestone use, density can also change. Auler *et al.*, (2017) reported that superficial application of limestone without overturning in relation to the control, in 0 to 0.10 m layer, detected significant interaction, demonstrating an increase in soil pH, clay dispersed in water, contents of Ca^{2+} and Mg^{2+} promoting a reduction in soil density. On the contrary, Spera *et al.*, (2008) obtained different values of soil density in layers of 0-0.05 m to 0.015-0.020 m, and in the layer of 0.015-0.020 m, an increase in density values was observed in proportion to the dose used, while in a layer of 0-0.05 m, the density values remained similar. Filho *et al.*, (2018) in Oxisols found that both soil amendments applied together reduced soil bulk density by up to 16% and penetration resistance in subsurface soil layers, which can be explained by the increase observed in the aggregate size class resulted in a better organization of soil particles and increasing of microporosity.

The soil pores are represented by cavities of different sizes and shapes, determined by the arrangement of solid particles, and constitute the volumetric fraction of soil occupied with air and solution (Hiel *et al.*, 2016). According to Auler *et al.*, (2017) surface application of limestone without inversion and the control, in layer of 0 to 0.10 m showed significant interaction. They further stated that the pH increased in soil, dispersed clay in water, and levels of Ca^{2+} and Mg^{2+}, as well as promoted a reduction in soil density, also influenced by reducing values of macroporosity and an increase in values of total porosity and micropores. Alternatively, Spera *et al.*, (2008), observed that there was a difference in the dynamics between used limestone doses and macro and micropores in dystrophic Red Ferralsols. Also, according to Auler *et al.*, (2017) liming promoted an increase in micro and macroporosity and contributed to the availability of water and soil aeration in 0.-0.10 and 0.10-0.20 m of undisturbed and disturbed soil.

Table 2: Aggregate stability, Bulk density, and Total porosity as affected by surface application of lime rates in different soil layers

Lime rates, kg ha^{-1}	**0**	**1000**	**2000**	**4000**
Soil Depth (m)	**Aggregate stability index (%)**			
0–0.05	79.3	87.2	84.9	80.4
0.05–0.10	66.3	79.1	73.7	72.3
0.10–0.20	68.3	71.3	71.1	68.1
0.20–0.40	66.5	72.1	67.5	70.3
0.40–0.60	59.3	65.3	54.1	72.8
Soil Depth (m)	**Soil bulk density (Mg m^{-3})**			
0–0.05	1.6	1.62	1.66	1.63
0.05–0.10	1.78	1.64	1.68	1.64
0.10–0.20	1.79	1.61	1.62	1.63
0.20–0.40	1.73	1.55	1.53	1.51
0.40–0.60	1.55	1.48	1.4	1.48
Soil Depth (m)	**Total porosity (%)**			
0–0.05	0.43	0.44	0.42	0.42
0.05–0.10	0.38	0.42	0.4	0.41
0.10–0.20	0.37	0.44	0.43	0.41
0.20–0.40	0.39	0.45	0.47	0.45
0.40–0.60	0.45	0.48	0.51	0.46

Source: Carmeis *et al.*, (2018)

2.3 Effects of Lime on the Yield of Crops

Liming induced favorable conditions for plant growth was the main reason for the yield increment of different crops (Temesgen *et al.*, 2017). Álvarez *et al.*, (2009) reported that the application of lime at an appropriate rate brings several chemical and biological changes in the soil, which is beneficial or helpful in improving crop yields in acid soils. Wang *et al.*, (2011) also reported that, yield increase from liming is mainly associated with an increase in soil pH and a reduction in plant uptake of Al and Mn. The response of applied lime could be affected by many factors in the soil. However, the type of crop species, time of application, and environmental variables such as moisture have a subtle effect on applied lime (Temesgen *et al.*, 2017). The applied lime significantly ($p < 0.001$) affected the grain yield of faba beans in Holeta (Temesgen *et al.*, 2017). The highest (2406 kg ha^{-1}) grain yield was obtained from the application of 4 t lime while the lowest (864 kg ha^{-1}) grain yield was obtained from with no lime. The grain yield enhancement observed due to the application of lime might be related to the nutrient supply of soil and availability to crop vegetative growth to improve photo interception and high dry matter partition to grain. The multiple positive effects of lime on the physical, chemical, and biological properties of soils are also reported to contribute to crop growth and increase grain yield (Horneck *et al.*, 2007). The grain yield of sorghum was significantly ($P < 0.05$) influenced by the interaction effect of lime and phosphorous rate (Getahun *et al.*, 2019), and the highest grain yield of sorghum was obtained from the application of 5.65 t lime ha^{-1} and 46 kg P2O5 ha^{-1}.as compared to the lowest grain yield (554.8 kg ha^{-1}) recorded for control. They further stated that the grain yield of sorghum was increased with the increasing levels of lime and phosphorus fertilizer. The positive effect of lime on sorghum grain yield was therefore likely due to its effect in increasing the soil pH, increasing the availability of nutrients, and reducing exchangeable acidity. The increase in the grain yield of sorghum due to the liming of acidic soils under different land use systems may be attributed to the reduction in acidity (H^+ and Al^{3+}) ions and reduction in nutrient deficiency of Ca and P (Getahun *et al*., 2019).

Mekonnen *et al*., (2014) revealed the combined application of 5 t manure and 2.2 t ha^{-1} lime increased grain yield and straw yield by 279 and 187 % in (crop) over the control. Temesgen *et al*., (2014) stated that successive applications of P increased grain yield and yield components, and counteracted Al toxicity by precipitating exchangeable Al^{3+} as $AlPO_4$. This could be the reason why large applications of phosphate fertilizers to acid soils overcome the toxic effects of Al and thereby improve the growth of plants (Temesgen *et al*., 2017). Getachew *et al*., (2017) reported that the application of lime and P fertilizer had significantly improved the grain yield of barley and soil chemical properties. Barley grain yield increased progressively with higher application of lime and P rates. Zerihun and Tolera, (2014) reported the increase of faba bean yield ranging from 11 to 23%, as the function of increasing lime application rates up to 6 t ha^{-1}.

Liming significantly increased nodule number, nodule volume, and nodule dry weight per plant of soybean as compared to the un-limed treatment (Abubakari, 2016). Temesgen *et al*., (2017) reported that the effect of lime on acid soil amelioration and barley grain yield was the highest during the initial four years, but in the fifth-year grain yield declined substantially. This yield reduction in the fifth year may indicate re-acidification of the soil. In Croatia, Andric *et al*., (2012) also reported increased soybean yield by 44% as a result of lime application over the control/un-limed treatments. Application of 2.0 and 1 t ha^{-1} lime recorded 72 and 48 % increases in yield, respectively, over no lime treatments in Nigeria (Buri *et al*., 2005). They further stated that the combined application of lime-phosphorus on Oxisols and Ultisols with pH ranging from 4.1-4.5 and 4.7-5.4 also showed a considerable increase in maize grain yield by both lime and phosphorus. The reason might be the increase in pH and the availability of other essential nutrient elements. Liming of acid soil increased the Plant height, fresh biomass, dry biomass, grain yields, harvest index, and P-uptake of barley (Achalu *et al*., 2012) and the increments related to the increase in soil fertility and reduction of the toxic concentration of acidic cations.

Table 3: Effect of lime on yield of some crops

Crops	**Grain yield (Kgha^{-1})**		**Percentage increment**	**Lime (t/ha)**	**References**
	Control	**Limed**			
Barley	675	1036	53	10	Achalu *et al*., (2012)
Barley	2898	4578	58	2.2	Temesgen *et al*., (2017)
Barley	3060	5117	67	1.65	Getachew *et al*., (2017)
Bean	1900	2600	37	9	Hipha *et al*., (2013)
Faba Bean	1509	2406	59	4	Geleta and Bekele, (2022)
Maize	2180	4880	124	4	Abdissa *et al*., (2018)
Maize	2200	3600	64	3.2	Mbakaya *et al*., (2011)
Sorghum	944	2469	162	5.64	Getahun *et al*., (2019)
Soybean	613	761	24	5.6	Dessalegn *et al*., (2018)
Soybean	2013	2494	24	1	Adriano *et al*., (2014)
Wheat	1420	2510	77	4.4	Chimdessa and Argaw, (2018)
Wheat	890	1980	123	2.2	Mekonnen *et al*., (2014)
Wheat	2710	4730	75	1.5	Kamaruzzaman *et al*., (2013)

Table 4: Average values of grain yield, dry biomass, pod harvest index, harvest index, and hundred seed weight of common bean genotype grown under lime-treated and untreated soils at Nedjo

Treatment	**Grain yield (t ha^{-1})**	**Dry biomass yield (t ha^{-1})**	**Pod Harvest Index**	**Harvest Index**	**Handed Seed Weight (g)**
Un-limed	1.9^b	3.6^b	1.01^a	0.33^a	18.8^b
Limed	2.6^a	5.3^a	1.05^a	0.34^a	19.5^a
PR	2.3	4.6	22.9	0.33	19.1
Mean	25.7	27.6	3.81	2.9	3.5
CV (%)	9.5	19.97	1.03	11.6	5.3

Source: Hirpa *et al*., (2013)

3. CONCLUSION

Application of lime at an appropriate rate brings several chemical and biological changes in the soil, which is beneficial or helpful in improving crop yields in acid soils. Liming is an important practice to correct soil acidity in order to maintain or increase soil fertility within sustainable management in the context of current agriculture. Application of lime improved the ability of the plant to absorb phosphorus, by eliminating Al toxicity, reducing exchangeable acidity, Al saturation, and increasing pH and thereby enhanced the vegetative growth, which resulted in increased dry biomass yield that in turn increased soil fertility and reduced the toxic concentration of acidic cations. An increase in soil pH results in the precipitation of exchangeable and soluble Al as insoluble Al hydroxides thus reducing the concentration of Al in soil solution. Liming acid soil results in an increase in the concentration of the exchangeable cations (Na^+, K^+, Ca^{+2}, and Mg^{+2}) and a decrease in micronutrients (Cu, Fe, Mn, and Zn) in the soil solutions, from exchange complex to the levels required and increasing nutrient availabilities for plant uptakes.

The effect of limes on soils is likely to be strongly dependent on lime composition, which depends on liming materials, application time, and soil moisture at the time of application. The reaction between lime materials and soil acidity is a slow and time-dependent reaction that needs proper use of lime and precaution before liming any acidic soils. Therefore, increases in productivity induced by liming, result in increasing soil PH, available phosphorus, cation exchange capacity, basic cations, microbial activity, organic carbon, total nitrogen, and decreasing leaching of nutrients, exchangeable aluminum, and acidity, which favor the physical and chemical properties of the soil.

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