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Application of Lime for Acid Soil Amelioration and Better Soybean Performance in SouthWestern Ethiopia

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Abstract
Soil acidity is one of the major soil chemical constraints which limit agricultural productivity in the mid and highlands of Ethiopia. The study was conducted to evaluate the influence of lime on yield and yield attributes of soybean in acid soil at Metu south western Ethiopia during 2010 to 2013 cropping season. The crop was evaluated in terms of yield and yield components. In this line, splitting into two and applying in two consecutive years as well as splitting of lime into three and applying in three consecutive years gave similar yield with full rate application of lime for soybean. Splitting into four was even gave similar grain yield with splitting lime into two and three.. Result of this experiment revealed that splitting the required amount of lime into 25%, 33%and 50% is possible if to be grown on this soil. Split application and full rate application gave almost similar soybean yield. However, resource of poor farmer who cannot afford the price of full dose lime can split in to two, three and four and apply every year without significant yield loss for both compared to one time application of full dose. Soybean grain yield was significantly ($P<0.05$) affected by the interaction of lime and year at Metu (Hurumu) . The highest grain yield observed on first and third year (2010&2012) at full dose application of lime.Even though lime level at 1.5* E.A (5.652t) and phosphorus at 46% shows good yield and had consistency across the year, Saied to be the best combination of Lime and P. Maintaining soil healthy is possible for the area because simultaneous and minimum use of lime and Phosphorus fertilizer give similar seed yield with maximum use of lime and Phosphorus on the study area. Phosphorus fixation, which is responsible for low availability of P, is one of the major problems of crop growth in acidic soils such as Nitsols of Metu area.
Keywords: Nitosols, Soybean, Lime, soil pH, exchangeable acidity

Introduction

Soybean crop is useful for the preparation of different kinds of foods, prevention of chronic human diseases, raw material for oil and concentrates food-producing factories. It is one of the most nutritious food crops; its protein has a good balance of the essential amino acids (FAO, 1994). The crop has a high commercial value and high concentration of protein, about 40%, calcium, phosphorus, fiber, and in addition it is cholesterol free (Hassan et al., 2010). It plays an important role in provision of food, cash and animal feeds (Mugendi et al., 2010). Soybean, like other leguminous crops has a positive impact on the soil; the canopies of soybean cover the soil and protect it from recurrent erosion (Latif et al., 1992). Soybean has potential to fix N from the atmosphere through biological fixation (Nieuwenhuis and Nieuwelink, 2002). This is important in farming systems where soils are continuously been exploited since the increasing population demands increased food production. Through research, it has been demonstrated that some varieties of this crop have the ability to fix nitrogen from 44 to 103 kg N ha-1 annually (Sanginga, 2003). In Kenya, this crop is relatively new and expected to increase production due to its importance in supply of food, income and improving household nutrition (Mugendi et al., 2010).

Potential yields of soybean are still below the expected (3.0 - 3.6 t ha-1), with average yields in central provinces ranging from 560 to 1100 kg ha-1 (Mahasi et al., 2010). Many factors are responsible for the low productivity, which include inherent poor soil fertility (Bationo et al., 2006), continuous decline of the soil fertility (Kimani et al., 2004), poor management practices and low agricultural input use (Njeru, 2009). The prevalence of acidity is associated with nitrogen (N), phosphorus (P) deficiency in the soil, aluminum (Al) toxicity, low extractable bases (Ca, Mg, K and Na), and reduced microbial activity which therefore results to low crop yield and land productivity (Crawford et al., 2008). Moreover, application of lime tends to raise the soil pH by displacement of H^+ , Fe^{2+}, Al^{3+}, Mn^{4+} and Cu^{2+} ions from 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). These are some of the major factors that adversely affect performance of soybean. According to survey of (Eyasu,2016) he found that 80% of Nitisol are strogly acidic having PH of 4.5-5.5.Soil acidity is a barrier to crop production in almost all regional states of Ethiopia., Some of the well-known areas severely affected by soil acidity in Ethiopia are Ghimbi, Nedjo, Hossana, Sodo, Chencha, Hagere-Mariam and Awi Zone of the Amahara regional state. Despite this coverage, no well-recorded documents are available describing the magnitude and extent of soil acidity in the country.

Soil acidification is a complex process resulting in the formation of an acid soil due to excessive concentration of non-soluble and toxic ions in the soil solution. In the context of agricultural problematic soils, acid soils are soils in which acidity dominates the problems related to agricultural land use. Consequently, the level of aluminum and hydrogen becomes too high causing the soil's negatively charged cation exchange capacity to be overwhelmingly blocked with positively charged hydrogen and aluminum, and the nutrients needed for plant growth become unavailable resulting into inhibition of root growth and plant development (Mesfin bebe, 2007; Kamprath, 1984; Fox, 1979).

The process of acidification results the replacement of basic cations Ca, Mg and K in the soil exchange sites with Al, Mn and Fe and increased the concentration of H^+ ion in the soil solution. Where soil pH is lower than optimal (5.5 and below) the availability of nutrients needed for growth is reduced. This condition also usually lead to Al and Mn toxicity plus deficiency in N, P, K, Mg, Ca and various micronutrients. This has multiplication for the plant growth and nutrient management as this lead to lack of or reduced response to applied fertilizers due to high P fixation by Al and nutrient deficiency which can results 50% and above yield reduction (IFPIR, 2010).

Availability of essential nutrients and biological activity in soils are generally greatest at intermediate pH at which organic matter break down and release of essential nutrients like N, P and S is enhanced. Improving acid soil fertility is basic to achieve long term food security and improve livelihood of farmers depending on this soil.

Soil of Illubabor areas is dominated by Nitisol/Oxisol. These soils are predominantly acidic and have been found that more than 80% of the landmasses originated from Nitisol are acidic. Liming is an important and commonly used acid soil management practices these days. Because, many small scale farmers of the country depend on this soil for their day today livelihoods its management has been given due attention. However, lime is obtained not for free as well as large quantity may be needed for highly affected areas and its transportation is difficult. Splitting the required amount of lime and applying every year may be a solution. Therefore, the activity was conducted with the objectives of determining efficiency of split application of lime on soybean productivity and properties of acid soils.

Materials and methods

The study was conducted on Hurumu woreda in Metu zone, South Western Ethiopia. The woreda is located at a distance of 587 km, south western of the capital Addis Ababa. Geographically, the woreda lies between latitudes of **8^0 03" N** and longitudes of **30^0" E** with altitudes ranging from 1550 meters above sea level. The mean annual temperature of the woreda ranges from 17.6-25ºC and the average annual rainfall is about 1300 mm per year The dominant soils of the area was reported (Mesfin ,1998) Nitisols which are sesquioxidic and moderately to strongly acidic. These soils have high clay content (35-50%), homogenous, highly developed medium angular blocky structures, and are silt clay in texture.

Field experiment was conducted on soybean for four cropping seasons on acid soils of Ilubabore zones of south-western Ethiopia.. Before commencement of the experiment, experimental field was characterized for selected soil physical and chemical properties, soil samples were collected from 0-15 cm depth for initial determination of soil fertility parameters. Thereafter, and to evaluate changes in soil as a result of applied treatments, soils were sampled at harvest. The soil samples were analyzed for pH, available, exchangeable acidity P, % N, and % OM. The soils of the experimental site were strongly acidic (pH = 4.46) according to soil classification based on soil pH (Eyasu, 2016); and low in available P (Tables 6)

Clark 63K soybean varieties were used in the investigation. Soybean seeds were sown by 60cm x 5cm spacing. The experiment was laid out in randomised complete block design with three replications. Lime requirement was calculated using exchangeable aluminium (Al) of soil. Five levels of treatments of split lime applications were (control, full dose of recommended lime applied at one time during the cropping season, two splits in which 50% of the dose applied in the first year and the rest 50% in the second year, three splits in which 33% of the dose applied in the first year, 33% in the second year and the rest 33% in the third year and four splits in which 25% of the dose applied in the first year, 25% in the second year, 25% in the third year and the rest 25% in the fourth year) applied. Lime was broadcasted uniformly by hand and incorporated into the soil a month before planting. Recommended rate of N, 46kg N $ha^{-}1$ and 20kg P ha-1, P2O5 were uniformly applied for all treatments. Urea and TSP were used as the source of N and P, respectively. Application of urea was made in two splits, half at sowing and half at 4-5 weeks after sowing; while the entire rate of phosphorus was applied at sowing in band. Data collected from the crop and soil were subjected to analysis of variance using SAS software packages and mean separation was done using LSD (Gomez and Gomez, 1984) at 5% probability level.

Result and Discussions

1. **Effect of split application of lime on soybean growth and yields**

Over years mean showed that split application of lime significantly ($P < 0.05$) affected soybean grain yield at this location. In this line, splitting into four, three, two and full dose at first cropping season not significantly affected grain yield of soybean. Whereas all splitting and full dose of lime application in the consecutive years gave Significant yield than control, and also grain yield variation observed among cropping seasons. Splitting application of lime into consecutive years gave similar grain yield with full rate application of lime. Splitting into four was even gave similar grain yield with splitting lime into two and three. This is may be due to the lime applied yearly increase the lime amount and that gradually increase buffering of the soil acidity and enhancing P release . Besides, result of this experiment revealed that splitting the required amount of lime into 25%, 33% and 50% is possible if to be grown on this soil. Split application and full rate application gave almost similar soybean yield at the testing site (Table 1). However, resource poor farmers who cannot afford the price of full dose lime can split in to two, three and four and apply every year without significant yield loss for both crops compared to one time application of full dose. Soybean grain yield was significantly ($P<0.05$) affected by the interaction of lime and year at Metu (Hurumu) (Table 2). The highest grain yield observed on first and third year(2010&2012) at full dose application of lime . Application of lime might contributed in releasing some amount of fixed P to be available for the crop. Therefore, for better soybean production, enough amount of NP should be applied with lime. But application of lime alone could not help crop production to be increased. This also indicates that deficiency of nutrient cannot be replaced by lime. As a result in acidic soils which are deficient in nutrient, it is important to apply fertilizer together with lime to increase production.

Plant height was not significantly ($p < 0.01$) affected by the treatments in 2010 cropping season, but in the consecutive years significantly ($p < 0.01$) affected, the highest plant height was obtained in the 50% lime receiving treatment , 25%, 33% and 50% lime receiving treatments 2011, 2012 and 2013 cropping seasons, respectively. While no lime application treatment recorded the lowest plant height (cm) (Table 3).

Soybean pod number per plant was significantly ($p < 0.05$) affected by the treatments The result showed that pod number of the soybean plant increased by increasing the cropping season of lime application. Liming at the rate of 25%, 33% and 50% lime splitting per year, increase the number of pod per plant. Lime control treatment also increase pod number per plant per season due to fertilizer application per seasons. Therefore, for improved pod number per plant increase, adequate amount of lime should be applied with fertilizer. However application of lime or fertilizer alone could not help soybean pod to be increased.

The dry matter production not significant for two following years by split lime application ,but for two years repeated differed significantly between limed and un limed or control treatments.

Application of splitting lime into 25%, 33% and 50% is and full dose treatments increased dry weight of soybean. The increased dry matter weight of total plant may be due to value of the treatment which resulted in vigorous vegetative growth parameters and yield attributes resulting in higher value. Lower dry matter production in 2012 cropping season may be due to climate change of seasonal variation. On the contrary, higher dry matter production of soybean in 2013 cropping season was the application of lime and fertilizer had an effect of synchronize efficiency of the crop parts. This increases the production of more number of leaves and stem. Similar results were reported by(Wassie *et al*, 2009).

Table 1. Effect of Split Application of Lime on Soybean seed Yield (kg ha^{-1})

Treatments	**2010**	**2011**	**2012**	**2013**	Over year Mean
Control	1689.7	1344b	1436b	1973b	1756.75b
25% every year	1510.3	1953a	1753ab	2390a	1959.83a
33% every year	1749.7	2024a	1739ab	2307a	1950.42a
50% every year	1737.7	2004a	1858a	2327a	1958.25a
Full dose	1709.3	2050a	1766ab	2188ab	1818.83ab
$LSD_{0.05}$	NS	470	360.91	238.35	156.3
CV (%)	9.26	13.33	11.21	5.66	10.01

Means with in a column with the same letter(s) are not significantly different at 0.05 probability level. ns =Not significantly different at 0.05 probability level

Table 2Interacion of Split Application of Lime by year on Soybean Yield (kg ha^{-1})

	Year			
Lime	**1(2010)**	**2(2011)**	**3(2012)**	**4(2013)**
Control	1689.7f-h	1510.3gh	1749.7e-f	1737.7f-h
25% every year	1709.3f-h	1824d-g	2186.7a-c	2143a-d
33% every year	1910.7b-f	1612f-h	1436.3h	1752.7e-h
50% every year	1739f-h	1857.7c-f	1765.7e-h	2077a-e
Full dose	2389.7a	2170a-c	2327a	2188.3ab
$LSD_{0.05}$		329.85		
CV (%)		10.58		

Means with in a column with the same letter(s) are not significantly different at 0.05 probabilities level. ns =Not significantly different at 0.05 probability level

Table 3. Effect of Split Application of Lime on Soybean plant height (cm)

Treatments	2010	2011	2012	2013
Control	53.33	60.27b	54.87b	63.67b
25% every year	55.67	62.8ab	58.6ab	69.8a
33% every year	53.67	62ab	63.13a	69.27a
50% every year	55.33	65.33a	63.33a	65.27b
Full dose	54.67	63.6ab	60.2a	67.93a
LSD $_{0.05}$	NS	4.69	5.12	1.995
CV (%)	5.96	3.97	4.53	1.58

Means with in a column with the same letter(s) are not significantly different at 0.05 probability level. ns =Not significantly different at 0.05 probability level

Table 4. Effect of Split Application of Lime on Soybean No.pod per plant

Treatments	2010	2011	2012	2013
Control	20b	25.33b	26b	35c
25% every year	24.33ab	30ab	32a	41.67b
33% every year	28.67a	32.67a	33.33a	44.67ab
50% every year	24.33ab	33.33a	30.5a	46a
Full dose	27.33ab	30ab	32.13a	43.67ab
LSD $_{0.05}$	8.4	7.2	4.29	4.04
CV (%)	17.9	12.64	7.4	5.08

Means with in a column with the same letter(s) are not significantly different at 0.05 probability level. ns =Not significantly different at 0.05 probability level

Table 5. Effect of Split Application of Lime on Soybean DM Biomass yield kg/ha

Treatments	2010	2011	2012	2013
Control	4800	2594	1878b	6000b
25% every year	4833.3	3147.3	2332a	6683.3a
33% every year	4983.3	3204.3	2686a	6483.3ab
50% every year	5033.3	3292	2420a	6516.7ab
Full dose	5066.7	3242	2388a	6200ab
LSD $_{0.05}$	NS	NS	395.63	5.35
CV (%)	5.86	12.65	8.98	642.19

Means with in a column with the same letter(s) are not significantly different at 0.05 probability level. ns =Not significantly different at 0.05 probability level

2. Influence of split application of lime on soil chemical properties

Application of lime influenced soil chemical properties. All split lime and full rate application significantly ($p<0.05$) increased pH. This is due to the fact that Hurumu soil is strongly acidic with an initial pH value of less than 5 and exchangeable acidity of about greater than 3. However, 25%, 33% and Full dose application of lime significantly lowered exchangeable acidity of the soil but difference was not observed among them. 50% application even significantly decreased exchangeable acidity of Hurumu soil over those of 25%, 33% and Full dose applications and this is in agreement with Anetor and Ezekiel (2007) who indicated that lime increased pH and available P in Nigeria. However, exchangeable acidity were decreased with increasing application. On the other hand lime did not influence total nitrogen (N) and organic matter of the soil. This indicates that application of lime is required to increase the soil nutrient availability, soil pH, soybean yield, and reduce exchangeable acidity at Hurumu. Although the soil pH was increased due to lime application, it did not reach to the desired range indicating a regular application of lime is needed (Table 7).

Table 6. Soil chemical properties of the soil (0-15 cm depth) prior to planting.

Parameter	Soli
pH water (1:2.5)	4.6
Exchangeable acidity (cmol kg-1 soil)	3.76
ppm P	4.16

% N	0.26
% OM	5.9

Table 7. Effect split application of lime on acidic properties of soil

Treatments	pH	Ex Acidity (Cmol kg^{-1})	Available P (ppm)	%N	%OM
Control	4.7b	3.81a	4.34b	0.27	5.91
25% every year	4.9ab	1.46b	5.15ab	0.27	6.25
33% every year	4.9ab	1.42b	6.69a	0.29	6.34
50% every year	5.0ab	0.54c	5.57ab	0.25	6.16
Full dose	5.1a	1.99b	5.49ab	0.25	5.81
$LSD_{0.05}$	0.26	0.7	2.2	NS	NS
CV (%)	12.87	20.16	21.45	1.37	6.3

Means with in a column with the same letter(s) are not significantly different at 0.05 probability level.
ns =Not significantly different at 0.05 probability level

Conclusion

Results showed that lime applied at the rate of Ex.Acidity combined with mineral NP fertilizer mostly improved soil conditions and soybean grain yields

Without a significant yield loss and harming soil healthy, splitting lime into one third and half and applying in three and two consecutive years, give similar yield with full rate of lime applied once in the first year. Therefore, resource poor farmers could split up to one-third and cultivate maize and soybean at Metu (Hurumu) as well as similar areas.

Application of lime soil chemical properties was better, increasing in pH Soils, more availability of phosphorus potassium and calcium whereas aluminum significantly reduced.

These preliminary results recommend the use of lime split alongside with mineral fertilizers to increase soybean yields. More research needs to be carried out for more seasons to assess the consistence of these findings.

The growth and yield of soybean respond to lime and chemical fertilizer the higher rate of lime and fertilizer s, the higher in yields.

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