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Effect of Balanced Fertilizers and Lime Rate on Maize (*Zea mays* L) Yield in Omo Nada District, Southwestern Oromia, Ethiopia

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Abstract: Declining of soil nutrients is among the factors that lead to low crop yields in Sub-Saharan Africa including Ethiopia. The experiment was conducted to verify and demonstrate the beneficial effect of lime and balanced fertilizer application rate in improving the yield of Maize on acid soils of Omo Nada district. The experiment comprised seven treatments namely; Control, NPS, NPSB, NPSB with 100% recommended rate of Lime, NPSB with 75% recommended rate of Lime, NPSB with 50% recommended rate of Lime and NPSB with 25% recommended rate of lime were laid out in Randomized Complete Block Design (RCBD) replicated across ten farmers' fields. Data analysis was conducted on grain yield data to detect variation among treatments. Partial budget analysis was also done to determine the economic feasibility of treatments. The results revealed that there were highly significant differences ($P < 0.01$) among treatments in their effect on grain yield of maize. Accordingly, NPSB with full recommended lime gave significantly superior yield of maize (in sites. This treatment increased the mean grain yield over the control by 27.26 qt/ha yields advantages. Application of lime alone did not increase the yield of Maize in all sites suggesting that the soil were severely depleted of essential nutrients. The result of partial budget analysis data also showed that the highest net benefit and marginal rate of return (466%) was obtained from NPSB with full recommended lime. Finally, the highest biological and economical yield of Maize was obtained from NPSB treatment applied at 100 kg/ha and full recommended rates of lime. Results suggest that nutrient depletion can be mitigated in the area through using of lime; hence longer-term productivity of smallholders can be sustained.

Keywords: Soil Acidity, Balanced Fertilizer, Maize Production, Lime

1. Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops in the world. It ranks third among other cereals after wheat and rice [1]. Maize is the most widely grown among cereal crops in Africa and a staple for around half the inhabitants in the continent. It is grown across diverse agro-ecological zones where over 200 million people depend on the crop for food security [2]. Maize accounts for almost half of the calories and protein consumed in Eastern and Southern Africa, and one-fifth in West Africa [3].

However, the yield is often limited due to a combination of several factors that include continuous mono cropping and inadequate fertilizer use, which in turn caused soil fertility degradation. Several studies revealed that optimum N and P rates differed for different maize growing locations [4] and with different cropping system, suggesting that the old tradition of using blanket fertilizer recommendation can no more be an appropriate practice to follow. The proper application of plant nutrients are determined by knowing the nutrient requirement of the crop and the nutrient supplying power of the soil [5].

Recently acquired soil inventory data from EthioSIS also revealed that in addition to N and P, nutrients such as S, B, Zn are deficient in Ethiopian soils in general and study area in particular [6]. Moreover, the magnitude of N, P and other micronutrient effects on grain yield of maize vary with sites due to differences in soil nutrient supplying capacity and crop management practices in the study area [7]. The yield obtained by the farmers in the study areas is low due inappropriate agronomic practice, lack of stable high yielder varieties, drought and soil erosion and poor essential soil nutrient [8].

Deteriorating soil fertility, shallow soil depth, high run-off and low in infiltration capacity of the soil are the major restriction for supportable agricultural production in Omo Nada. So something is done to repair soil fertility first to increase crop production. The most common problems in all regions where precipitation is high enough to leach appreciable amounts of exchangeable bases from the soil surface [9]. There are different literature that showed at soil pH < 5.5 affects the growth of crops due to high concentration of aluminum (Al) and manganese (Mn), and deficiency of P, nitrogen (N), sulfur (S) and other nutrients [10].

The southwestern region of Ethiopia covers areas with highly suitable for maize on inherently fertile Nitisol with humid to sub-humid climate zones. Jimma administrative zone have declining soil fertility that is one of the major constraints for maize production. Therefore, to overcome soil acidity problem using liming material is the primary options to raises soil Ph at which crops vigorously grow properly [11]. The major recently recommended blended fertilizers for Omo Nada by ATA is NPSB [8] but the optimum rates of the recommended blended fertilizer for maize crops is not yet identified for Omo nada district.

Moreover, liming contributes appreciable amount of basic secondary macronutrients like Ca^{2+} and Mg^{2+} which are essential for plants [12]. Accordingly, Evaluation of Lime and blended Fertilizers Effects on grain yield of Maize at Omo Nada district, Jimma Zone was started by Bedele Research Center as joint activity with Jimma University CASCAPE project during 2017. The result showed that soil pH of experimental site was falling in very strongly acidic (4.05-5.03) before sowing and change to moderately acidic (4.18-5.67) after harvest in cropping season of 2017 [13].

Alemayehu [13] reported that change in pH from very strongly acidic (4.05) to moderately acidic 5.67 and yield of 41.72 qt/ha was recorded from the treatment combination of 100 kg/ha NPSB with 1.42 ton/ha lime for maize, followed by the change in pH from 4.05 to 5.31 and yield 39 qt/ha was obtained from the treatment combination of 100 kg/ha NPSB with 1.065 ton/ha lime. Although the soil pH was increased due to lime application, it did not reach to the desired range needed by maize (5.5-7.0). Therefore, the objectives of this study was to verify and demonstrate the beneficial effect of lime and balanced fertilizer application rates in improving the yield of Maize on acid soils in Omo Nada district, Southwestern Oromia, Ethiopia.

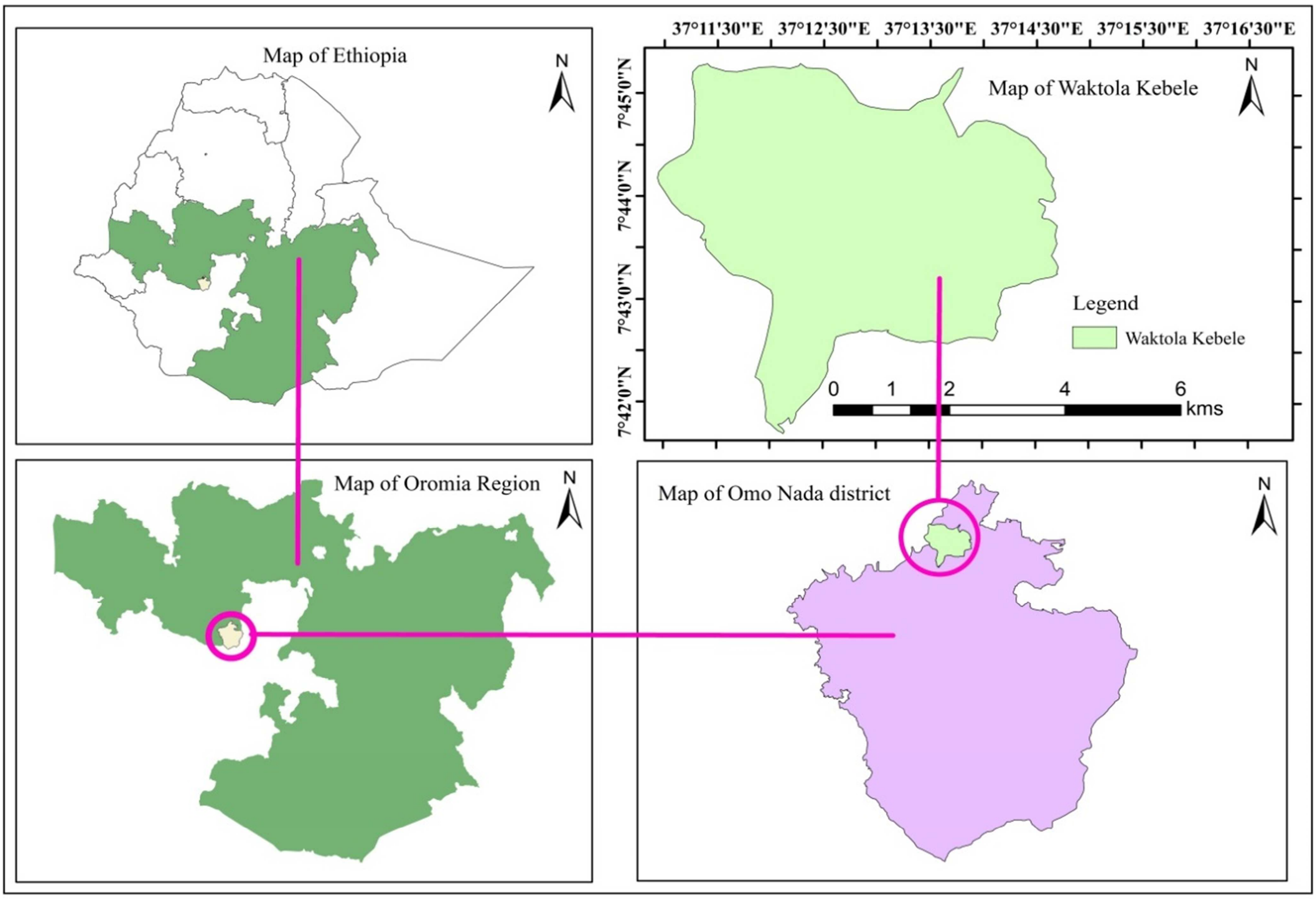


Figure 1. *Map of the Study area.*

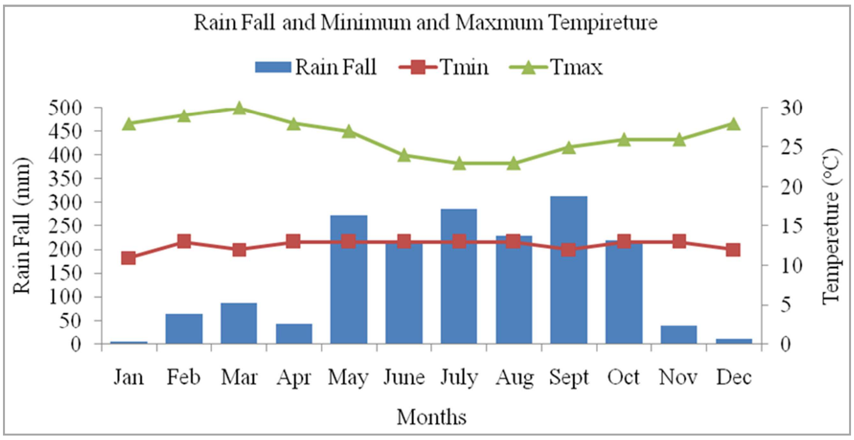


Figure 2. *The annual rainfall, maximum and minimum temperature of the study area.*

2. Materials and Methods

2.1. Description of Study Area

The study was conducted on farmers' field at waktola Keble, Omo Nada district, Jimma Zone of southwestern Oromia. Geographically, the area is located at 07°42'45.7" to 07°43'48.7" latitude (N) and 037°12'59.1" to 037°13'41" longitude (E). The altitude ranges from 1617 to 1893 m.a.s.l falling in a tepid moist to cool highlands agro ecological zone. The landforms of the area are characterized by undulating to rolling plateaus, scattered moderate hills, and dissected side slope sand river gorges [14].

It is situated in cool to sub-humid highlands of southwestern Ethiopia. The main rainy season in the study area stretches from March to September with bimodal distribution. The thirty years average mean annual rainfall recorded was 1198 mm and the minimum and maximum temperature was about 11.8°C and 27.2°C, respectively. Nitisol are the dominant reference soil groups in the upper slopes in the low lying plain areas [15]. According to the harmonized soil map of Africa [16], the major reference soil groups of the southwestern highland plateaus are Nitisol, Vertisol, Leptosol, Regosol, Cambisol and Acrisols. Nitisol are the dominant reference soil groups in coffee-growing areas of southwest Ethiopia and in the study area, which have a depth of more than 1.5 m, clayey and red in color. These soils are well drained with good physical properties such as high water holding capacity, a deep rooting depth and stable soil aggregate structure.

2.2. Lime Requirement Determination

For lime recommendation, soil sample from sites were collected before lime application and subjected to analyses of acidity attribute. When soil pH is below 5.5, liming is a common method to increase the soil pH and reduce acidity. But the amount of lime required to bring certain pH to optimum range for crop growth depends on some factor as organic matter, clay content and soil pH. Lime Requirement (LR) of sites and crops were determined based on exchangeable acidity (Ex. Ac) [17]. LR (ton/ha) =Exchangeable Acidity*1.5*10. Where; LR=Lime Requirement. To avoid over liming, an adaptation factor was proposed that takes the Al sensitivity of crops into account. Factor = < 1 for Al-tolerant crops = 1.0 for moderately Al-tolerant crops = 1.5 for Al- sensitive crops [18]. Based on soil result recommended rate of lime (2.94 ton/ha) was uniformly applied to the experimental field because soil acidity is a common problem in the district. Lime ($CaCO_3$) was evenly broad casted manually and thoroughly mixed in the upper 15cm depth of the soil one month before seed sowing.

2.3. Field Layout and Experimental Design

The experiment comprised Eight treatments were used (1) Control (2) NPS (3) NPSB (4) NPSB with 100% recommended rate of Lime (5) NPSB with 75% recommended rate of Lime (6) NPSB with 50% recommended rate of Lime (7) NPSB with 25% recommended rate of lime (8) recommended lime alone were laid out in randomized complete block design (RCBD) replicated across ten farmers' fields in each location. The plot size 10m×10m (100m^2) was used for the experiment. Composite soil samples were taken from eight site randomly selected farm fields. Results of the test indicated that the soil samples were within the highly acidic category (soil pH ranged 3.11-5.13) as per the Acid Soils Management and Lime Application Guideline that Federal Ministry of Agriculture published [19] (Table 1). Fertilizer rates of 100 kg NPS kg/ha, 100 kg/ha NPSB and 100 kg/ha Urea was applied and half urea applied after 45 days.

Table 1. *Treatment Combination.*

Treatment code	Lime rates	Fertilizer kg/ha	Treatment combination
1	0	0	0:00
2	0	100 NPS	0:100 NPS
3	0	100NPSB	0:100NPSB
4	100% RL	0	100% RL: 0
5	100% RL	100NPSB	100% RL:100 NPSB
6	75% RL	100NPSB	100% RL:100 NPSB
7	50% RL	100NPSB	100% RL:100 NPSB
8	25% RL	100NPSB	100% RL:100 NPSB

RL=Recommended Lime.

2.4. Data Analysis

Analysis of variance was conducted for grain yield data using SAS software [20]. Means were separated using least significance difference method (LSD).

Table 2. *pH and Lime requirement of experimental locations before planting.*

Site No	pH before sowing	Lime requirement (Qt/ha)
Site 1	5.04	3.9
Site 2	4.6	5.9
Site 3	3.12	14
Site 4	4.88	4.1
Site 5	5.13	2.5
Site 6	3.66	9.1
Site 7	3.71	7.4
Site 8	3.65	11.6
Site 9	3.02	14.3

Soil pH of experimental sites were ranged from extremely acidic (3.12) to strongly acidic (5.13) according to [21] report. The recommended lime for the experimental sites was ranged from 2.5-14.3 Qt/ha. The result showed that soil pH affected maize production because soil pH results less than the maize required proposed as FAO [21] (pH 5.5-7). In general maize as crop does not tolerate pH condition for less than 5.5, preferring an optimum range of 6-7.2. In acid soil the root of maize suffer impairment from Aluminiem toxicity limiting nutrient uptake.

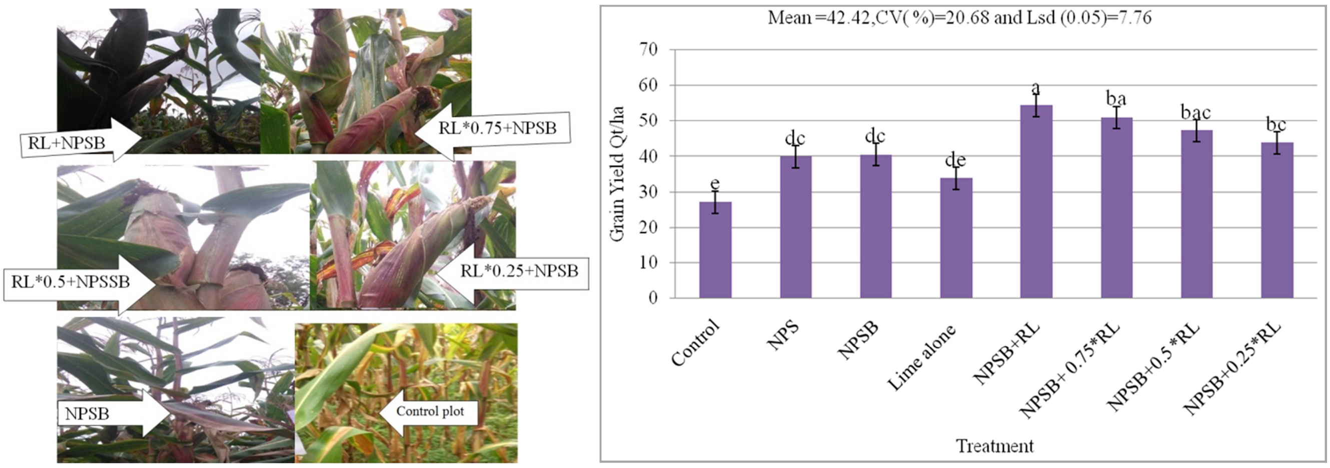
Table 3. *Soil pH values after harvesting of maize at Omo Nada district.*

Treatment	Average pH before harvesting	pH after harvesting	change observed
Control	4.45	4.71	0.26
NPS	4.45	4.77	0.32
NPSB	4.45	4.64	0.19
Lime alone	4.45	5.08	0.63
NPSB+RL	4.45	5.16	0.71
NPSB+ 0.75*RL	4.45	5.06	0.61
NPSB+0.50 *RL	4.45	5.01	0.56
NPSB+0.25*RL	4.45	4.84	0.39

3. Results and Discussions

3.1. Effect of Liming on Soil pH Level

Application of lime raised soil pH from an average value of 4.125 to above 5.08. As showed in (table 2) the differences of pH were observed between the treatments. The pH values of treatment plots that received recommended lime plus fertilizer had the highest pH (5.16). The result indicated soil is not neutralized because the pH of the soil under the study area (pH: 4.71-5.16) qualify for extremely acidic to a strongly acidic which are pH: <4.6, 4.6- 5.5 [21]. The result showed that soil pH affects maize production because soil pH results less than the maize required proposed as FAO [21] (pH 5.5-7).



Bars capped with same letter (s) are not significantly different P=0.05 according to LSD test.

Figure 3. *Agronomic Performance of lime and balanced fertilizer effect at Omo Nada district Note; RL=Recommended lime.*

The result of grain yield demonstrated that application of blended fertilizer alone or combined with fertilizers significantly increased maize yield over the control. As to Blended fertilizers alone NPS and NPSB application in all fertilizer combination alone increased grain and biomass yield of Maize (Figure 1). NPS and NPSB alone did not affect the yield in the district but their combined application significant affect maize yield. This increased yield might in part due to increased pH and reduced exchangeable aluminum and in part might be due to improved nutrients recovery as a result of lime application. As shown on above the table 3: the higher yields was observed by combining of 100 NPSB with 100% recommended lime that followed by 75% recommended lime, 50% recommended lime respectivily. More over, yield obtained from lime alone is greater than the control; this showed that the area is highly affected by acidity and need lime treatment.

3.2. Economic Analysis

Economic optimum yield levels were identified using preliminary partial budgeting and dominance analysis [22]. For the partial budget, analysis post harvest agronomic data were used and also account for percentage loss due to harvesting date and mechanism, storage, transport, etc. This was done by reducing the total yield by the recommended level of 10%, and arriving at the net yield. Then to determine the gross benefit by multiplying net yield by the field price (market price adjusted for any costs related to storage, transportation, etc.). Then all costs and benefit of each treatment were calculated separately to arrive at the net benefit of each treatment. This was helped researchers identify treatments with highest benefit for application of lime. Net benefits and costs that vary between treatments were used to calculate marginal rate of return to investment capital as to move from a less expensive to a more expensive treatment. Economic analysis was carried considering only the purchasing cost of inputs as farmers normally use family labor to process, transport and apply lime and fertilizers to crop fields. Moreover, sensitivity analysis was made to see the sensitivity of the recommended rate when subjected to input and output price changes.

Table 4. *Partial Budget of in-depth trail.*

Partial budget	Treatment							
	RL+ NPSB	**0.75 RL+NPSB**	**0.5 RL+NPSB**	**0.25 RL+NPSB**	**Only RL**	**Only NPS**	**Only NPSB**	**Control**
GY (qt ha^{-1})	54.3	50.9	47.2	43.6	33.7	39.8	40.4	27.1
AY (qt ha^{-1})	48.87	45.81	42.48	39.33	30.33	35.82	36.36	24.39
GFB (Birrha^{-1})	42028.2	39396.6	36532.8	33823.8	26083.8	30805.2	31269.6	20975.4
Urea (Birr/100 kg)	1260.69	1260.69	1260.69	1260.69	0	1260.69	1260.69	0
NPS (Birr/100 kg)	0	0	0	0	0	1271	0	0
NPSB (Birr/100 kg)	0	0	0	0	0	0	1281.78	
LA (100 birr /day)	400	300	200	100	400	0	0	0
TVC (Birr/ha)	1660.69	1560.69	1460.69	1360.69	400	1271	1281.78	0
Net benefit	40367.5	37835.91	35072.11	32463.11	25683.8	29534.2	29987.82	20975.4
MRR	2.4							

Note: - RL=recommended lime, GY=Grain yield, AY=Adjusted Yield, GFB=Growth Field Benefit, LA=Lime Application, TVC=Total variable Cost and MRR=Marginal Rates of return.

The results of partial budget analysis data are shown in (Table 4) Accordingly, the highest net benefit (40367.5 ETB) was obtained from NPSB with full Recommended lime treatment followed NPSB with 75% of full recommended lime treatment 37835.91EB. The highest marginal rate of return (243%) was obtained from NPSB with full recommended lime treatments. In this experiment, it was found that blended Fertilizer application alone did not increase the maize yield on farmers' field due to acidity problem.

4. Conclusion and Recommendations

In this experiment, it was found that balanced application of fertilizer alone did not increase the maize yield but greater due to acidity problem. This agreement with report of [14] that showed Fertilizer application alone did not significantly increase the yield of crops in these unless it is applied along with lime or inorganic fertilizers due to severe nutrient depletions prevailing in these areas. In such a case, application of lime raises the pH and makes the nutrients available to crops. The current experiment confirmed that lime is essential but must be complimented with balanced plant nutrients in order to get adequate Maize yield in the study areas. Hence it is economically feasible to improve maize yield and yield components on acidic soils of the study area by combined use of lime and NPSB fertilizer. Therefore, soil test based lime and NPSB application can be used for the sustainable production of maize on acidic soils in Ethiopia. Accordingly, 100%, 75%and 50% recommended lime rates had statistically significant effect on yield and 100% recommend lime with 100kg/ha NPSB blended is best on the study area.

5. Prospects

Effects of Balanced fertilizer and lime rate on Maize have the best option to tackle acidity problem and increase crop production. However various aspects remain to be investigated.

Thus, future research endeavor should focus on:

1. Combined balanced fertilizer and lime application based on their properties is needed.
2. Research Institution should focus on solving of acidity problem as main work.

Conflict of Interest

The all authors declare that there is no conflict of interest regarding the publication of this article.

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