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The Influence of Applying Lime and NPK Fertilizers on Yield of Maize and Soil Properties on Acid Soil of Areka, Southern Region of Ethiopia

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Abstract

Soil acidity is one of the major soil problems that limit agricultural productivity in the mid and highlands of Ethiopia. For its strong acid neutralizing effect, liming is the most frequently used practice to treat acid soils. This study was conducted to know the effect of lime and NPK nutrients on the yield of maize and soil chemical properties on acid soils of Areka. Five levels of NPK (Check, NP, NK, PK, NPK) and three levels of lime (0, half and full dose of the required amount) were arranged in a factorial experiment using randomized complete block design (RCBD) with three replications. Urea, TSP, and Potassium chloride were used as the sources of NPK, respectively, whereas calcitic limestone was used as the source of lime. The lime was applied one month before planting of the test crop. Nitrogen was applied in split, half at planting and half at knee height (45 days after planting). The whole doses of TSP and KCl were applied at planting time. Soil samples were collected from 0-30 cm before planting (one composite sample from the experimental site) and at harvest (from each treatment plot) to evaluate different soil chemical properties and analyzed using standard laboratory procedures. Crop data such as plant height, biomass yield and grain yield were collected and analysed using SAS program. Application of full dose lime (1800 kg/ha) with 69 kg N and 20 kg P/ha gave significantly higher result than the control and the plot that received only fertilizer (without lime). Application of NP + full dose lime significantly increased maize production over the NK and PK treatments whether NK and PK are applied alone or with both doses of lime. Application of lime alone did not influence maize production at Areka. Application of NP significantly increased maize production over the control and lime alone treatments both in the first and second years of the experiment. Application of NK either alone or with half dose of lime did not increase maize production over the non-fertilized treatment (control). But it increased maize production significantly over the control treatment when integrated with full dose of lime. Soil analysis indicated that pH, P, Ca and CEC were increased with application of lime. In conclusion, enough amount of NP should be applied with the required amount of lime for better production of maize at acidic soil of Areka. Therefore, 69 kg N/ha and 20 kg P/ha with 1800 kg lime/ha are recommended for better production of maize at Areka.

Keywords: Lime, NPK fertilizers, Residual effect

Background and Justification

In all humid climates, acidification of soil is a natural process and one that has major ramifications for plant growth. As soils become more acid, particularly when pH drops below 4.5, it becomes increasingly difficult to produce food crops. Aluminium and manganese become more soluble (i.e.

more of the solid form of these elements will dissolve in water when the soil is acid) and toxic to plants, most plant nutrients become more limited in supply, and a few micronutrients become more soluble and toxic. These problems are particularly acute in humid tropical regions that have been highly weathered (Harter, 2002). The ideal soil pH for many crops is slightly acidic, between 6.0 and 7.0 (The Pennsylvania State University, 1995) as all nutrients are available in well-balanced proportion in this range (Bierman and Carl, 2005). Soil acidity is one of the major problems (chemical constraints) limiting the agricultural productivity of mid and highlands of Ethiopian soils. Soil acidification is a major soil degradation issue in many parts of Southern Region. Areka is one of such areas with strongly acidic soil. It is often an insidious soil degradation process, developing slowly, although indicators such as falling yields, leaf discolorations in susceptible plants, lack of response to fertilizers can indicate that soil pH is falling to critical levels. If it is not corrected, acidification can continue until irreparable damage takes place in the soil.

Major causes of acidity are leaching and plant uptake of basic cations (Ca and Mg), production of organic acids from organic matter decomposition, and application of acidifying N fertilizers (Ammonium/ammonia N sources including products like urea) (Bierman and Carl, 2005).

High levels of soil acidity (low soil pH) can cause reduction of root growth, nutrient availability, affect crop protectant activity (The Pennsylvania State University, 1995), reduction and total failure of crop yields and deterioration of soil physical properties. In general it affects the biological, chemical and physical properties of soil, which in turn affect the sustainability of crop production in both managed and natural ecosystem.

The adjustment and maintenance of soil acidity is a very important soil management for crop production. Lime is the major means of ameliorating soil acidy (Anetor and Ezekiel, 2007) because it has very strong acid neutralizing capacity, which can effectively remove existing acid. Liming increases the uptake of nutrients, stimulate biological activity and reduce toxicity of heavy metals. Liming raises the soil pH and causes the aluminum and manganese to go from the soil solution back into solid (non-toxic) chemical forms. Regular applications of lime are required on many soils to maintain soil pH in the desired range, because soil acidification is an ongoing process (Bierman and Carl, 2005). Limestone is the most commonly used material to increase soil pH. However, for most efficient crop production on acid soils, application of both lime and fertilizer are required. Since lime make minerals more available to plants, liming without fertilizers application results in soil fertility decline that might lead to serious problem of production. Therefore, applying fertilizer elements to correct nutrient constraints caused by acidity is necessary. Lime and fertilizer management practices are primary importance for proper management of acid soils. Although some attempts are made recently to ameliorate acids soil, much research work is needed to give recommendations on the interactive effect of liming and fertilizers. The objectives of this study were; to see effect of lime and NPK on the yield of maize, soil chemical properties, and to see residual effect of lime.

Materials and Methods

The study was conducted on acidic soil of Areka in Boloso Sore Wereda of Wolaita Zone for three consecutive years (cropping seasons). The type of the soil is alisol, which is strongly acidic with pH of 4.87. Lime requirement was calculated using exchangeable aluminium (Al) of the soil. Five levels of NPK (Check, NP, NK, PK, NPK) and three levels of lime (0, half and full dose of the required lime) were arranged in a factorial experiment using randomized complete block design (RCBD) with three replications. Urea, TSP, and Potassium chloride were used as the sources of N, P and K, respectively, whereas calcitic limestone was used as the source of lime. The lime was incorporated in to the soil one month before planting of maize. Nitrogen was applied in split half at planting and half at knee height (45 days after planting). The whole doses of TSP and KCl were applied at planting time. All other necessary agronomic managements were carried out properly and equally for all treatments.

Soil samples were collected from 0-30 cm to evaluate different soil chemical properties before planting (one composite sample from the experimental site) and at harvest (from each treatment plot). All soil parameters were analyzed using standard laboratory procedures, and finally data were statistically analysed using SAS program

Results and Discussion

Application of lime alone did not influence maize production at Areka. Plant height, biomass and grain yields (here after referred as maize production) were not affected by lime application. However, application of lime with fertilizer generally increased maize production. Application of full dose lime (1800 kg/ha) with 69 kg N and 20 kg P/ha gave significantly higher result than applying only the fertilizer without lime (Tables 1, 2 and 3), which is in agreement with Okalebo et al. (2009) who stated that combined application of lime with nitrogen and phosphorus significantly increased maize yield in Kenya. Therefore, instead of applying only fertilizer on acidic soils, it is better to integrate with lime for better production of maize.

Application of NP significantly increased maize production over the control and lime alone treatments both in the first and second years of the experiment. Application of NP + full dose lime (1800 kg/ha) significantly increased maize production over the NK and PK treatments whether NK and PK are applied alone or with both doses of lime. This treatment also gave significantly higher yield than the NP alone treatment in the third year of the experiment, which indicates full dose lime left residue for third year production when applied with 69 kg N and 20 kg P/ha. But, although application of NP alone significantly increased maize production over NK and NK + half dose lime, it did not significantly affect the production over NK + full dose of lime in both first and second years. Application of NP alone did not significantly increase maize production over PK treatments either applied alone or integrated with lime. Application of NP fertilizers either alone or with half dose of lime did not significantly increase maize production over NPK treatments applied either alone or integrated with both doses of lime. NP + full dose of lime significantly increased maize production over NPK and NPK + half dose of lime but it did not give significantly higher result over NPK + full dose of lime.

Application of NK either alone or with half dose of lime did not increase maize production over the non-fertilized treatment (control). But it increased maize production significantly over the control treatment when integrated with full dose of lime, which might be attributed to the releasing of fixed P due to lime application. This result was consistent in the second year of the experiment too. Application of NK with full dose of lime also significantly increased maize production over the NK alone and NK + half dose of lime. No difference in maize production was observed (obtained) between application of NK or NK + half dose of lime and not applying fertilizers. This implies that half dose of lime is not enough to release adequate amount of P, for maize production, from fixed P in Areka soil in the absence of application of P fertilizer. But the result showed that in the absence of application of P fertilizer, applying full dose of lime is enough to release adequate amount of P from the fixed P in the above soil. Instead of applying NK either alone or with half dose of lime, planting without fertilizer was better for maize production as cost of production could be reduced.

Application of PK alone did not significantly increase maize production over the control treatment (non-fertilized treatment). However, when PK fertilizers were integrated with both half and full dose of lime, maize production was significantly increased over the control treatment. This might be because of the lime helped in releasing of fixed P in to the soil solution. Although application of NP significantly increased maize grain yield over the control, PK alone did not significantly increase maize yield over the control. This indicates that both N and P are deficient in Areka soil, but P is the most deficient as the soil analysis result witnessed (Tables 4, 5 and 6). All PK treatments (PK alone and PK with lime) significantly increased maize production over the NK alone and NK + half dose of lime, but not significantly higher than NK + full dose of lime. Application of PK + full dose of lime did not significantly increase maize production over PK and PK + half dose of lime.

Application of lime might contributed in releasing some amount of fixed P to be available for the crop. Therefore, for better maize production at Areka, enough amount of NP should be applied with lime. But application of lime alone could not help maize production to be increased. This also indicates that deficiency of N and P cannot be replaced by lime. As a result in acidic soils which are deficient in N and P, it is important to apply N and P together with lime to increase maize production.

The same result was obtained in the second and third years of the experiment. First year lime application without fertilizer did not affect maize production in the second and third years of production. But the residual effect of first year lime application was observed on those treatments with fertilizers and lime. Therefore, lime is important to increase maize production on acidic soil of Areka but it should be integrated with fertilizer. When it is applied with fertilizer, it works not only for first year production but also for second and third years of production. When lime was applied alone (without fertilizer), it had no residual effect for the second and third cropping seasons. But when it was applied with fertilizers, residual effect was seen in the second and third cropping seasons. Application of lime with NP and NPK showed that there was residual effect up to the third cropping seasons. On the other hand, its residual effect was seen only in the second cropping season when it was applied with NK and PK fertilizers.

Application of lime influenced soil chemical properties. Soil pH, available phosphorus (P), cation exchange capacity (CEC), and calcium (Ca) were increased in all cropping seasons with increasing application of lime (Tables 4 and 5) and this is in agreement with Anetor and Ezekiel (2007) who indicated that lime increased pH and available P in Nigeria. However, potassium (K) and 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, maize yield, and reduce exchangeable acidity at Areka. 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.

Conclusion and recommendation

Although application of lime alone did not influence maize production at Areka, better maize yield was obtained when lime was applied in combination with fertilizer. When 1800 kg/ha lime was applied in combination with 69 kg N and 20 kg P/ha, it left residue for third year production but no residue effect was seen when applied alone. Soil pH, available phosphorus (P), cation exchange capacity (CEC), and calcium (Ca) were increased in all cropping seasons with increasing application of lime. Though pH was increased due to lime application, for the pH range after application of lime is still in the strongly acidic range, regular application of lime is required to increase the pH to the desired range. Therefore, the use of 69 kg N + 20 kg P + 1800 kg lime/ha could be recommended for better production of maize at Areka.

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Table 1. Mean height of maize plant in meter as influenced by application of lime-NPK

No.	Treatment	First year (2007)	Second year (2008)	Third year (2009)
1	Control (without fertilizer and lime)	1.70 de	1.70 de	1.44
2	No fertilizer and 900 kg lime/ha	1.70 de	1.70 de	1.51
3	No fertilizer and 1800 kg lime/ha	1.84 abcde	1.84 abcde	1.50
4	69 kg N + 20 kg P + 0 lime/ha	1.93 abc	1.93 abc	1.40
5	69 kg N + 20 kg P + 900 kg lime/ha	1.99 a	1.99 a	1.37
6	69 kg N + 20 kg P + 1800 kg lime/ha	2.05 a	2.05 a	1.37
7	69 kg N + 75 kg K + 0 lime/ha	1.63 e	1.63 e	1.47
8	69 kg N + 75 kg K + and 900 kg lime/ha	1.76 cbde	1.76 bcde	1.51
9	69 kg N + 75kg K + 1800 kg lime/ha	1.73 cde	1.73 cde	1.42
10	20 kg P + 75 kg K+ 0 lime/ha	2.00 a	2.00 a	1.32
11	20 kg P + 75 kg K+ and 900 kg lime/ha	1.95 ab	1.93 abc	1.32
12	20 kg P + 75 kg K+ 1800 kg lime/ha	2.01 a	2.01 a	1.53
13	69 kg N + 20 kg P + 75 kg K + 0 lime/ha	1.86 abcd	1.86 abcd	1.40
14	69 kg N + 20 kg P +75 kg K + and 900 kg lime/ha	2.01 a	2.01 a	1.44
15	69 kg N + 20 kg P + 75 kg K1800 kg lime/ha	1.96 ab	1.96 ab	1.34
	lSD at 5 %	0.207	0.209	NS

	CV	6.61 %	6.66 %	7.79

Means with the same letter are not significantly different

Table 2. Mean biomass yield of maize in kg/ha as influenced by application of lime-NPK

No.	Treatment	First year (2007)	Second year (2008)	Third year (2009)
1	Control (without fertilizer and lime)	7812.5 e	8267 def	10087
2	No fertilizer and 900 kg lime/ha	7118.1 e	7491 f	12333
3	No fertilizer and 1800 kg lime/ha	8159.7 cde	8503 def	8083
4	69 kg N + 20 kg P + 0 lime/ha	10763.9 ab	11316 ab	10394
5	69 kg N + 20 kg P + 900 kg lime/ha	10763.9 ab	11252 abc	15936
6	69 kg N + 20 kg P + 1800 kg lime/ha	12118.1 a	12434 a	19438
7	69 kg N + 75 kg K + 0 lime/ha	6805.6 e	7742 ef	12011
8	69 kg N + 75 kg K + and 900 kg lime/ha	6493.1 e	7327 f	17847
9	69 kg N + 75kg K + 1800 kg lime/ha	7951.4 de	9219 cdef	12978
10	20 kg P + 75 kg K+ 0 lime/ha	9895.8 bc	10180 bcd	9185
11	20 kg P + 75 kg K+ and 900 kg lime/ha	9930.6 bc	10339 bcd	14808
12	20 kg P + 75 kg K+ 1800 kg lime/ha	10520.8 ab	10604 abc	10936
13	69 kg N + 20 kg P + 75 kg K + 0 lime/ha	9618.1 bcd	9902 bcd	12705
14	69 kg N + 20 kg P +75 kg K + and 900 kg lime/ha	9652.8 bcd	9817 bcde	11068
15	69 kg N + 20 kg P + 75 kg K1800 kg lime/ha	10902.8 ab	11155 abc	12730
	lSD at 5 %	1774.6	2076.3	NS
	CV	11.49	12.79 %	36.76 %

Means with the same letter are not significantly different

Table 3. Mean grain yield of maize in kg/ha as influenced by application of lime-NPK

No.	Treatment	First year (2007)	Second year (2008)	Third year (2009)
1	Control (without fertilizer and lime)	2847.2 fgh	3015.5 efgh	2661bc
2	No fertilizer and 900 kg lime/ha	2708.3 gh	2851.1 fgh	2662bc
3	No fertilizer and 1800 kg lime/ha	2968.8 efgh	3094.8 defgh	2324c
4	69 kg N + 20 kg P + 0 lime/ha	3802.1 bcde	4722.0 ab	4015bc
5	69 kg N + 20 kg P + 900 kg lime/ha	4513.9 ab	4715.8 abc	5562[illegible]
6	69 kg N + 20 kg P + 1800 kg lime/ha	5034.7 a	5160.0 a	[illegible]
7	69 kg N + 75 kg K + 0 lime/ha	2517.4 h	2815.5 gh	2995bc
8	69 kg N + 75 kg K + and 900 kg lime/ha	2152.8 h	2421.5 h	4639abc
9	69 kg N + 75kg K + 1800 kg lime/ha	3437.5 defg	4041.4 bcde	3725bc
10	20 kg P + 75 kg K+ 0 lime/ha	3576.4 cdef	3679.5 cdefg	3333bc
11	20 kg P + 75 kg K+ and 900 kg lime/ha	3784.7 bcde	3935.5 bcde	5297ab
12	20 kg P + 75 kg K+ 1800 kg lime/ha	4097.2 bcd	4133.4 abcd	3541bc
13	69 kg N + 20 kg P + 75 kg K + 0 lime/ha	3750.0 bcde	3862.9 bcdef	3625bc
14	69 kg N + 20 kg P +75 kg K + and 900 kg lime/ha	3750.0 bcde	3810.2 bcdefg	3225bc
15	69 kg N + 20 kg P + 75 kg K1800 kg lime/ha	4340.3 abc	4445.3 abc	4473abc
	lSD at 5 %	866.61	1042.3	NS
	CV	14.59 %	16.48 %	44.22 %

Means with the same letter are not significantly different

Table 4. Chemical properties of soil as influenced by application of lime and NPK in the first cropping season

Treatment	pH	P, ppm	% OC	% OM	CEC, meq/100 g soil	N, %	Ca, cmol/kg	K, cmol/kg	Exchangeable acididty, meq/100 g

									soil
Control (without fertilizer and lime)	5.2	1.6	3.06	5.27	16.0	0.14	7.0	0.41	1.36
No fertilizer and 900 kg lime/ha	5.4	1.6	3.12	5.38	18.2	0.168	7.0	0.37	0.80
No fertilizer and 1800 kg lime/ha	5.5	2.00	3.25	5.60	23.4	0.140	10.0	0.33	1.04
69 kg N + 20 kg P + 0 lime/ha	5.2	4.2	3.38	5.83	18.0	0.098	8.0	0.28	1.44
69 kg N + 20 kg P + 900 kg lime/ha	5.2	4.6	2.93	5.04	20.6	0.14	8.0	0.33	1.12
69 kg N + 20 kg P + 1800 kg lime/ha	5.2	5.40	3.12	5.38	23.2	0.14	9.0	0.26	1.04
69 kg N + 75 kg K + 0 lime/ha	5.1	2.2	3.45	5.94	18.0	0.14	7.0	0.43	1.60
69 kg N + 75 kg K + and 900 kg lime/ha	5.4	2.2	3.19	5.49	22.0	0.182	7.0	0.42	0.96
69 kg N + 75kg K + 1800 kg lime/ha	5.4	7.00	2.93	5.04	26.0	0.154	9.0	0.36	0.96
20 kg P + 75 kg K+ 0 lime/ha	5.3	4.6	3.25	5.6	19.4	0.126	8.0	0.49	1.28
20 kg P + 75 kg K+ and 900 kg lime/ha	5.3	5.2	3.25	5.60	19.6	0.126	8.0	0.35	0.80
20 kg P + 75 kg K+ 1800 kg lime/ha	5.3	6.6	3.32	5.72	22.4	0.140	8.0	0.4	0.88
69 kg N + 20 kg P + 75 kg K + 0 lime/ha	5.1	4.40	3.19	5.49	22.0	0.154	7.0	0.36	1.44
69 kg N + 20 kg P +75 kg K + and 900 kg lime/ha	5.3	5.20	3.19	5.49	23.0	0.112	9.0	0.31	0.96
69 kg N + 20 kg P + 75 kg K1800 kg lime/ha	5.5	8.40	3.19	5.49	25.4	0.126	12.0	0.35	0.80

Table 5 . Chemical properties of soil as influenced by application of lime and NPK in the second cropping season

Treatment	pH	P, ppm	% OC	% OM	CEC, meq/100 g soil	N, %	Ca, cmol/kg	K, cmol/kg	Exchangeable acididty, meq/100

									g soil
Control (without fertilizer and lime)	5.2	2.60	2.80	4.82	22.0	0.168	8.0	0.40	9.0
No fertilizer and 900 kg lime/ha	5.2	3.00	2.80	4.82	23.2	0.238	9.0	0.37	8.0
No fertilizer and 1800 kg lime/ha	5.4	6.40	2.73	4.71	24.4	0.07	10.0	0.35	10.0
69 kg N + 20 kg P + 0 lime/ha	5.0	5.80	2.80	4.82	21.2	0.182	7.0	0.33	7.0
69 kg N + 20 kg P + 900 kg lime/ha	5.0	6.20	3.06	5.27	21.0	0.140	7.0	0.31	7.0
69 kg N + 20 kg P + 1800 kg lime/ha	5.0	6.40	2.80	4.82	22.4	0.210	8.0	0.36	8.0
69 kg N + 75 kg K + 0 lime/ha	4.9	2.80	2.80	4.82	21.2	0.210	5.0	0.45	9.0
69 kg N + 75 kg K + and 900 kg lime/ha	5.0	2.80	2.99	5.15	21.8	0.168	7.0	0.43	5.0
69 kg N + 75kg K + 1800 kg lime/ha	5.3	3.00	2.67	4.59	22.0	0.154	9.0	0.46	7.0
20 kg P + 75 kg K+ 0 lime/ha	5.1	6.80	2.80	4.82	21.6	0.140	6.0	0.47	7.0
20 kg P + 75 kg K+ and 900 kg lime/ha	5.2	7.00	2.80	4.82	22.0	0.168	7.0	0.47	8.0
20 kg P + 75 kg K+ 1800 kg lime/ha	5.3	7.20	2.80	4.82	23.6	0.168	8.0	0.46	6.0
69 kg N + 20 kg P + 75 kg K + 0 lime/ha	5.1	5.80	2.86	4.93	20.0	0.154	6.0	0.43	6.0
69 kg N + 20 kg P +75 kg K + and 900 kg lime/ha	5.2	6.80	2.93	5.04	20.2	0.196	9.0	0.42	9.0
69 kg N + 20 kg P + 75 kg K1800 kg lime/ha	5.6	7.40	2.86	4.93	24.8	0.168	10.0	0.45	10.0

Table 6 . Chemical properties of soil as influenced by application of lime and NPK in the third cropping season

Treatment	P (mg/kg)	% OM	CEC, meq/100 g soil	N, %	Ca, cmol/kg	K, cmol/kg
Control (without fertilizer and lime)	4.11	4.34	20	0.2	7.4	0.56

No fertilizer and 900 kg lime/ha	6.44	4.5	21	0.21	9.2	0.70
No fertilizer and 1800 kg lime/ha	6.72	4.53	23	0.21	10.2	0.64
69 kg N + 20 kg P + 0 lime/ha	5.96	4.64	21	0.22	8.2	0.87
69 kg N + 20 kg P + 900 kg lime/ha	6.29	4.57	22	0.21	8.5	0.74
69 kg N + 20 kg P + 1800 kg lime/ha	7.31	4.34	28	0.2	10	0.62
69 kg N + 75 kg K + 0 lime/ha	5.58	4.57	20.4	0.21	7	0.98
69 kg N + 75 kg K + and 900 kg lime/ha	6.15	4.67	23	0.22	9	0.73
69 kg N + 75kg K + 1800 kg lime/ha	6.53	4.34	25	0.2	11	0.91
20 kg P + 75 kg K+ 0 lime/ha	6.53	4.5	20	0.21	8	0.91
20 kg P + 75 kg K+ and 900 kg lime/ha	6.87	4.6	20.6	0.21	8.4	0.71
20 kg P + 75 kg K+ 1800 kg lime/ha	7.21	4.5	21	0.21	10.5	0.71
69 kg N + 20 kg P + 75 kg K + 0 lime/ha	5.49	4.64	19	0.22	6.5	0.56
69 kg N + 20 kg P +75 kg K + and 900 kg lime/ha	7.06	4.6	20	0.21	7.8	0.28
69 kg N + 20 kg P + 75 kg K1800 kg lime/ha	7.36	4.34	25	0.2	9.4	0.20