Macro and Micro Nutrients for Optimizing Maize Production at Hawassa Zuria District, Southern Ethiopia

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Abstract
Lack of practical information on the use of multi-nutrient fertilizer blends involving the actual limiting nutrients for specific site and crop is a problem for sustainable maize production. A trial was conduct to evaluate different fertilizer types for maize production in Southern Ethiopia during the main cropping season of 2016 and 2017. Fertilizer treatments were based on limiting nutrients of the area including NPS, NPSB and NPSBCu at different rate. The trial consists of ten treatments (1) no fertilizer (control) (2) NPS: 69 kg N + 23.5 kg P + 10 kg S/ha (3) NPS: 92 kg N + 31.3 kg P + 13 kg S/ha (4) NPS: 115 kg N + 39 kg P + 17 kg S/ha (5) NPSB: 69 kg N + 23.5 kg P + 10 kg S + 1.07 kg B/ha (6) NPSB: 92 kg N + 31.3 kg P + 13 kg S + 1.4 kg B/ha (7) NPSB: 115 kg N + 39 kg P + 17 kg S + 1.7 kg B/ha (8) NPSBCu: 69 kg N + 23.5 kg P + 10 kg S + 1.07 kg B + 0.625 kg Cu/ha (9) NPSBCu: 92 kg N 31.3 kg P + 13 kg S + 1.4 kg B + 0.625 kg Cu/ha and (10) NPSBCu:115 kg N + 39 kg P + 17 kg S + 1.7 kg B + 0.625 kg Cu/ha. The trial was conducted on two farms and treatments were laid out in a randomized complete block design replicated three times in each farm. Crop characteristics measured were analyzed using Proc GLM procedures in the SAS 9.3 program. Economic analysis was also performed to investigate the economic feasibility of the fertilizers for maize production. Applying the deficient soil nutrients, nitrogen, phosphorus, sulphur and boron was improved maize yield. Treatment 7 (NPSB: 115, 90, 17, 1.7) gave significantly ($P < 0.05$) higher maize yield compared to some fertilizer treatments and the control. Similarly, highest net benefit (31962.2 Ethiopia birr/ha) was obtained from treatment 7 with acceptable marginal rate of return-(224%). Therefore, NPSB in the nutrient ratio of 115: 90: 17: 1.7 is recommended as the best option for maize producers around H/zuria district.
Keywords: macro and micronutrient, maize yield, fertilizer types, economic feasibility

1. Introduction

Maintenance of soil fertility is a major concern in tropical Africa, particularly with the rapid population increase. Improving food production and soil resources in the smallholder farm sector of Africa has become an enormous challenge (**Smaling and Braun, 1996)**. The main determinant of Africa's position at the bottom of the development scale is the need to tackle soil fertility depletion as the fundamental constraints (**Sanchez and Leakey, 1997**). For many cropping systems in Africa, nutrient balances are negative that indicating soil mining (**Bationo et al., 1998**).

Ethiopia is one of the sub-Saharan African countries where severe soil nutrient depletion restrains agricultural crop production and economic growth. The annual per-hectare net loss of nutrients is estimated to be at least 40 kg N, 6.6 kg P and 33.2 kg K (Scoones and Toulmin, 1999). Continuous cropping, high proportions of cereals in the cropping system, low organic matter content of soils the application of suboptimal levels of mineral fertilizers, and existence of problem soils (vertisoles and soil acidity) aggravate the decline in soil fertility (Tanner et al., 1991; Hailu et al., 1991; Workneh and Mwangi, 1992).

Among several management options, site-specific fertilizer direction is currently increased noticeably to tackle the problem. However, fertilizer trials involving multi-nutrient blends that include micronutrients are at initial stage in Ethiopian. After the soil fertility map is developed by Agricultural Transformation Agency (ATA) in 2016, 13 blended fertilizers containing N, P, K, S, B, Zn and Cu in different mix form have been recommended for south nation nationalities and people regional state (SNNPRS). In addition to macro nutrients applying different blends including micronutrients can increase maize yield. Research finding in Malawi provides a striking example of how N fertilizer efficiency for maize can be raised by providing appropriate micronutrients on site-specific basis. Supplementation by S, Zn, B, and K increased maize yields by 40% over the standard N-P recommendation alone (John et al., 2000). However, there is no enough information on the impact of different types of fertilizers containing macro and micronutrients in SNNPRS, while the soil is deficient in nitrogen, phosphorus, sulfur, boron, zinc and copper.

Maize is a staple food for millions of people in Ethiopia which is the most important crop in terms of calorie intake in the rural parts of the country. Berhane et al. (2011) reported maize accounted for 16.7 % of the national calorie intake followed by sorghum (14.1 %) and wheat (12.6 %) among the major cereals. Compared to the 1960s the share of maize consumption among cereals more than doubled to nearly 30% in the 2000s, whereas the share of teff, a cereal that occupies the largest area of all crops in Ethiopia, declined from more than 30% to about 18% during the same period (Demeke 2012). Therefore, identification of proper fertilizer blends for specific site to enhance maize production is crucial.

2. Materials and Methods

Two years field trial was conducted with maize in Hwawasa zuria Woreda (district) of the Southern Nations, Nationalities and Peoples Regional State (SNNPRS) in the main cropping season of 2016 and 2017. The experimental site was located between 07.0038 N latitude and 038.2255 E longitudes at an altitude of 1705 m above sea level. The experiment was designed based on the nutrient deficiency of the area which indicated in the soil fertility map of Ethiopia produced by Agricultural Transformation Agency (ATA) (2016). Accordingly, three types of fertilizers (NPS, NPSB, NPSBCu) were used in different rates. The experiment consists of ten treatments (1) no fertilizer (control) (2) NPS: 69 kg N + 23.5 kg P + 10 kg S/ha (3) NPS: 92 kg N + 31.3 kg P + 13 kg S/ha (4) NPS: 115 kg N + 39 kg P + 17 kg S/ha (5) NPSB: 69 kg N + 23.5 kg P + 10 kg S + 1.07 kg B/ha (6) NPSB: 92 kg N + 31.3 kg P + 13 kg S + 1.4 kg B/ha (7) NPSB: 115 kg N + 39 kg P + 17 kg S + 1.7 kg B/ha (8) NPSBCu: 69 kg N + 23.5 kg P + 10 kg S + 1.07 kg B + 0.625 kg Cu/ha (9) NPSBCu: 92 kg N 31.3 kg P + 13 kg S + 1.4 kg B + 0.625 kg Cu/ha (10) NPSBCu:115 kg N + 39 kg P + 17 kg S + 1.7 kg B + 0.625 kg Cu/ha.

Experimental layout

The experiment was conducted on two farms in each year and laid out in a randomized complete block design using 4.5 m by 4.2 m plot size and replicated three times in each farm. To avoid mixing up of treatments the plots were separated by 1 and 1.5 m space between plots and blocks, respectively. All doses of NPS and NPSB fertilizers were applied at planting time and urea was top dressed 45 days after planting. For copper foliar application was used. Improved Maize variety (Lemu) was planted in rows and other crop management practices were used as recommended for the crop.

Agronomic and economic analysis

Agronomic data for maize, including plant height, cob length, total biomass, grain yield and 1000 seed wieght, were collected. Analysis of variance for all data was done using Proc GLM procedures in the SAS 9.3 program (SAS Institute Inc., Cary, NC USA). The least significant difference (LSD) at 5% probability level was used to establish the significance of differences between the means.

An economic analysis was used to investigate the economic feasibility of the three fertilizer types (NPS, NPSB and NPSBCu) for maize production. The partial budget, dominance and marginal rate of return were calculated. For partial budget analysis averages yield that was adjusted downwards by 10% was used, assuming that farmers would get ~10% less yield than is achieved on an experimental site. The average open market price for maize (6.5 Ethiopian Birr (ETB))/kg) and the official prices for NPS (10.94 ETB/kg), NPSB (10.28 ETB/kg), N as Urea (8.76 ETB/kg) and Cu as copper sulfate (1000 ETB/kg) were used for the analysis. For a treatment to be considered a worthwhile option for farmers, the minimum acceptable marginal rate of return should be over 50% (CIMMYT, 1988). However, Gorfu et al. (1991) suggested a minimum acceptable rate of return should be 100%. Therefore, the minimum acceptable marginal rate of return considered in this study is 100%.

3. Result and discussion

The two year combined analysis indicated that there was statistically significant difference between the treatments. All fertilizer treatments significantly ($P < 0.05$) increased maize grain and biological yield compared to the control (no fertilizer). Significantly high grain yield was obtained from the plots treated by treatment 7 (NPSB: 115 kg N + 39 kg P + 17 kg S + 1.7 kg B/ha) compared to most fertilizer treatments, while the lowest yield was recorded from the control (table 1). Similar study indicated that maximum grain, stover and total biomass yield were obtained by applying blended fertilizers, whereas the lowest grain yield was recorded from control plots (Dagne, 2016). In addition, this experiment showed significantly higher vegetative growth (total biomass and plant height) in fertilizer treatments compared to the control. Dagne 2016, also reported blended fertilizer significantly increased plant height as compared to the recommended NP fertilizers and the control. Higher vegetative growth obtained in this study might be attributed from adequately applied nutrients to the soil. Plant growth and development retarded if any of nutrient elements is less than its threshold value in the soil or not adequately balanced with other nutrient elements (Landon, 1991). The low yield in untreated plots might be due to reduced leaf area development resulting in lesser radiation interception and, consequently, low efficiency in the conversion of solar radiation (Sallah et al., 1998).

Table 1. Yield and yield components of maize influenced by different nutrients at Hawassa zuria

Treatments	Grain yield kg/ha	1000 Seed weight (gm)	Total biomass (t/ha)	Plant height (cm)	Cob length (cm)
1. No fertilizer	3775.3d	224.9c	11.2c	209.3b	14.5
2. NPS: 69 kg N + 23.5 kg P + 10 kg S/h	5175.8c	246.8bc	15.5a	231.6a	16.63
3. NPS: 92 kg N + 31.3 kg P + 13 kg S/ha	5584.8bc	259.9ab	15.3a	231.1a	16.47
4. NPS: 115 kg N + 39 kg P + 17 kg S/ha	5833.4ab	278.9a	15.6a	228.2a	16.9
5. NPSB: 69 kg N + 23.5 kg P + 10 kg S + 1.07 kg B/ha	5247.4c	270.4ab	13.8b	226.3a	15.5
6. NPSB: 92 kg N + 31.3 kg P + 13 kg S + 1.4 kg B/ha	5701.0ab	273.5ab	15.7a	228.8a	16.37
7. NPSB: 115 kg N + 39 kg P + 17 kg S + 1.7 kg B/ha	6130.5a	279.6a	16.2a	229.9a	16.3
8. NPSB: 69 kg N + 23.5 kg P + 10 kg S + 1.07 kg B + 0.625 kg Cu/ha	5508.0bc	256.4ab	15.1ab	230.3a	16.6
9. NPSB: 92 kg N 31.3 kg P + 13 kg S + 1.4 kg B + 0.625 kg Cu/ha	5730.5ab	261.7ab	15.6a	230.3a	16.53
10. NPSB:115 kg N + 39 kg P + 17 kg S + 1.7 kg B + 0.625 kg Cu/ha	5854.7ab	275.4ab	15.8a	231.3a	16.47
LSD (0.05)	444.87	31.21	1.31	11.8	NS
CV(%)	13.5	11.1	12.1	3.6	7.1

Note: Values followed by the same letter are not significantly different at $P < 0.05$.

This study also indicated that plots treated with lower N (69 kg/ha) gave significantly low yield compared to the plots treated with high N (115 kg/ha) (table 1). This result in line with Jones, (1985) who stated that iinadequate N availability during the first two to six weeks after planting can result in reduced yield potentials.

In general, the result obtained in this experiment ratified the soil fertility map developed for the area. Base on the soil fertility map prepared by Agricultural Transformation Agency (ATA) (2016), nitrogen. phosphorus, sulfur, boron and copper are deficient in the soil. Similarly, Kelsa et al. (1992) stated that low soil fertility is among the greatest constraints to maize production in Ethiopia. Although adoption of new varieties especially maize hybrid is moving fast in Ethiopia, fertilizer management techniques need to supplement the existing potential of the varieties (Benti, 1993).

Economic analysis

The dominance analysis (Table 2) indicated that except treatment 5, 6, 7 and 8, other treatments were dominated by the treatments with lower variable cost with higher net benefit. Treatment 5 had the lowest total variable costs and higher net benefits than the treatment with the next lowest total variable costs, treatment 2. Treatment 6 had lower total variable cost and gave high net benefit compared to treatment 3 and 9. Similarly, treatment 7 had lower total variable cost with high net benefit than treatment 4 and 10. Based on the dominance analysis treatment 5, 6, 7 and 8 were a potential options (Table 2). Therefore, treatments 2, 3, 4, 9 and 10 were eliminated from further economic analysis and only the dominant treatments were considered further in the partial budget analysis (Table 3).

Based on the partial budget analysis (Table 3), the treatment with the higher net benefit was treatment 7 (31962.2 ETB/ha) compared to treatment 5, 6 and 8. However, the marginal rates of return for these treatments were 268, 295 and 205%. This means that for each 1 ETB investment, the producer can get more than 100%. Since the minimum acceptable rate of return assumed in this experiment was 100%, all these treatments can give an acceptable marginal rate of return for the extra investment. However, since copper is not available in the local market, treatment 8, which contains copper fertilizer cannot be accepted as the preferred option.

Table2. Economic (partial budget and dominance) analysis of fertilizers on maize at Hawassa zuria

Treatments	NPSB (kg/ha)	NPS (kg/ha)	Cu (kg/ha)	N kg/ha	Av. Yield	Adj. yield	TCTV (EB/ha)	Revenue (EB/ha)	NB (EB/ha)	MRR (%)
1	0	0	0	0	3775.3	3397.8	0	22085.5	22085.5	
5	150	0	0	91	5247.4	4722.7	2338.9	30697.3	28358.3	
2	0	142	0	91	5175.8	4658.2	2350.8	30278.4	27927.6	D
8	150	0	0.625	91	5508	4957.2	2838.9	32221.8	29382.8	
6	200	0	0	122	5701	5130.9	3124.4	33350.9	30226.4	
3	0	189	0	122	5584.8	5026.3	3136.6	32671.1	29534.4	D
9	200	0	0.625	122	5730.5	5157.5	3624.4	33523.4	29899.0	D
7	250	0	0	152	6130.5	5517.5	3901.2	35863.4	31962.2	
4	0	237	0	152	5833.4	5250.1	3924.6	34125.4	30200.8	D
10	250	0	0.625	152	5854.7	5269.2	4401.2	34250.0	29848.8	D

Yield adjustment =10%, field price of maize = 6.5 Ethiopian Birr/kg, official price for urea-N = 8.75 Ethiopian Birr/kg, NPS fertilizer = 10.9 Ethiopian Birr/kg, NPSB fertilizer = 10. 3 Ethiopian Birr/kg, copper sulfate-Cu = 1000 Ethiopian Birr/kg, TCTV = total costs that varies, NB = net benefit, D indicates dominated treatments that are rejected, MRR = marginal rate of return.

Table 3. Economic (partial budget and marginal rate of return) analysis of fertilizers on maize at Hawassa zuria

Treatments	Av. Yield	Adj. yield	TCTV (ETB/ha)	Revenue (ETB/ha)	NB (ETB/ha)	MRR (%)
1.No fertilizer	3775.3	3397.8	0	22085.5	22085.5	
5. NPSB: 69,54,10, 1.07	5247.4	4722.7	2338.9	30697.3	28358.3	268
8. NPSB: 69,54,10, 1.07 + Cu	5508	4957.2	2838.9	32221.8	29382.8	205
6. NPSB: 92,72,13, 1.4	5701	5130.9	3124.4	33350.9	30226.4	295
7. NPSB: 115,90,17, 1.7	6130.5	5517.5	3901.2	35863.4	31962.2	224

Yield adjustment =10%, field price of maize = 6.5 Ethiopian Birr (ETB)/kg, official price for urea-N = 8.75 ETB/kg, NPS fertilizer = 10.9 ETB/kg, NPSB fertilizer = 10. 3 ETB/kg, copper sulfate-Cu = 1000 ETB/kg, TCTV = total costs that varies, NB = net benefit, MRR = marginal rate of return.

4. Conclusion and Recommendation

This study revealed that applying the deficient soil nutrients, nitrogen, phosphorus, sulphur and boron, indicated in the soil fertility map of the area (Hawassa zuria) was improved maize yield. Treatment 7 (NPSB: 115, 90, 17, 1.7) gave significantly higher maize yield compared to some fertilizer treatments and the control.

The highest net benefit (31962.2 ETB/ha) was obtained from treatment 7, applying NPSB fertilizer in the nutrient ratio of 115: 90: 17: 1.7, with acceptable marginal rate of return (224%) which is more than the minimum acceptable marginal rate of return (100%) considered in this experiment. Similarly, treatment 5, 6 and 8 gave considerable net benefit with acceptable marginal rate of return. However, since copper is not available in the local market, treatment 8, which contains copper fertilizer cannot be accepted by the producers. Therefore, NPSB in the ratio of 115: 90: 17: 1.7 is recommended as the best option for maize producers around H/zuria. Applying NPSB (92, 72, 13, 1.4) and NPSB at 69, 54, 10 and 1.07 nutrient combination can be also used as alternative options.

Reference

ATA (Agricultural Transformation Agency), 2016. Soil Fertility Status and Fertilizer Recommendation Atlas of the Southern Nations Nationalities and Peoples' Regional State, Ethiopia, by Ministry of Agriculture and Natural Resources and Agricultural Transformation Agency, Ethiopian, Addis Ababa, Ethiopia.

Bationo, A., F. Lompo and S. Koala, 1998. Research on nutrient flows and balances in West Africa: state-of-the-art. Agric. Ecosyst. And Environ. J. 71: 19-35.

Benti Tolessa, 1993. The need and objective of the 1st National Maize Workshop. In: Proceedings of the 1st National Maize Workshop of Ethiopia. 5-7 May, 1992, IAR and IMWIC, Addis Ababa, Ethiopia.

Berhane, G., Paulos, Z., Tafere, K., & Tamru, S. (2011). Food grain consumption and calorie intake patterns in Ethiopia. Addis Ababa: IFPRI.

CIMMYT. (1988). From agronomic data to farmer recommendations: An Economics Training Manual. Completely revised edition. Mexico. D.F.

Dagne Chimdessa, 2016. Blended Fertilizers Effects on Maize Yield and Yield Components of Western Oromia, Ethiopia. Journal of Agriculture, Forestry and Fisheries. Vol. 5, No. 5, 2016, pp. 151-162.

Demeke, M.(2012).Analysis of incentives and disincentives for maize in Ethiopia.. Technical notes series, MAFAP. Rome: FAO.

Gorfu, A., Taa, A., Tanner, D.G., & Mwangi, W. (1991) On-farm research to derive fertilizer recommendations for small-scale bread wheat production: methodological issues and technical results. Report No. 14. IAR, Addis Ababa, Ethiopia.

Hailu G.H., Tunner, D.G., Mengistu, H. 1991. Wheat research in Ethiopia: a historical perspective. Addis Ababa:IAR/CIMMYT.

John I. H., E. Mayorga, E. Tsamakis, M. E. McClain, A. Aufdenkampe, P. Quay, and J. E. Richey. 2000. Organic matter in Bolivian tributaries of the Amazon River: A comparison to the lower mainstream, Limnol. Oceanogr., 45(7), 1449–1466, American Society of Limnology and Oceanography, Inc.,Washington NCS. 1992. Ethiopia nation

Jones, C. A. 1985. C4 grasses and cereals: growth, development, and stress response. John Wiley & Sons, Inc., New York.

Kelsa Kena, Tadesse Yoannes and Tesfa Bogale, 1992. Influence of fertilizer and its management practices onmaize grain yields in major maize producing areas of Ethiopia. In: proceedings of the first national maize work shop of Ethiopia. IAR (Institute of Agricultural Research), Ethiopia

Landon, J. R., 1991. Booker tropical soil manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York. 474p.

Sallah, P. Y., N. J. Ehlke and J. L. Geadelmann. 1998. Progress from selection inmaize population evaluatedunder three nitrogen fertiliser levels. African J. Crop Sci. 6: 241-248.

Sanchez, A. P. and R. B. Leakey, 1997. Land use transformation in Africa: three determinants for balancing food security with natural resource utilization. Agron J. 7: 15-23.

SAS Institute Inc. 2002 JMP-5 Statistical Software, Version 5. Cary, USA.

Scoones, I. and C. Toulmin. 1999. Soil nutrient budgets and balances: What use for policy? Managing Africa's Soils No. 6

Smaling, E. M. and A. R. Braun, 1996. Soil fertility research in sub-Saharan Africa: new dimensions, new challenges. Commun. Soil Sci. and Plant Anal. J. 27: 365-386.

Tanner, D.G. Amanuel Gorfu and Kassahun Zewdie, 1991. Wheat Agronomy Research in Ethiopia

Workneh Negatu and W. Mwangi. 1992. An Economic Analysis of the Response of drum wheat to fertilizer: Implications for sustainable wheat production in the Central Highlands of Ethiopia. In: D.G. Tanner (ed.). The Eighth Regional Wheat Workshop for Eastern, Central and Southern Africa. CIMMYT.