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Effects of NPSB and foliar application of copper fertilizers on yield and yield components of maize in Halaba, Southern Ethiopia

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Abstract

Maize is one of the most economically important cereal crops produced by millions of farmers inEthiopia. It is believed that practical information on the use of multi-nutrient fertilizer blends involving the actual limiting nutrients for specific site and crop may improve maize production and contribute to food security. Hence, an experiment was conducted in 2016 and 2017 croppingseason to evaluate NPSB with and without Cu fertilizer and to determine the optimum rate for maize production in Halaba area. NPSB fertilizer with and without Cu was arranged in nine treatments. The treatments were:(1) no fertilizer (control), (2) NPSB: 69 kg N + 23.5 kg P + 10 kg S + 1.07 kg B/ha, (3) NPSB: 92 kg N + 31 kg P + 13 kg S + 1.4 kg B/ha, (4) NPSB: 115 kg N + 39 kg P + 17 kg S + 1.7 kg B/ha, (5) NPSB: 138 kg N + 15.7 kg P + 10 kg S + 1.07 kg B/ha, (6)NPSBCu: 69 kg N + 23.5 kg P + 10 kg S + 1.07 kg B + 0.625 kg Cu/ha, (7) NPSBCu: 92 kg N + 31 kg P + 13 kg S + 1.4 kg B + 0.625 kg Cu/ha, (8) NPSBCu: 115 kg N + 39 kg P + 17 kg S + 1.7 kg B + 0.625 kg Cu/ha and (9) NPSBCu: 138 kg N + 15.7 kg P + 10 kg S + 1.07 kg B + 0.625kg Cu/ha. Two farms were used for the trial and the treatments were arranged in a randomized complete block design (RCBD) replicated three times. Different crop parameters were measured and analyzed using SAS 9.3 program. Economic analysis was also performed to investigate thefeasibility of fertilizer treatments for maize production. Based on statistical analysis, ttreatment 5(NPSB: 138 kg N + 15.7 kg P + 10 kg S + 1.07 kg B/ha) gave significantly higher maize yield compared to all other fertilizer treatments and the control. The highest net benefit (33,329 ETB/ha)was also obtained from this treatmentwith acceptable marginal rate of return (557%) even underthe projected 20% input price increment.

Keywords: Maize yield; Economic feasibility; Optimum fertilizer rate; Nutrient deficiency

1. Introduction

Improving food production and soil resources in the smallholder farm sector of Africa has becomean enormous challenge (Smalingand Braun, 1996). Hence, the need to tackle soil fertility depletionis among the fundamental constraints in Africa (Sanchezand Leakey, 1997). For many cropping systems in the continent, nutrient balances are negative, indicating continuous 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 netloss 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 proportion of cereals in the cropping system, low organic mattercontent of soils, application of suboptimal levels of mineral fertilizers, and occurence of problematic soils (Vertisols and salt affected and acidsoils) aggravate the decline in soil fertility status in the country (Tanner *et al.*, 1991).

Among several management options, the need for site-specific fertilizer recommendations is currently increasing noticeably to tackle the problem. However, fertilizer trials involving multi- nutrient blends that include micronutrients are at initial stage in Ethiopia. After the development of soil fertility map of the country by Agricultural Transformation Agency (ATA) in 2016, 13 blended fertilizers containing N, P, K, S, B, Zn and Cu in different mix forms have been

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recommended for south nation nationalities and people regional state (SNNPRS). It is obvious that, in addition to macro nutrients, applying different blends including micronutrients increases maize yield. In line with this, research findings in Malawi provide a striking example of how N fertilizer efficiency for maize canbe raised by applying appropriate micronutrients on site-specificbasis, where it was observed that 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 enoughinformation on the impact of different types offertilizers containing macro and micronutrientson maize production in SNNPRS, while the soil is said to be 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 termsof calorie intake in the rural parts of the country. In line with this, Berhane *et al*. (2011) have reported that 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 was more than doubled to nearly 30% in the 2000s, whereas the shareof teff, a cereal that occupies the largest crop area in Ethiopia, declined from more than 30% to about 18% during the same period (Demeke 2012). Therefore, this study was initiated to identifyproper fertilizer blends for enhanced maize production in Halaba area.

2. Material and methods

Two years field trial was conducted with maize as a test crop in Halaba speciel Woreda of the Southern Nations, Nationalities and Peoples Regional State (SNNPRS) in the main cropping seasons of 2016 and 2017. The experimental site was located between 7^0 24′ 59.99″ N latitude and38^0 14’ 60.00″ E longitudes at an altitude of 1850 m above sea level. The experiment was designedbased on the nutrient deficiency of the area as indicated in the soil fertility map of the region (ATA, 2016). Accordingly, two types of fertilizers (NPSB and NPSBCu) were used in different rates. The experiment consisted of nine treatments: (1) no fertilizer (control), (2) NPSB: 69 kg N + 23.5 kg P + 10 kg S + 1.07 kg B/ha, (3) NPSB: 92 kg N + 31kg P + 13 kg S + 1.4 kg B/ha, (4) NPSB: 115 kg N + 39 kg P + 17 kg S + 1.7 kg B/ha, (5) NPSB: 138 kg N + 15.7 kg P + 10 kg S + 1.07 kg B/ha, (6) NPSBCu: 69 kg N + 23.5 kg P + 10 kg S + 1.07 kg B + 0.625 kg Cu/ha, (7) NPSBCu: 92 kg N + 31 kg P + 13 kg S + 1.4 kg B + 0.625 kg Cu/ha, (8) NPSBCu: 115 kg N + 39 kg P + 17kg S + 1.7 kg B + 0.625 kg Cu/ha and (9) NPSBCu: 138 kg N + 15.7 kg P + 10 kg S + 1.07 kg B + 0.625 kg Cu/ha.

2.1. Experimental layout

The experiment was conducted on two farms in each year in a randomizedcomplete block design using 4.5 m by 4.2 m plot size and replicated three times. To avoid mixingup of treatments the plots were separated from each other by 1.00 m with a spacing of 1.50 m between blocks. All doses of 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 Shone was planted in rows and all other field management practices were applied as recommendedfor the crop.

2.2. Agronomic and economic analysis

Plant height, cob length, total above ground fresh biomass yield, grain yield and 1000 seed weight were measured at harvest. Analysis of variance for all datawas done using Proc GLM procedures of SAS version 5. (SAS Institute Inc., 2002). Least significant difference (LSD) at 5% probability level was used to treatment means. Besides, economic analysis was also done to investigate the feasibility of fertilizer treatments (NPSB and NPSBCu) for maize production. Partial budget and dominance analysis and marginal rate of returnwere calculated. For partial budget analysis, averages yield that was adjusted downwards by 10%was used, assuming that farmers would get about10% less yield than is achieved on an experimental site (CIMMYT, 1988). The average open market price for maize (6.5 Ethiopian Birr(ETB)/kg) and the official prices for 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. All other costs including those incurredfor field operations were considered uniform and the same for all plots. 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 that a minimum acceptable rate of return should be 100%. Therefore, the minimum acceptable marginal rate of return considered in this study was 100%.

3. Results and Discussion

The present study indicated that there was significant difference between the treatments. All fertilizer treatments significantly ($P < 0.05$) increased maize grain and biological yields, as compared to the control (no fertilizer). Significantly higher grain yield was obtained from the plot treated with NPSB at a rate of 138 kg N + 15.7 kg P + 10 kg S + 1.07 kg B/ha (treatment 5) as compared to the other fertilizer treatments and the control, which resulted in the lowest grain yield(Table 1).Similarly, treatment 5 exhibited significantly higher above ground total fresh biomass yield than did the control plot and other fertilizer treatments, except for treatment 3 and 4. The yield advantage of treatment 5 was 102 % over the control plot. In line with this, Jafer (2018) has reported that application of NPSB fertilizer significantly increased maize grain yield, compared tothe control (no fertilizer), where the yield advantage of NPSB fertilized plot was 136% over the control. Other parameters measured in the present experiment were, however, not significantly influenced by the applied fertilizers. Although balancing soil nutrients is required, based on the current study, N seems more limiting nutrient of maize production in the area compared to P, as the amount of N in NPSB fertilizer in treatment 5 was 138kg and that of P was only 15.7kg. Similarly, Habtamu (2015) has reported that application of 90/15 kg N/P ha^{1}significantly improvedmaize grain yield (5360 kg/ha) at Chilga district in north Gonder zone. As presented in Table 1, grain yield of maize was increased as the level of applied N increased. In the soil fertility map of the area (Halaba)(ATA, 2016), Cu is one of the nutrients identified as deficient in the soil. However, this study revealed that Cu did not affect the grain yield as well as vegetative growth ofmaize.

Table 1 Yield and yield components of maize as influenced by different rates of nutrients inHalaba Woreda

	Treatments	**Plant height (cm)**	**Cob Length(cm)**	**Total biomass yield (t/ha)**	**Grain yield (kg/ha)**
1.	Control	199.2	50.52	8.56 d	3096.2c
2.	NPSB: 69 +23.5 +10 + 1.07 kg/ha	211.2	52.58	12.78 bc	5115.4 b
3.	NPSB: 92 + 31 +13 + 1.4 kg/ha	217.4	56.47	14.18ab	5429.7 b
4.	NPSB: 115 + 39 +17 + 1.7 kg/ha	212.6	53.87	13.96abc	5443.4 b
5.	NPSB: 138 + 15.7 + 10 +1.07 kg/ha	217.3	54.72	15.09 a	6262.2a
6.	NPSBCu: 69 +23.5 +10 + 1.07 + 0.625 kg/ha	216.1	57.45	12.83bc	5181.9 b
7.	NPSBCu: 92 + 31 +13 + 1.4 + 0.625 kg/ha	210.1	55.55	13.13bc	5200.0 b
8.	NPSBCu: 115 +39 +17 + 1.7 + 0.625 kg/ha	217.6	56.45	12.56c	5324.1 b
9.	NPSBCu: 138 + 15.7 + 10 +1.07 + 0.625 kg/ha	216.0	54.57	13.60bc	5619.9 b
	LSD (0.05)	NS	NS	1.47	630.97
	CV (%)	7.02	11.94	15.15	18.33

Figures followed by the same letter(s) with in a column are not significantly different at P < 0.05.

Differences between the treatments were not significant for plant height and cob length, through the fertilized plots generally resulted in higher values than did the control for both parameters (Table 1).

3.1.1. Economic analysis

Results of the dominance analysis (Table 2) indicated that, except treatment 2, 3 and 5, all othertreatments were dominated by the treatment with lower variable cost and higher net benefit. Treatment 2 (NPSB: 69 + 23.5 + 10 + 1.07kg/ha) had the lowest total variable cost and higher netbenefit than did treatment 6 (NPSBCu: 69 + 23.5 + 10 + 1.07 + 0.625 kg/ha), which had the next lowest total variable costs (TVC). Treatment 3 (NPSB: 92+31+13+1.4kg/ha) had lower total variable cost and higher net benefit than did treatment 7 (NPSBCu: 92+31+13+1.4+0.625kg/ha). Similarly, treatment 5(NPSB: 138+15.7+10+1.07kg/ha) had lower total variable cost with higher net benefit than did treatments 4 (NPSB: 115+39+17+1.7kg/ha), 8(NPSBCu: 115+39+17+1.7+0.625kg/ha) and 9 (NPSBCu: 138+15.7+10+1.07+0.625kg/ha). Based on the dominance analysis, treatment 2, 3, and 5 were found to be potential options (Table 2). Therefore,treatments 4, 6, 7, 8 and 9 were eliminated and only the dominant treatments were considered forfurther partial budget analysis (Table 3).

Based on the partial budget analysis (Table 3), the treatment with the higher net benefit was treatment 5 (33,329 ETB/ha) compared to treatment 2 and 3. However, the marginal rates of returnfor treatments 2 and 3 were 521 and 134%, respectively. 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.

Table 2 Economic (partial budget and dominance) analysis of fertilizerrates for maizeproduction in Halaba special woreda

Treat	NPSB (kg/ha)	Cu (kg/ha)	N kg/ha	Av. Yield	Adj.yield	TVC (EB/ha)	Revenue(EB/ha)	NB (EB/ha)	MRR(%)
1	0	0	0	3096.2	2786.6	0.0	18112.7	18112.8	
2	150	0	41	5115.4	4603.9	1901.2	29925.1	28023.9	
6	150	0.625	41	5181.9	4663.7	2401.2	30314.1	27912.9	D
3	200	0	72	5429.7	4886.7	2686.7	31763.8	29077.1	
7	200	0.625	72	5200.0	4680.0	3186.7	30420.0	27233.3	D
5	100	0	260	6262.2	5635.9	3304.6	36633.9	33329.3	
4	250	0	102	5443.4	4899.1	3463.4	31843.9	28380.5	D
9	100	0.625	260	5619.9	5057.9	3804.6	32876.4	29071.9	D
8	250	0.625	102	5324.1	4791.7	3963.4	31145.9	27182.6	D

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

Table 3 Economic (partial budget and marginal rate of return) analysis of fertilizer ratesformaize production in Halaba special woreda

	Treatment (kg/ha)	Av. Yield	Adj.yield	TVC (EB/ha)	Revenue(EB/ha)	NB (EB/ha)	MRR(%)
1.	No fertilizer	3096.2	2786.6	0.0	18112.8	18112.8	
2.	NPSB: 69,23.5,10, 1.07	5115.4	4603.9	1901.2	29925.1	28023.9	521
3.	NPSB: 92,31,13, 1.4	5429.7	4886.7	2686.7	31763.8	29077.1	134
4.	NPSB: 138, 15.7, 10,1.07	6262.2	5635.9	3304.6	36633.9	33329.3	688

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

3.2. Sensitivity analysis

Table 4 Partial budget analysis at projected future prices of NPSB and urea fertilizers for maizeproduction in Halaba special woreda

Treatments (kg/ha)	Av. Yield	Adj. yield	TVC (EB/ha)	Revenue(EB/ha)	NB (EB/ha)	MRR(%)
1. No fertilizer	3096.2	2786.58	0.00	18112.77	18112.77	
2. NPSB: 69,23.5,10, 1.07	5115.4	4603.86	2281.42	29925.09	27643.67	418
3. NPSB: 92,31,13, 1.4	5429.7	4886.73	3224.01	31763.75	28539.73	95
5. NPSB: 138, 15.7, 10,1.07	6262.2	5635.98	3965.48	36633.87	32668.39	557

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

As market conditions are ever changing due to various reasons, recalculationof the partial budget considering future prices would be necessary to pinpoint treatments, which can remain stable and sustain acceptable returns for farmers, despite fluctuations in input prices. In the present study, it was assumed that the official price of NPSB and urea fertilizers will increaseby 20%. An assumption of price increment in these fertilizers emanated mainly from expected changes in the exchange rate and cost of transportation. Hence, based on the sensitivity analysis (Table 4), treatment2 (NPSB: 69 kg N + 23.5 kg P + 10 kg S +1.07 kg B/ha) and 5 (NPSB: 138 kgN + 15.7 kg P + 10 kg S + 1.07 kg B/ha) would give an economic yield response and also sustainacceptable returns even under 20% input price increment that farmers likely face in the future. However, treatment 3 (NPSB: 92 kg N + 31 kg P + 13 kg S+ 1.4 kg B/ha) may not sustain the economic return with the projected future input price (Table 4). Although two treatments (2 and 5) seemed to sustain economically acceptable return, treatment 5 gave significantly higher grain yield than did treatment 2 (Table 1). Therefore based on both statistical and economical evidences,treatment 5 can be accepted as the best option for maize farmers in Halaba area.

4. Conclusion and Recommendation

The present study revealed that applying the deficient soil nutrients, such as nitrogen, phosphorus,sulphur and boron, as indicated in the soil fertility map of the area (Halaba) improved maize yield,with significantly higher values for treatment 5 (NPSB: 138 kg N + 15.7 kg P + 10 kg S + 1.07 kgB/ha) than for other fertilizer treatments and the control. The highest net benefit (33,329ETB/ha)was also obtained from treatment 5 with acceptable marginal rate of return (557%) even under theprojected input price, which was more than the minimum acceptable marginal rate of return (100%) considered in this experiment. Similarly, treatment 2 gave considerable net benefit with acceptable marginal rate of return even when input price increased by 20%. However, based on the statistical analysis, treatment 2 gave significantly lower yield as compared to treatment 5. Therefore, based on both statistical and economic evidences, treatment 5 can be taken as a potentialoption for maize production in the area. Thus, NPSB: 138 kg N + 15.7 kg P + 10 kg S + 1.07 kg B/ha could be recommended as the best option for maize producers around Halaba. In the currentstudy, NPS and NPSB fertilizers were used in compound form and, thus, separate effect of each nutrient was not evaluated. Furthermore, the treatment set up of the experiment lacked positive control (recommended NP) to compare against the newly imported NPS and NPSB fertilizers. Therefore, future field trials should focus on evaluating the influence of individual nutrients and recommended NP rates along with their compound formulations on crop performance to avoid confounding effects.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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