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Responses of Maize to Different Fertilize Rates and Application of Copper in Wondo Genet, 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. On-farm trials were conduct on two farmers' field to evaluate different fertilizer types and rates for maize production in Wondo Genet woreda, Southern Ethiopia, during the main cropping seasons of 2016 and 2017. The trial consisted of ten treatments: control (no fertilizer) (T1); NPSCu at 69 kg N, 23.5 kg P, 10 kg S + 0.625 kg Cu/ha (T2), 92 kg N, 31 kg P, 13 kg S + 0.625 kg Cu/ha (T3), 115 kg N, 39 kg P, 17 kg S + 0.625 kg Cu/ha, (T4); NPSBCu at 69 kg N, 23.5 kg P, 10 kg S, 1.07 kg B + 0.625 kg Cu/ha (T5), 92 kg N, 31 kg P, 13 kg S, 1.4 kg B + 0.625 kg Cu/ha (T6), 115 kg N, 39 kg P, 17 kg S, 1.7 kg B + 0.625 kg Cu/ha (T7); NPS at 69 kg N, 23.5 kg P, 10 kg S/ha (T8), 92 kg N, 31 kg P, 13 kg S/ha (T9), and 115 kg N, 39 kg P, 17 kg S/ha (T10) were arranged in a randomized complete block design replicated three times at each farm. Growth and yield parameters of maize were collected to assess the effects of fertilizers and their rates, and partial budget analysis was performed for grain yield to evaluate the feasibility of fertilizer treatments. Results from ANOVA analysis showed that application of the three blended fertilizers types and their rates significantly affected maize yield and yield attributes. However, yield responses of maize to the same rates of the three-blend type were similar. The highest net benefit was resulted from application of NPS at 115 kg N, 39 kg P, 17 kg S/ha, followed by NPSBCu at 69 kg N, 23.5 kg P, 10 kg S, 1.07 kg B + 0.625 kg Cu/ha) and NPS at 69 kg N + 23.5 kg P + 10 kg S/ha, with higher marginal rates of returns of 643%, 271% and 227%, respectively. Though application of NPSBCu at 69 kg N, 23.5 kg P, 10 kg S, 1.07 kg B + 0.625 kg Cu/ha had positive grain yields, did not significant differ from NPS at 115 kg N, 39 kg P, 17 kg S/ha treatment. We can, therefore, recommend the use of NPS at 115 kg N, 39 kg P, 17 kg S/ha to optimize maize yield and net profit for farmers with good resource, while the use of NPS at 69 kg N, 23.5 kg P, 10 kg S/ha could benefit farmers with few resources. However, further trials including wider levels and individual nutrients of given nutrients along with recommended NP are suggested to study the impacts of each nutrient.

Keywords: Economic Feasibility, Fertilizer Rate, Blended Fertilizers Type, Maize Yield

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) [13]. As the main determinant of Africa's development, soil fertility depletion is a fundamental constraint that results in very low agricultural production (Sanchez and Leakey, 1997) [10]. For many cropping systems in the continent, nutrient balances are negative which is indicating soil mining (Bationo *et al*., 1998) [1]. Ethiopia is one of the sub-Saharan African countries, where agricultural production is largely constrained by severe soil nutrient depletion. 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) [12]. Continuous cropping, high proportion of cereals in the cropping system, low organic matter content of soils, application of sub optimal levels of mineral fertilizers, and large area coverage of problem soils (Vertisols and soil acid soils) aggravate the problem of decline in soil fertility (Tanner *et al*., 1991; Hailu *et al*., 1991) [5, 6].

Among several management options, the need for site-specific fertilizer recommendation is currently increased noticeably to tackle the problem. It is believed that replineshement of both macro and micro nutrient that are deficient to soils can increase crop yield. Research findings in Malawi showed a striking example of how N fertilizer use efficiency of maize can be raised by providing appropriate micronutrients on site-specific basis, where supplementation by S, Zn, B, and K increased maize yields by 40% over the standard N-P recommendation alone (John *et al*., 2000) [7]. However, fertilizer trials involving multi-nutrient blends that include micronutrients are at initial stage in Ethiopia. After the soil fertility map was developed by Agricultural Transformation Agency (MoARD and ATA, 2016) [9], four blended fertilizer types for Wondo Genet woreda and eight blended fertilizer types containing N, P, S, B, Zn and Cu in different blends were recommended for South Nation, Nationalities and People Regional State (SNNPRS). However, the identified belended fertilizer types need validation and the determination of rates for identified blend type for specific area and crop is mandatory for full application. Maize is a staple food for millions of people in Ethiopia and is the most important crop in terms of calorie intake in the rural parts of the country. Berhane *et al*. (2011) [2] 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 1960s, the share of maize consumption among cereals was more than doubled to nearly 30% in the 2000s, whereas the share of 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) [4]. As Wondo Genet woreda is one of the potential maize growing areas in the region, this study was initiated with the aim of validating the identified fertilizer blends and determining the rates for enhanced maize production in the woreda.

Materials and Methods

A field trial was conducted on maize in Wondo Genet Woreda of the Southern Nations, Nationalities and Peoples Regional State (SNNPRS) in the main cropping seasons of 2016 and 2017. The experiment was designed based on the nutrient deficiency of the area as indicated in the soil fertility map of the region produced by Agricultural Transformation Agency (ATA, 2016) [9]. Accordingly, three types of fertilizers (NPS, NPSCu, and NPSBCu) were used in different rates. The experiment consisted of ten treatments: control (no fertilizer) (T1); NPSCu at 69 kg N, 23.5 kg P, 10 kg S + 0.625 kg Cu/ha (T2), 92 kg N, 31 kg P, 13 kg S + 0.625 kg Cu/ha (T3), 115 kg N, 39 kg P, 17 kg S + 0.625 kg Cu/ha, (T4); NPSBCu at 69 kg N, 23.5 kg P, 10 kg S, 1.07 kg B + 0.625 kg Cu/ha (T5), 92 kg N, 31 kg P, 13 kg S, 1.4 kg B + 0.625 kg Cu/ha (T6), 115 kg N, 39 kg P, 17 kg S, 1.7 kg B + 0.625 kg Cu/ha (T7); NPS at 69 kg N, 23.5 kg P, 10 kg S/ha (T8), 92 kg N, 31 kg P, 13 kg S/ha (T9), and 115 kg N, 39 kg P, 17 kg S/ha (10) were tested.

Experimental layout

The experiment was conducted on two farms in each season in a randomized complete block design using 4.5 m by 4.2 m plot replicated three times. To avoid mixing up of treatments, the plots were separated by 1 m with 1.50 m spacing between blocks. Whole doses of NPS and NPSB blended fertilizers were applied at planting time and urea was top dressed 45 days after planting, while foliar application was used for copper. Improved Maize variety, Lemu, was planted in rows of 75 cm and 25 cm apart between rows and within rows, respectively and all other field management practices were applied as recommended for the crop.

Data Collection

Agronomic data for maize, including plant height, cob length, total above ground fresh biomass yield, grain yield and 1000 seed weight, were recorded at harvest. Plant height and cob length were measured from randomly selected five plants/plots, whereas total above ground fresh biomass yield was weighted by harvesting the whole plants from the net plot area.

Agronomic and economic analysis

The collected data were subjected to analyses of variance for all data (ANOVA) using Proc GLM procedures of SAS version 5 (SAS Institute Inc., 2002). Least significant difference (LSD) was computed at 5% probability level to separate treatment means whenever significant different between means observed. Economic analysis was carried out to investigate feasibility of the fertilizer types (NPS, NPSCu and NPSBCu) and their rates for maize production. Partial budget and dominance analysis and marginal rate of return (MRR) were calculated. For partial budget analysis, average yield was adjusted downwards by 10%, assuming that farmers would get about10% less yield than is achieved at 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 of total variable cost (TVC). All other plot management costs were assumed to be uniform and the same for all the treatments. For a treatment to be considered a worthwhile option for farmers, the minimum acceptable marginal rate of return should be over 50% (CIMMYT, 1988) [3]. However, Gorfu *et al*. (1991) [5] have 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%.

Results and Discussion

Results of combined analysis over two years indicated that statistically significant differences among the treatments were observed for all tested parameters except cob length. All blended fertilizers types and their rates significantly ($P \leq 0.05$) increased maize grain yield over the control (Table 1). Application of NPSCu at 115 kg N. 39 kg P, 17 kg S + 0.625 kg Cu/ha (T4) resulted in statistically higher grain yields (5301.4kg/ha) than that of T2, T6, T8 and T9 but it was at par with that of T3, T5 and T10. Similarly, T4 had significantly tallest plant height and highest total above ground biomass yield when compared with that of T2, T8, T9 and T10. The highest thousand seed weight was recorded from T10 while the lowest from T1 (untreated control) (Table 1). In agreement with this result, Landon (1991) [8] has reported that plant growth and development would be retarded if any of nutrient elements is less than its threshold value in the soil or not adequately balanced with other nutrient elements. We did not find significant difference among fertilizer types used with regard to yield and most yield components.

Partial budget analysis

The result of partial budget analysis of fertilizers was presented in Table 2.

Table 1: Yield of maize as influenced by different fertilizer types & rates in Wondo Genet

Treatments	Plant height (cm)	1000 seed wt(gm)	Biomass yield (t/ha)	Grain yield (kg/ha)
1 Control (no fertilizer)	202.0b	212.8c	12.9e	3506.6 d
2. NPSCu: 69, 23.5, 10, 0.625 kg/ha	212.1ab	232.5ab	16.6d	4534.0 c
3. NPSCu: 92, 31,13+ 0.625 kg/ha	214.8ab	228.6abc	20.1ab	5088.1 abc
4.NPSCu: 115, 39, 17+ 0.625 kg/ha	222.3a	234.7cab	20.4a	5301.4 a
5. NPSBCu: 69, 23.5, 10, 1.07 + 0.625 kg/ha	216.7ab	237.0ab	18.0abcd	4920.7 abc
6. NPSBCu: 92, 31, 13, 1.4 + 0.625 kg/ha	217.3a	236.5ab	18.0abcd	4632.2 bc
7. NPSBCu: 115, 39, 17, 1.7 + 0.625 kg/ha	219.3a	235.9ab	19.7abc	5161.4 ab
8. NPS: 69, 23.5, 10 kg/ha	214.2ab	222.4bc	17.3cd	4549.6 bc
9 NPS: 92, 31, 13 kg/ha	211.9ab	225.2bc	17.5c d	4623.1 bc
10. NPS: 115, 39, 17 kg/ha	209.4ab	242.5a	17.7bcd	5126.2 abc
LSD at 0.05	14.98	17. 21	2.62	621.85
CV (%)	8.64	9.20	18.12	16.17

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

Table 2: Partial budget analysis of fertilizers for maize production in Wondo Genet woreda

Treat	NPSB	NPS	Cu	N	AY	Adj. Y	TVC	GB	NB	MRR (%)
1	0	0	0	0	3507	3156	0	20514	20513	
8	0	142	0	91	4550	4095	1554	26615	25061	293
5	150	0	0.63	91	4921	4429	2042	28786	26744	345
2	0	142	0.63	91	4534	4081	2054	26524	24470	D
9	0	189	0	122	4623	4161	2069	27045	24977	D
6	200	0	0.63	122	4632	4169	2556	27098	24542	D
3	0	189	0.63	122	5088	4579	2569	29765	27197	112
10	0	237	0	152	5126	4614	2594	29988	27395	101
7	250	0	0.63	152	5161	4645	3070	30194	27124	**D**
4	0	237	0.63	152	5301	4771	3094	31013	27919	103

AY= average yield, Adj Y= Adjusted yield by 10%, TVC = total cost that varies in ETB/ha, GB = gross benefit in ETB/ha, NB = net benefit ETB/ha, D indicates dominated treatments that were rejected, MRR = marginal rate of return, Fertilizers such as NPSB, NPS, Cu and N are indicated in Kg/ha

Treatment 4 exhibited higher net benefit (ETB 27,919.4 /ha) compared to treatment 5, 8 and 10, which resulted in net benefit of 26,744.90, 25,061.10 and 27,394.30 ETB/ha with marginal rates of return of 345, 293 and 780%, respectively.

Table 3: Economic (partial budget and marginal rate of return) analysis for blended fertilizer rates applied to maize in Wondo Genet woreda

Treatments (kg/ha)	Av. Yield	Adj. yield	TVC (EB/ha)	Revenue (EB/ha)	NB (EB/ha)	MRR (%)
1. No fertilizer	3507	3156	0	20513.6	20513.6	
8. NPS: 69,23.5,10	4550	4095	1554	26615.2	25061.1	293
5. NPSBCu: 69, 23.5,10,1.07, 0.625	4921	4429	2042	28786.1	26743.9	345
NPSCu: 92,31,13, 0.625	5088	4579	2569	29765.4	27196.9	86
10. NPS: 115, 39,17	5126	4614	2594	29988.3	27394.3	780
4. NPSCu: 115, 39,17, 0.625	5301	4771	3094	31013.2	27919.4	105

This suggests that farmers' can recover their cost and can get extra 3.45, 2.93 and 7.8 ETB for each 1 ETB invested. Since the minimum acceptable rate of return assumed in this experiment was 100%, all these treatments were found to give an acceptable marginal rate of return.

Table 4: Partial budget analysis at projected future prices of NPS, NPSB, urea and copper fertilizers for maize production in Wondo Genetworeda

Treatments (kg/ha)	Av. Yield	Adj. yield	TVC (EB/ha)	Revenue (EB/ha)	NB (EB/ha)	MRR (%)
1. No fertilizer	3507	3156	0.0	20513.6	20513.6	
8. NPS: 69,23.5,10	4550	4095	1864.8	26615.2	24750.4	227
5. NPSBCu: 69, 23.5,10,1.07, 0.625	4921	4429	2450.4	28786.1	26335.7	271
3. NPSCu: 92,31,13, 0.625	5088	4579	3082.8	29765.4	26682.6	55
10. NPS: 115, 39,17	5126	4614	3112.8	29988.3	26875.5	633
4. NPSCu: 115, 39,17, 0.625	5301	4771	3712.8	31013.2	27300.4	71

Sensitivity analysis

Market prices are ever changing for different reasons and, hence, calculation of the partial budget considering future prices would be necessary to pinpoint treatments, which could 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 NPS, NPSB, urea and copper fertilizers will increase by 20%. An assumption of price increment in these fertilizers emanated mainly from changes in the exchange rate and transportation cost. Hence, based on the sensitivity analysis, T5, T8 and T10 would give an economic yield response and also sustain acceptable returns even under 20% input price increment that farmer's likely face in the future (Table 4). However, treatment 4 may not sustain acceptable returns under the 20% input prise increment (Table 4). Therefore, farmers could use either of the two fertilizer rates, treatment 8 or 10, depending on their resource and preference.

Conclusion and Recommendations

In the present study, it was observed that maize yield significantly increased with application of blended fertilizers compared to the control (no fertilizer). Although there were no significant difference among the effects of fertilizer types (NPS, NPSCu and NPSBCu) or/and their rates on the yield, suggesting that inclusion of B and Cu nutrients to NPS fertilizers did not bring any significant yield increment. The highest net benefit was also obtained from application of NPS at115 kg N, 39 kg P, 17 kg S/ha (T10), followed by NPSBCu at 69 kg N, 23.5 kg P, 10 kg S, 1.07 kg B + 0.625 kg Cu/ha (T5) and NPS at 69 kg N, 23.5 kg P, 10 kg S/ha (T8) with acceptable marginal rates of return of 633, 271 and 227%, respectively. However, no significant yield difference was obtained between T5 and T8. Therefore, we can recommend the use of NPS at 115 kg N, 39 kg P, 17 kg S/ha to optain maximum yield and net profit for farmers with good resource, while the use of NPS at 69 kg N, 23.5 kg P, 10 kg S/ha could benefit farmers with few resources. However, further trials including wider levels and individual nutrients of given nutrients along with recommended NP are suggested to study impacts of each nutrient.

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