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Research paper

Determination of Rates of NPSB Blended Fertilizer for Better Production of Maize in Debub Ari District, Southern Ethiopia

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In many developing countries mining plant nutrients by crop removal without adequate replenishment combined with imbalance plant nutrition practices, poses a serious threat to agricultural production. A field experiment was conducted for two consecutive years (2017 to 2018) to observe the response of maize to different rates of NPSB fertilizer. The experiment comprises of five treatments: control (no fertilizer), 150 kg NPSB + 41 kg urea (46N, $54P_2O_5$, 10S, 1.07B), 200kg NPSB + 72kg urea (69N, $72P_2O_5$, 13.5S, 1.4B), 250kg NPSB 102 kg urea (92N, $90P_2O_5$, 17S, 1.75B), and 100kg NPSB + 260kg urea (138N, $36P_2O_5$, 6.7S, 0.71B) were tested using randomized complete block design with three replications. The initial soil physical and chemical analysis indicated that the study area is generally characterized as medium in soil fertility and moderately acidic. The analyzed soil data after harvesting showed that the application of blended fertilizer rates numerically increased the total nitrogen and available sulfur in the soil. However, some nutrients like available P, K, and B become decreased numerically in the soil after harvesting. The result showed that there were significant differences ($p<0.05$) between treatment. The application of different levels of NPSB fertilizer significantly influenced maize grain yield but there were no significant difference on plant height and biomass yield of maize. 65 to 117% grain yield improvements over control was obtained by application of different rates of NPSB. The highest grain yield of maize was recorded from 100kg NPSB + 260kg urea (138N, $36P_2O_5$, 6.7S, 0.71B) application of the highest net benefit (ET Birr 24226.7) and MRR% (699.1) was also obtained by application of 100kg NPSB + 260kg urea (138N, $36P_2O_5$, 6.7S, 0.71B). It is then recommended that to improve maize yield at Debub Ari and similar agro ecology and soil condition areas application of 100kg NPSB + 260kg urea ha^{-1} (138N, $36P_2O_5$, 6.7S, 0.71B) is recommended.

Key words: *maize yield, blended fertilizer, NPSB, economic benefit*

INTRODUCTION

Soil nutrient depletion and mismanagement of plant nutrients is a threat to providing food for the world's population in 2020 (Gruhn et al., 2000). In many developing countries, the loss of soil fertility from continual nutrient mining by crop removal without adequate replenishment poses a serious threat to agricultural production ATA (2014) and specifically the nutrient become critically deficient (Sharma et al. 2016). It is already causing yield decreases as large as those caused by other forms of environmental degradation (FAO, 1998), particularly a serious problem in a Sub-Sahara Africa (SSA) by challenging agricultural productivity and rural livelihoods (Gruhn et al., 2000). Ethiopia is one of SSA countries, extremely suffered by negative soil nutrient balance; average rate of soil nutrients deficit as of 2000 were estimated at 47 kg nitrogen (N) ha^{-1}, 7 kg phosphorous (P) ha^{-1}, and 32 kg potassium (K) ha^{-1} (Roy et al., 2003). Mineral fertilizations are the most important inputs for increasing yields. Over the past three decades, additional nutrients applied as fertilizer have been responsible for 55 percent of the yield increases in developing countries (FAO, 1998). Fertilizer recommendations should take into consideration specific soil and crop types, expected yield goal, farming system, agro-climatic and environmental conditions (Isherwood, 2000). Through appropriate and balanced fertilizations, soils can be restored and bioavailability of micronutrients increased (IFA, 2015). However, in Ethiopia, average rate of fertilizer application is about 40kg ha^{-1}, low as compared to global fertilizer rate. Long established blanket recommendation rates of 100 kg DAP ha^{-1} and 100 kg urea ha^{-1} are common practices (Mesfin, 2009). Cereals (Teff, Maize, Sorghum, Wheat and Barley) are the major food crops in terms of area coverage (72.12%) and volume of production (67.85%) in Ethiopia. The contribution of maize in ensuring food security is quite substantial, sharing 16.98% and 27.02% in area coverage and production of cereals with national average yield of 3675 kg ha^{-1} (CSA, 2017). Maize is highly responsive to mineral fertilization particularly to N fertilization. Balanced fertilizer use is not only the first requirement; rather it prerequisite for improving the efficiency of conventionally applied major nutrients (Sharma et al., 2016). The recent national soil inventory data also revealed S, B and Zn deficiencies are widespread in Ethiopian soils, while some soils are also deficient in K, Cu, Mn and Fe (MoANR and ATA, 2016). However, fertilizer trials involving multi-nutrient blends that include micronutrients are rare. Very recently, a soil test crop response based calibration, and validation of seven blended fertilizer formula in comparison to common NP fertilizers trials have been made by EIAR and RARIs but positive responses were recorded in only few location. According to EthioSIS fertilizer type recommendation map/Atlas, eight types of fertilizer blends are identified for SNNPRS. Similarly five types of blended fertilizers for Debub Ari woreda, but only NPSB blend was identified for testing site/kebele (ATA, 2016). Maize producing farmers have been using the identified blend based on the recommendation given by extension office. However, the identified blends types were not validated and the rates were not determined for the woreda in general. Therefore, this study was initiated with the objective of determining the optimum rate of the selected fertilizer type for production of maize at Debub Ari District, southern Ethiopia.

MATERIALS AND METHODS

The study area was located in 05°50’ N and 36°41’ E with an elevation of 1445m asl and found 7 km to north east of Jinka town. The site has bio-modal rainfall pattern with shorter rainy season from March to May and longest rainy season from August to November. The total annual rainfall is 1272.4 ± 250.7 mm. The annual mean minimum and maximum temperatures are 16.3 ± 0.9°C and 27.7 ± 1.4°C, respectively. On farm study was carried out on two farmer’s field at Arkisha and Baytsemal kebele in Debub Ari woreda, South Omo Zone, in the main rainy season of 2017 and 2018 to evaluate the effect of different NPSB rates on maize production. The field experiment was laid out in a Randomized Complete Block Design (RCBD) replicated three times. The treatments consists of five rates of NPSB blend viz. control (no fertilizer), 150 kg NPSB + 41 kg urea (46N, 54P_2O_5, 10S, 1.07B), 200kg NPSB + 72kg urea (69N, 72P_2O_5, 13.5S, 1.4B), 250kg NPSB 102 kg urea (92N, 90P_2O_5, 17S, 1.75B), and 100kg NPSB + 260kg urea (138N, 36P_2O_5, 6.7S, 0.71B). A blended fertilizer NPSB was used based on soil fertility and fertilizer type recommendation Atlas for SNNPRS (ATA, 2016). Fertilizer rates were set based on initial N and P rates determined for maize crop. N dose was adjusted with urea application. The plot size used was 4.5 m wide and 4 m long with 1 m space between plots. Urea and NPSB fertilizers were used as sources of the nutrients (N, P, S, and B). NPSB fertilizer was applied on the sides of maize seed in rows and covered with thin soil before maize planting to avoid contact with seeds, while N was applied in two split: half of the urea was side dressed at planting and the remaining half at about 45 days after planting. Maize variety (variety BH140) was planted in rows using intra-row spacing of 30 cm and inter-row spacing of 75 cm. Two seeds were planted per hole and thinned down to one plant after full emergence. All agronomic practices like weeding, thinning and cultivation were carried out by farmers with consultation of researchers. However, all data collection was exclusively done by researchers.

Soil sampling and analysis

Before planting, soil samples were randomly taken from the experimental field at a depth of 0 to 20cm using an auger and the samples were mixed thoroughly to produce one representative composite sample of 1 kg. After harvesting soil sample were taken from each plot at depth of 0 to 20 cm using auger in a Zigzag movement from five spots. The collected soil samples were air-dried and ground to pass 2 mm for all parameters and 0.5 mm (for total N and OC) sieves, prepared and analyzed using standard soil laboratory procedures.

Crop data collection and analysis

Yield and yield component data such as plant height, 100 seeds weight, and biomass and grain yields were recorded at harvesting. Plant height measurement was carried out on randomly selected five plants and averaged by dividing the sum to number of plants. Total above ground biomass per plot was weighted by harvesting all plants from 4 central rows (net plot area of 4m*3m). Grain yield was collected from all plants harvested for biomass and adjusted to 11.5% moisture.

Data analysis

The collected yield and yield component parameters data were subjected to analysis of variance (ANOVA) and Least Significant Difference (LSD) test was used for mean separation at 5% significance level whenever treatments were significant. SAS version 9.1 statistical software program (SAS, 2010) was employed for the data analysis.

Economic analysis

To evaluate the economic feasibility and to make a rational choice among the different levels of the fertilizer for maize production, partial budget analysis was carried out following CIMMYT procedures (CIMMYT, 1988). The grain yield was down adjusted by 10% to reflect the situation in actual production by farmers. The average open market price for maize was Ethiopian Birr 7.0/kg and the official price for NPSB was ETB 14/kg while that of Urea was ETB 9/kg. The application costs also considered. To consider the economic feasibility of the rate, the minimum acceptable marginal rate of return considered in this study is 100%.

RESULTS AND DISCUSSION

Soil Fertility Status before Planting and after Harvesting

The initial soil physical and chemical analysis indicated that the study area is generally characterized as medium in soil fertility and moderately acidic (Table 1). The availability of all analyzed nutrients was medium for the growth of most crops.
The analyzed soil results before the application of the treatments shown in (Table 1) revealed that the particle size distribution of the soil was sandy clay .The soil had a pH of 5.63 which is moderately acidic. According to Tekalign (1991) and Hariram and Dwivedi (1994) the soil total nitrogen, organic carbon and sulfur were under medium while the soil available P and K was high. According to Jones (2003) classification, the available B content in the soil become low. Thus, soil fertility status of the study site was low to high for the effective production of maize. The analyzed soil data after harvesting showed that the application of blended fertilizer rates numerically increased the total nitrogen and available sulfur in the soil (Table 2). However, some nutrients like available P, K, and B become decreased numerically in the soil after harvesting, which may be due to the utilization of more P, K, and B by maize crop production. Tisdale *et al*. (1993) pointed out that the application of sufficient amount of N promotes P uptake of plants by increasing shoot and root growth, altering plant metabolism, and increasing the solubility and availability of P.

The effects of NPSB fertilizer rates on yield and yield components of maize are presented in Table 1. Application of different rates of NPSB significantly influenced plant height and biomass yield of maize over untreated control, but there were no significant difference among the rates of NPSB. Application of different rates of NPSB did not significant affected 1000 seed weight of maize. The control (without fertilizer) resulted significantly ($p<0.05$) inferior plant height, biomass and grain yield as compared to that of all the applied NPSB fertilizer rates. 1000 seed weight by control treatment was also inferior, but did not differ significantly. Several previous studies showed that yield attributing parameters increased by increased level of N (Sapkota et al., 2017; Bakht and Masood et al., 2006, 2011; Okumura et al., 2011). There was significant ($p<0.001$) NPSB rates effect on grain yield of maize. Hence, 100 kg NPSB + 260 kg urea ha^{-1} gave the highest maize grain yield (4657.1 kg ha^{-1}) and it was lowest at untreated control. Maize yield increased by increasing the

Table 1. Soil physical and chemical properties of the experimental site before planting

Soil properties	Values	Rates	References
Clay	32		
Silt	18		
Sand	50		
Textural class		Sandy clay	
pH(H2O)	5.63	Moderately acidic	Jones, 2003
Organic carbon (%)	0.68	Medium	Tekalign, 1991
Organic matter (%)	1.17	Medium	Tekalign, 1991
Total N (%)	0.06	Medium	Tekalign, 1991
Available P (ppm)	45.85	Very high	Jones, 2003
Available K(meq/100g)	0.80	High	FAO, 2006
Available S(ppm)	18.25	Medium	Hariram and Dwivedi, 1994
Available B (ppm)	0.57	Low	Jones, 2003

Table 2. Some soil chemical properties of the experimental site after harvesting

Treatments	**Soil properties**						
	OC (%)	OM (%)	TN (%)	Av P (ppm)	AvK(meq /100g)	Av S (ppm)	Av B (ppm)
Control	1.61	2.78	0.14	33.50	0.53	20.54	0.06
150kgNPSB+41kg UTD	1.97	3.39	0.17	33.55	0.55	24.33	0.16
200kgNPSB+72kgUTD	1.65	2.85	0.14	34.40	0.55	23.66	0.20
250kgNPSB+102kgUTD	1.82	3.14	0.16	28.45	0.54	27.01	0.12
100kgNPSB+260kgUTD	1.95	3.36	0.17	35.60	0.58	18.53	0.06
Rates	high	high	high	high	medium	high	low
Reference	Tekalign, 1991	Tekalign, 1991	Tekalign, 1991	Jones, 2003	FAO, 2006	Hariram & Dwivedi, 1994	Jones, 2003

Note: UTD= Urea Top Dressing

Table 3. Effect of different rates of NPSB fertilizer on maize production

Treatments	Plant Height (cm)	100 Seed (g)	Biomass (kg ha^{-1})	Grain (kg ha^{-1})
Control	149.9^{b}	28.34	6302^{b}	2144.5^{c}
150kgNPSB+41kg Urea	181.9^{a}	30.52	10190^{a}	3558.5^{b}
200kgNPSB+72kg Urea	190.1^{a}	30.9	10180^{a}	4011^{ab}
250kgNPSB+102kg Urea	182.9^{a}	32.65	11320^{a}	4501^{ab}
100kgNPSB+260kg Urea	179.5^{a}	31.1	12356^{a}	4657.1^{a}
Mean	176.9	30.7	10070	3774
CV	8.4	15.9	38.1	27.6
LSD	14.2	NS	3683	998.3

Note: 100kg NPSB (the blend we used) = 18.1 N- 36.1 P2O5 + 6.7S + 0.71B; N is adjusted from urea

Table 4. The Partial Budget Analysis for different rates of NPSB fertilizer for maize production

Variables	Treatments				
	Control (no fertilizer)	150kgNPSB + 41kg Urea	200kgNPSB + 72kg Urea	250kgNPSB +102kg Urea	100kgNPSB +260kg Urea
Av. Yield	2144.5	3558.5	4011.0	4501.0	4657.1
10% Adj. yield	1930.1	3202.7	3609.9	4050.9	4191.4
TCV (EB/ha)	0.0	3289.6	4603.6	5905.1	5113.0
Gross Benefits (EB/ha)	13510.4	22418.6	25269.3	28356.3	29339.7
Net Benefit (EB/ha)	13510.4	19129.0	20665.7	22451.2	24226.7

Table 5. Dominant analysis for fertilizers

Variables	Control (no fertilizer)	150kgNPSB +41kg Urea	200kgNPSB +72kg Urea	100kgNPSB +260kg Urea	250kgNPSB +102kg Urea
TCV (Birr/ha)	0.0	3289.6	4603.6	5113.0	5905.1
Net Benefit (Birr/ha)	13510.4	19129.0	20665.7	24226.7	22451.2^{D}

Table 6. Marginal rate of return (%MRR) for fertilizers

Variables	Control	150 kg NPSB + 41kg Urea	200 kg NPSB + 72kg Urea	100 kg NPSB + 260 kg Urea	250kg NPSB + 102kg Urea
TCV (Birr/ha)	0.0	3289.6	4603.6	5113.0	5905.1
Net Benefit (Birr/ha)	13510.4	19129.0	20665.7	24226.7	22451.2
MRR (%)		170.8	116.9	699.1	D

level of N but at lower P level. Sapkota et al., (2017) also reported increased maize grain yield with increase in N rates. Similar increment trend was observed in biomass yield of maize thought there were no significant differences among applied rates except with that of control. The applied rates of NPSB fertilizer increased biomass and grain yield by 61 to 96% and 65 to 117%, respectively, over the control. Report by Redai et al., (2018) showed that different combination of N-P-K significantly improved yield over control. A similar finding was reported by Ayeni and Adetunji (2010) who reported that more than 100% maize biomass and 11 to 57% grain yield increase over control due to application of NPK fertilizer alone whereas 77 to 164% grain yield increase over control was reported due to combined application of poultry manure with NPK fertilizer. In addition, significant and positive effect of NPKSZn blended fertilizer application on grain yield of sorghum was reported by Redai et al., (2018).

Partial Budget Analysis

Data in table4, 5 and 6 showed that the highest net benefit and percent marginal rate of return (MRR%) were recorded by application of 100kg NPSB + 260kg urea (138N, 36P_2O_5, 6.7S, 0.71B) followed by application of 200kg NPSB + 72kg urea (69N, 72P_2O_5, 13.5S, 1.4B). Application of 150 kg NPSB + 41 kg urea (46N, 54P_2O_5, 10S, 1.07B) also gave promising net benefit and relatively higher MRR% (Table 4). The advantageous were obtained due to the applied blended fertilizer, highest economic benefits (117% yield increase) and highest gross margin were obtained from 100kg NPSB + 260kg urea (138N, 36P_2O_5, 6.7S, 0.71B) treated plots. This increased yield might be attributed to application of increased of N.

CONCLUSION

Majority of variations in yield potential of crops are not only due to application of fertilizers other edaphic and climatic factors should be considered. The initial soil physical and chemical analysis indicated that the study area is generally characterized as medium in soil fertility and moderately acidic. The current on-farm results showed that maize production was influenced by application of different rates of NPSB blend. Increased rate of N significantly affected the grain yield of maize. The application of 100kg NPSB + 260kg urea ha^{-1} (138N, 36P_2O_5, 6.7S, 0.71B) gave significantly higher maize grain yield as compared to untreated control and 150 kg NPSB + 41 kg urea ha^{-1} treated plots. The highest net benefit (ET Birr 24226.7) and %MRR (699.1%) were also obtained by application of 100kg NPSB + 260kg urea ha^{-1} (138N, $36P_2O_5$, 6.7S, 0.71B). Hence, application of 100kg NPSB + 260kg urea ha^{-1} (138N, $36P_2O_5$, 6.7S, 0.71B) could be recommended for maize production for Debub Ari woreda and other similar Agro-ecological Zone and soil condition. Additional work is needed to verify the results and demonstrate in wider areas for further use including NP and N alone fertilizer treatments.

AUTHOR CONTRIBUTIONS

The authors initiated and wrote the research proposal, conducted the research in the field, reviewing and editing of research proposal and Manuscript; did data entry and analysis and writing the full manuscript. All are equally contributed.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

ETHICS APPROVAL

Not applicable

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