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Full-length Research Article

Evaluation of Blended Fertilizer Rates for Improved Sorghum [*Sorghum bicolor,* (L.) Moench.] Yield in Derashe District, Southern Ethiopia

Ewnet Zeleke Kayda[1], Tarekegn Keriso Menisho[1], Geremew Biramo Doliso[1], Metadel Minaye Getahun[1], and Thomas T. Minda[2,*]

[1]*Southern Agricultural Research Institute, Arba Minch Agricultural Research Center, Arba Minch, Ethiopia*

[2]*Faculty of Meteorology & Hydrology, Water Technology Institute, Arba Minch University, Ethiopia*

**Corresponding author: ewnet.zelekea@yahoo.com*

Abstract

Sorghum is one of the main grains grown in Derashe district, southern Ethiopia. However, its production is limited by many factors. Of these, less fertile soil is predominant. In the region, the rational use of fertilizers has not been studied. In addition, the type of fertilizer required and the optimal fertilizer rate for the area have not been quantified. Field trials were carried out in Derashe district to evaluate the ratio of compound fertilizers to improve sorghum yield. The treatments were laid out in a Randomized Complete Block Design, with three replications, using Melkam sorghum variety. The experiment had thirteen treatments consisting of control (no fertilizer), four different types of blended fertilizers (NPS, NPSB, NPSZn and NPSZnB) each with three rates. Our analysis show that the highest grain yield was recorded from the plot that receive 225 $kg{\cdot}ha^{-1}$ NPSZnB + 117 $kg{\cdot}ha^{-1}$ urea in the first year, In the second year, the highest yield was recorded from the plot that received 150 $kg{\cdot}ha^{-1}$ NPS + 88 $kg{\cdot}ha^{-1}$ urea. In both years, the lowest grain yield was measured from the plots treated with no fertilizer (control). The marginal analysis showed that application of 112 $kg{\cdot}ha^{-1}$ NPSZnB + 59 $kg{\cdot}ha^{-1}$ urea is economically the most profitable than the other treatments. Based on our findings, it is recommended to apply 112 $kg{\cdot}ha^{-1}$ NPSZnB + 59 $kg{\cdot}ha^{-1}$ urea for the profitable production of Melkam sorghum variety in the study area.

Keywords: grain yield, Melkam variety, optimum fertilizer rate, soil fertility lose.

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1. INTRODUCTION

Sorghum [*Sorghum bicolor,* (L.) Moench.) is grown as one of the major food cereals in Ethiopia. The crop is the second, after maize, most cultivated crop in total production (CSA, 2011). It is well adapted to a wide range of precipitation and temperature regimes. Sorghum crop drought tolerance and adaptation attributes have made it the favorite crop in drier and marginal areas (Shiferaw and Yoseph, 2014). The crop is a staple food in South Omo and Segen area People's zones, Southwest Ethiopia. The region is characterized as hot arid and semi-arid agro-ecological class and known for recurrent droughts (Habte *et al*., 2020). It is utilized in various forms such as for making local bread (*Injera*) and for the preparation of local alcoholic beverages such as *Tela* and *Areke*. It is also consumed as roasted and boiled grain. Sorghum stover is used as feed for animals and as housing and fencing material (Shiferaw & Yoseph, 2014). Though the crop is very important for smallholder farmers in Ethiopia, it is characterized by poor crop performance and low yields. Low soil fertility is among the major challenges for the low sorghum yield (Amelework *et al*., 2016).

Despite the low soil fertility status, in Ethiopian agriculture, fertilizer applications have been focused only on nitrogen and phosphorous fertilizers. Those fertilizers are in the form of Di-ammonium phosphate (DAP) and Urea or blanket recommendation for the major food crops. In this regard, the other essential macro and micronutrients have been neglected (Melkamu et al., 2019). Besides, in the country, there has been unbalanced use of fertilizers resulting in soil fertility lose and plant nutrient imbalances (Hordofa, 2020; IFDC, 2015).

The Ethiopian Soil Information System (EthioSIS) has conducted soil fertility mapping to identify deficient soil nutrients in Ethiopian soils (Ethio-SIS, 2016). EthioSIS also suggested fertilizer recommendations for the different districts of the country based on the soil fertility mapping results. The soil map dataset revealed that most of the nutrients are deficient in Ethiopian soils. The same applies to our study area. Therefore, the present study was designed to evaluate the appropriate blended fertilizer type and determine the optimum blended fertilizer rates for sustainable production of sorghum in Derashe district. Accordingly, we conducted field trials on different blended fertilizer rates in two consecutive seasons during 2018 and 2019.

2. MATERIALS AND METHODS

2.1. Description of the study area

The experiment was conducted in Derashe district (5° 06' N latitude and 37° 30' E longitude), which is located in the Southern Nations, Nationalities and Peoples Regional State (SNNPRS). The experiment was conducted for two consecutive years under rain fed condition during the main season of 2018 and 2019. The mean annual rainfall in the area ranged from 600-1600 mm.

The agro-climatic condition of the study area is categorized as *Dega* (cold), *Woyina-dega* (moderate) and *Kola* (warm) with 17.2%, 34.2% and 48.6%, respectively. The area has bimodal rainfall climatology that the major rainy season is the *belg* season during March to May. The small rain received during September to November.

2.2. Soil sampling and analysis

Prior to sowing, soil samples were collected from the experimental field. The samples were collected from the surface (0–40 cm). The samples were thoroughly mixed, air dried and grinded to pass through a 2 mm sieve to analyze and quantify the soil physicochemical parameters. Soil parameters such as soil texture, soil pH, organic carbon, total nitrogen, available phosphorus, available sulfur, and Cation exchange capacity (CEC) were the analyzed.

2.3. Experimental treatments design and procedures

The Melkam sorghum variety was used for the study. The experiment consisted of four (NPS, NPSB, NPSZn and NPSZnB) blended fertilizers each with three levels and control treatment. The treatments details are listed in (Table 1).

Table 1: Description of treatments, fertilizer type, rate and their composition

No.	**Treatments ($kg \cdot ha^{-1}$)**	**Rate of individual nutrient ($kg \cdot ha^{-1}$)**				
		N	**P_2O_5**	**S**	**Zn**	**B**
1	Control	0	0	0	-	-
2	100 NPS + 59 urea	46	38	7	-	-
3	150 NPS + 88 urea	69	57	10.5	-	-
4	200 NPS + 171 urea	92	76	14	-	-
5	105 NPSB + 59 urea	46	38	7	-	0.71
6	158 NPSB + 88 urea	69	57	10.5	-	1.06
7	211 NPSB + 171 urea	92	76	14	-	1.42
8	109 NPSZn + 59 urea	46	38	7	2.4	-
9	164 NPSZn + 88 urea	69	57	10.5	3.6	-
10	218 NPSZn + 171 urea	92	76	14	4.8	-
11	112 NPSZnB + 59 urea	46	38	8.18	2.5	0.75
12	168 NPSZnB + 88 urea	69	57	13.08	3.75	1.1
13	225 NPSZnB + 171 urea	92	76	16.36	5	1.5

The treatments were arranged in randomized complete block design (RCBD) with three replications (Gomez et al., 1984). The whole dose of blended fertilizers as source of N, P, S, Zn and additional N from urea to reach the half rate of N were applied at sowing time. The remaining half of N from urea was applied at knee height of the crop. Borax was applied in foliar as source of

B. The spacing between the blocks and plots were 1m and 1m, respectively. The seeds were drilled in to rows of 0.75m apart and then thinned at the spacing of 0.2m.

All crop management practices were applied as recommended. Agronomic data such as panicle length, plant height, biomass yield, grain yield and 1000 seed weight were collected. The collected data were subjected to analysis of variance, using the SAS statistical software version 9.0 (Littell et al., 1996). And mean comparisons for the significantly different variables among treatments were made using Least Significant Differences (LSD) test at 0.05 level of significance.

Economic analysis was done following the CIMMYT partial budget analysis procedure (Program et al., 1988). Total variable costs (TVC), gross benefit (GB), net benefit (NB), marginal cost (MC) and marginal benefit (MB) were calculated. After calculating MC and MB, the dominated treatments are identified. Following this, the marginal rate of return (MRR in %) was calculated for the treatments that are not dominated.

3. RESULTS AND DISCUSSION

3.1. Soil Test Results

The official laboratory analysis results indicated that proportions of soil particle size distribution were 40% sand, 10% silt and 50% clay with clay loam textural class. The soil pH at the experimental site was 8.87. Soils having pH above 8 are categorized as strongly alkaline (Tadesse *et al*., 1991). The organic carbon (OC) and total nitrogen (TN) were 2.14 and 0.17%, respectively. These can rated moderate (Tadesse *et al*., 1991). The experimental soil contains 28.39 mg kg^{-1} available P, which can be rated as optimum (Ethio-SIS, 2016). The cation exchange capacity was 66.6 cmol (+) Kg^{-1} which is categorized as very high (Hazelton & Murphy, 2007). The soil contains 2.28 mg kg^{-1} S which can be taken as deficient (Ethio-SIS, 2016).

3.2. Plant Height and Panicle Length

The results of ANOVA showed that blended fertilizer rates did not bring significant variation on plant height of sorghum in the first year. Similarly, plant height did not show significant variation in the second year with the application of different treatments except for the control treatment that lowered significantly from the others. The highest plant height was recorded from plots that receive 225 $kg{\cdot}ha^{-1}$ NPSZnB + 171 $kg{\cdot}ha^{-1}$ urea and 150 $kg{\cdot}ha^{-1}$ NPS + 88 $kg{\cdot}ha^{-1}$ urea in the first and second years, respectively. On the other hand, the lowest plant height was recorded from the control treatment (Table 2). This result substantiates that the soil analysis the area is deficient in nutrients such as S. The application of blended fertilizers resulted in an increase in plant height. In agreement with this, Wako and Usmane, (2020) reported the increment of plant height with the application of blended fertilizer over untreated ones.

Table 2: Plant height and panicle length of sorghum as influenced by different rates and types of blended fertilizers in Derashe district.

	Plant height (cm)		Panicle length (cm)	
Treatments ($kg \cdot ha^{-1}$)	**2018**	**2019**	**2018**	**2019**
Control	127.0^{b}	167.6^{b}	18.7^{d}	25.3^{b}
100 NPS + 59 urea	136.1^{ab}	174.0^{ab}	22.0^{abc}	27.6^{ab}
150 NPS + 88 urea	144.0^{a}	181.6^{a}	23.4^{ab}	27.3^{ab}
200 NPS + 171 urea	144.6^{a}	177.6^{ab}	24.0^{a}	28.0^{ab}
105 NPSB + 59 urea	138.6^{ab}	175.6^{ab}	22.2^{abc}	28.3^{a}
158 NPSB + 88 urea	134.9^{ab}	172.3^{ab}	21.1^{abc}	27.0^{ab}
211 NPSB + 171 urea	142.8^{a}	175.6^{ab}	22.4^{abc}	26.6^{ab}
109 NPSZn + 59 urea	128.0^{b}	176.3^{ab}	20.6^{bc}	26.3^{ab}
164 NPSZn + 88 urea	136.2^{ab}	177.0^{ab}	22.0^{abc}	27.6^{ab}
218 NPSZn + 171 urea	144.4^{a}	175.0^{ab}	23.3^{abc}	27.0^{ab}
112 NPSZnB + 59 urea	134.5^{ab}	179.6^{ab}	20.2^{c}	27.3^{ab}
168 NPSZnB + 88 urea	138.9^{ab}	174.6^{ab}	22.2^{abc}	28.3^{a}
225 NPSZnB + 171 urea	144.9^{a}	176.3^{ab}	22.7^{abc}	26.0^{ab}
CV	5.9	4.0	8.4	7.0
LSD (%)	13.7	12.2	2.9	2.9

Means within a column followed by same letter are not significantly different from each other at $P \leq 0.05$; LSD = least significant difference; CV = coefficient of variation

Application of different rates of blended fertilizers significantly increased panicle length over the control treatment but the other treatments are statistically similar with each other in both years. Though all treatments are statistically similar, the highest panicle length was measured from the plot that received 200 $kg \cdot ha^{-1}$ NPS + 171 $kg \cdot ha^{-1}$ urea in the first year. The application of 105 $kg \cdot ha^{-1}$ NPSB + 59 $kg \cdot ha^{-1}$ urea and 168 $kg \cdot ha^{-1}$ NPSZnB + 88 $kg \cdot ha^{-1}$ urea resulted with the highest panicle length (28.3 cm) in the second year. The lowest panicle length was recorded from the control in both years. This result is in line with the findings of Gebremeskel *et al*., (2017) who reported the increment of panicle length of two sorghum verities with application of blended fertilizers over the control.

3.3. Thousand Seed Weight, Biomass Yield and Grain Yield

The analysis of variance showed no significant difference for thousand seed weight of sorghum due to the treatments effect in both years (Table 3) The current result disagrees with previous work of Gebremeskel *et al*. (2017) who reported significant variation of thousand seed weight of sorghum with the application of different types of blended fertilizer on sorghum varieties.

Biomass yield was significantly affected by the treatments in the first year whereas the difference in biomass yield with the application of treatments is statistically not significant in the second year. The highest biomass yield (10756 kg·ha^{-1}) was recorded from plots that received the highest amount of NPSZnB and 171 kg·ha^{-1} urea. The lowest biomass yield (7437 kg·ha^{-1}) was recorded from the control treatment. In line with this finding, Gebremeskel *et al*. (2017) showed increased biomass yield with the application of NPSZn blended fertilizer. Choudhary *et al*. (2017) also reported that combined application of micronutrients (Fe + Zn + B) significantly increased biological yield (17.42 %) and grain yield (25.33 %) of sorghum over the control. Melaku *et al*. (2018) reported the increment of biomass yield with increasing rate of N application.

Table 3: Thousand seed weight, biomass yield and Grain yield of sorghum as influenced by different types of blended fertilizers in Derashe district.

Treatments (kg·ha^{-1})	**Thousand seed weight (g)**		**Biomass yield (kg·ha^{-1})**		**Grain yield (kg·ha^{-1})**	
	2018	**2019**	**2018**	**2019**	**2018**	**2019**
Control	18.0	25.6^{a}	7437.0^{d}	11454.0^{a}	1266.7^{d}	2094.0^{b}
100 NPS + 59 urea	17.6	29.6^{a}	8741.0^{abcd}	13134.0^{a}	1866.7^{abcd}	2563.0^{ab}
150 NPS + 88 urea	21.6	27.3^{a}	9956.0^{abc}	12588.0^{a}	1955.7^{ab}	3844.0^{a}
200 NPS + 171 urea	22.0	27.3^{a}	10074.0^{abc}	10450.0^{a}	1896.0^{abc}	2562.7^{ab}
105 NPSB + 59 urea	21.3	27.3^{a}	8504.0^{bcd}	10742.0^{a}	1570.3^{abcd}	2958.7^{ab}
158 NPSB + 88 urea	20.3	25.0^{a}	9185.0^{abcd}	11288.0^{a}	1807.3^{abcd}	2292.0^{b}
211 NPSB + 171 urea	22.0	26.0^{a}	8207.0^{cd}	9329.0^{a}	1510.7^{bcd}	2188.0^{b}
109 NPSZn + 59 urea	20.6	28.0^{a}	7733.0^{d}	12750.0^{a}	1377.7^{cd}	2813.0^{ab}
164 NPSZn + 88 urea	21.0	25.6^{a}	10696.0^{ab}	13342.0^{a}	1955.7^{ab}	2937.7^{ab}
218 NPSZn + 171 urea	22.0	23.6^{a}	10667.0^{ab}	11671.0^{a}	1985.3^{ab}	2187.7^{b}
112 NPSZnB + 59 urea	22.6	23.3^{a}	9333.0^{abcd}	10888.0^{a}	1748.0^{abcd}	2916.7^{ab}
168 NPSZnB + 88 urea	21.0	27.6^{a}	8829.0^{abcd}	9304.0^{a}	1688.7^{abcd}	3000.0^{ab}
225 NPSZnB + 171 urea	22.3	27.3^{a}	10756.0^{a}	10458.0^{a}	2133.3^{a}	2208.7^{b}
CV	9.7	18.0	14.0	27.0	20.2	30.0
LSD (%)	NS	NS	2192.8	NS	606.5	1305.0

Means within a column followed by the same letter are not significantly different from each other at P ≤ 0.05; LSD = least significant difference; CV = coefficient of variation

Our results showed significant effect of treatments on grain yield on sorghum in both years. The highest grain yield was recorded from the plot that received 225 kg·ha^{-1} NPSZnB + 117 kg·ha^{-1} urea in the first year, whereas it was from the plot that received 150 kg·ha^{-1} NPS +88 kg·ha^{-1} urea in the second year. The lowest grain yield was measured from the plots treated with no fertilizer (control) in both years. From Table 3, it can be observed that the control treatment resulted in the lowest grain yield and other measured parameters compared to the other treatments. This substantiates that the importance of blended fertilizers to increase crop yield. The result is in concurrence with the findings of Weldegebriel *et a*l., (2018) reported that application of blended NPKSZn increased sorghum grain yield by 136.5% over the control treatment. Similarly, (Wako & Usmane, 2020) explained increased grain yield with the application of NPSZnB blended fertilizer. It is also reported that plots treated with blended fertilizers resulted in highest grain yield compared with the untreated (control) on other cereals such as maize and barley (Chimdessa, 2016; Hordofa, 2020).

3.4. Economic Analysis

Economic analysis was done to evaluate the economic benefits of rates of different blended fertilizers on sorghum (Table 4). The economic analysis was done using mean of the two years grain yield data. The partial budget analysis shows that the highest net benefit was obtained from the application of 150 kg·ha^{-1} NPS + 88 kg·ha^{-1} urea followed by 164 kg·ha^{-1} NPSZn + 88 kg·ha^{-1} urea.

Table 4: partial budget and marginal analysis of blended fertilizers on grain yield of sorghum.

Treatments (kg·ha^{-1})	AGY (Kg·ha^{-1})	GB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	MC	MB	MRR (%)
0	1512.32	21928.57	0	21928.57	-	-	
100 NPS + 59 urea	1993.37	28903.79	2674	26229.68	2674.00	4301.12	160.85
105 NPSB + 59 urea	2609.87	37843.04	2757	26795.07	82.55	565.38	684.91
109 NPSZn + 59 urea	2006.42	29093.02	2883	24461.64	126.02	D	-
112 NPSZnB + 59 urea	2038.05	29551.73	2997	27440.12	114.38	2978.47	2604.12
150 NPS + 88 urea	1844.69	26747.93	4003	33840.06	1005.93	6399.94	636.22
158 NPSB + 88 urea	1664.42	24134.02	4135	22612.60	132.35	D	-
164 NPSZn + 88 urea	1885.82	27344.32	4325	27604.81	189.29	D	-
168 NPSZnB + 88 urea	2202.03	31929.44	4487	26106.37	162.77	D	-
200 NPS + 117 urea	1877.85	27228.83	5332	23761.16	844.46	D	-
211 NPSB + 117 urea	2099.12	30437.17	5514	18620.00	182.16	D	-
218 NPSZn + 117 urea	2109.92	30593.77	5749	21479.84	234.97	D	-
225 NPSZnB + 117 urea	1953.90	28331.55	5996	22335.67	246.89	D	-

AGY: Adjusted grain yield; GB: Gross benefit TVC: Total variable cost; NB: Net benefit; MC: Marginal cost; MB: Marginal benefit; MRR: Marginal rate of return; ETB: Ethiopian Birr.

The economic analysis showed that application of 112 kg·ha^{-1} NPSZnB + 59 kg·ha^{-1} urea is economically the most profitable than the other treatments. This treatment corresponds to the highest marginal rate of return (MRR, 2604%). This mean that for each 1 ETB additional investment on fertilizer, farmers can earn a return of 26 ETB. The next economically feasible treatment was 105 kg·ha^{-1} NPSB+59 kg·ha^{-1} urea (MRR of 685%). The analysis also showed that application of the treatments except the dominated ones gave above 100% MRR which is an acceptable rate of return (CIMMYT, 1998) (Table 4).

4. CONCLUSIONS

The results of this study showed that in the first year, all the measured parameters of sorghum except for thousand seed weight responded positively (statistically significant) to the application of the ratios. different fertilizers. Similarly, in the second year, plant height, panicle length and seed yield of sorghum responded positively (statistically significant) to the fertilization treatments. The highest grain yield was obtained from the application of 225 kg·ha^{-1} NPSZnB + 171 kg·ha^{-1} urea, in the first year. Whereas in the second year, the highest grain yield was recorded from the application of 150 kg·ha^{-1} NPS + 88 kg·ha^{-1} urea. In terms of economic feasibility, the application of 112 kg·ha^{-1} NPSZnB + 59 kg·ha^{-1} urea resulted in highest economic return. Therefore, based on our study, it is recommended to apply 112 kg·ha^{-1} NPSZnB + 59 kg·ha^{-1} in the study area and areas having the same soil and agroecological conditions.

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Conflict of the interest

The authors declare that they have no conflict of interest.

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