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Effect of blended fertilizer types for improving production of sorghum (*Sorghum bicolor* L.) in Bena Tsemay district, Southwestern Ethiopia

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Abstract

Depletion of soil organic matter, depletion of macro- and micronutrients, lack of local specific fertilizer recommendation per commodity are among core constraints in Ethiopian soils that hinders crop production including sorghum. The experiment was conducted to evaluate blended fertilizer type effect on improving production of sorghum in Bena Tsemay district, Southwestern Ethiopia. The experiment was carried out in 2018 and 2019 main cropping season and laid out in RCBD following three replications with spacing of 75cm between rows and 20cm between plants. It was done by using control, (46N+68.7P_2O_5) kgha^{-1}, (142NPS+141Urea) kgha^{-1}, (150NPSB+141Urea) kgha^{-1}, (160NPSBZn+144Urea) kgha^{-1}, (155NPSZn+141Urea) kgha^{-1}, (197NPSBK+141Urea) kgha^{-1} and (207NPSBZnK+141Urea) kgha^{-1} treatments. Full dose of blended fertilizer, phosphorus, boron and potassium chloride fertilizers were applied at planting time and urea was applied in two split. Partial budget analysis with dominance and marginal analysis was done for economic evaluation. The result has revealed that sorghum has responded well to the application of macronutrients with micronutrients (Zn and B) than unfertilized. Application of 150kgha^{-1}NPSB+141kgha^{-1}Urea resulted in highest grain yield, while the lowest grain yield was recorded from the control. The highest economic returns of 230.06% was obtained from application of 150kgha^{-1}NPSB+141kgha^{-1}Urea; and it gives 43.85% yield increment and 31.86% increment in economic return over the control. Application of 150kgha^{-1}NPSB+141kgha^{-1}Urea was recommended for farmers and investor's to produce sorghum on the study area and similar agro ecologies, as it was optimum for improving sorghum production. Further investigation should be done on plant nutrient uptake, nutrient use efficiency and optimization.

Keywords: Blended fertilizer, Economic Return, Productivity, Sorghum.

INTRODUCTION

Sorghum (*Sorghum bicolor* L.) belonging to the family Poaceae, it is produced in many countries of the world and the fifth major cereal crop in the world in terms of tonnage after maize, wheat, rice and barley [1]. It is the third most important cereal crop in Ethiopia and forth in Southern region in terms of area of production [2]. In Ethiopia, it is adapted to a wide range of environments, and hence can be produced in the high lands, medium altitude and low lands. Sorghum is widely produced more than any other crops in the areas where there is moisture stress [3]. It is a staple food crop on which millions of poor Ethiopians lives depend. It has tremendous uses for the Ethiopian farmer of which no part of this plant is ignored rather used for animal feed and for construction of houses and fences; and as fuel wood [4, 5].

Depletion of soil organic matter, depletion of macro- and micronutrients, lack of local specific fertilizer recommendation per commodity and limited guidance to farmers on possible integration of fertilizer with other soil and water management practices, removal of top soil by erosion and change of soil physical properties are among core constraints in Ethiopian soils [6]. Ethiopian soils have been subjected to severe degradation caused by natural and man-made factors [7]. Rate of mineralization of soil mineral and organic matter nutrients, returning of nutrients to the soil through the use of both organic and inorganic fertilizers, nutrient removal from the soil through harvesting and erosion are among the factors that affects soil fertility depletion [8]. Soil fertility depletion in smallholder farmers' is the fundamental biophysical root cause of declining per capita food production [9]. Low soil fertility and shortage of moisture is the major constraints in the reduction of growth and productivity of sorghum [10]. Low productivity of sorghum in the study zone, with average yield of 20.92 Quintalha^{-1} which is even below the national average yield of

27.26 Quintalha^{-1} [11, 2]. Fertilizer use in Ethiopia has focused mainly on the use and application of nitrogen and phosphorous fertilizers for almost all crops; such unbalanced application of plant nutrients may aggravate the depletion of other important nutrients in soils [12].

Blended fertilizer amended with enough amount of nitrogen and phosphorous on sorghum gave the highest yield, nutritional content and economic return [13]. Moreover, the appropriate use of nitrogen and phosphorous fertilizer for sorghum production optimize economic return through increasing production sorghum, where there is low practice of using optimum level of fertilizer [14]. Moreover, increases in yield due to application of potassium, Sulfur and Zinc in different parts of the country which leads the country started using fertilizers which can supply the deficient nutrients [7]. Additionally, application of macronutrients in combination with micronutrient enhanced sorghum yield and improved N, P and K uptake and its nutrient use efficiency [15]. Thus, according to [16] the study area was deficient in macro- and micro-nutrients. Therefore, this experiment was conducted to evaluate different blended fertilizer type effect on improving production of sorghum in Bena Tsemay district, southwestern Ethiopia.

MATERIALS AND METHODS

Study area description

The study was conducted 2018 and 2019 main cropping season in Bena Tsemay District, southwestern Ethiopia. The experimental site was situated at latitude of 5°35.781'North, longitude of 36°41.203'East and at the elevation of 1391 metres above sea level. The annual average rainfall of the woreda ranges between 601 to 1600 mm. The minimum and maximum annual temperature of 27.5°C and >27.5°C, respectively. The study area has diversity of climate, soil, and land forms. The topography of the woreda includes mountains, hills, uplands and lowland plains. The District generally experiences two cropping seasons namely belg and meher.

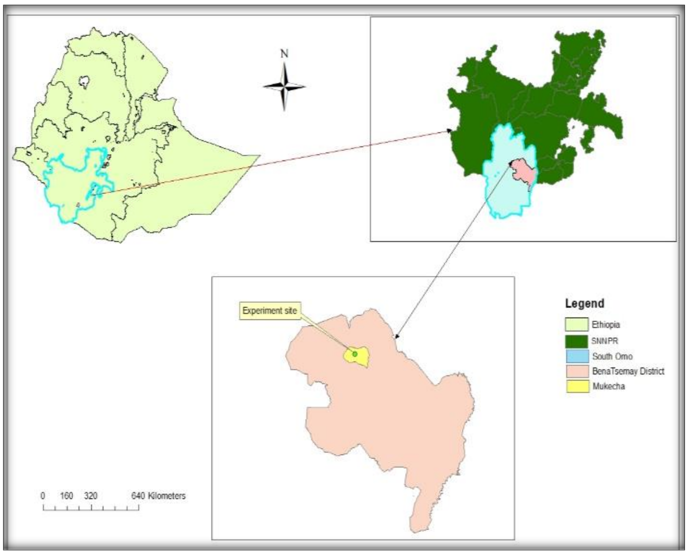

Figure 1: Map of study area

Experimental design and treatments

The experiment was laid out in Randomized Complete Block Design following three replications. The experimental site was ploughed and harrowed before sowing. Improved sorghum variety Teshale was used for the experiment. Plot size was 4.5meter by 4meter. Furrow rows were made manually in spacing of 75 cm apart and sorghum seed was drilled manually and thinned by 20cm spacing between plants.

Table 1: Treatment set up of the experiment

Fertilizers (kgha^{-1})	Nutrient (kgha^{-1})					
	N	P_2O_5	S	B	Zn	K
Control	0	0	0	0	0	0
Recommended NP	46	68.7	0	0	0	0
142NPS+141Urea	92	54	9.94	0	0	0
150NPSB+141Urea	92	54	10.05	1.06	0	0
160NPSBZn+144Urea	92	54	11.68	1.07	3.57	0
155NPSZn+141Urea	92	54	11.78	0	3.46	0
197NPSBK+141Urea	92	54	10.05	1.06	0	28.37
207NPSBZnK+141Urea	92	54	11.6	0.52	3.56	30.64

Where N= Nitrogen; P= Phosphorus; S= Sulphur; B= Boron; Zn= Zinc and K= Potassium

A source of nitrogen, Phosphorous, Potassium and Boron was Urea, TSP, KCl and Borax respectively. Full dose of blended fertilizers and Phosphorous fertilizers were applied at planting time and urea was applied in two split for those treatments including urea.

Data Collection and analysis

Treatments effect on sorghum were determined using plant height, number of tillers per plant, panicle length, above ground biomass, thousand kernel weight and grain yield. Composite soil sample was collected from experimental area before planting in zigzag movement with the sampling depth of 0-20 cm and analyzed for texture, pH, organic carbon, total nitrogen, available phosphorus, potassium, sulphur and boron. Analysis of variance was performed using the SAS Statistical Software Version 9.1. Treatment effects were considered significant in all statistical calculations if the P-value < 0.05. Means were separated using Least Significant Difference (LSD) test.

Economic analysis

The economic evaluation comprising partial budget analysis with dominance and marginal analysis was carried out. Grain yield was valued based on average market price collected from the local markets during two consecutive years of production; for estimation of economic parameters. The average cost of urea, NPS, NPSB, NPSZn, TSP, Borax and KCl were 14.62, 13.99, 15.32, 15.32, 15.85, 700 and 15.46 Ethiopian birr (ETB) per kilogram respectively. A wage rate of 50 birr a man per day and sorghum grain value of 10 birr per kilogram was considered. The dominance analysis procedure, which was used to select potentially profitable treatments, was carried out by first listing the treatments in order of increasing costs that vary. When the net benefit of preceding treatments found to be higher than net benefit of subsequent treatment, it is considered as dominated (D). The selected treatments by using this technique were referred to as un-dominated (Non-dominated) treatments. For each pair of ranked un-dominated treatments, a percentage marginal rate of return (% MRR) was calculated. The %MRR between any pair of un-dominated treatments denoted the return per unit of investment in crop management practices which expressed as percentage. Marginal rate of return (MRR) was calculated as the ratio of differences between net benefits of successive treatments to the difference between total variable costs of successive treatments. For a treatment to be considered as a worthwhile option to farmers, the MRR needed to be in between 50% and 100% [17]. Thus, the minimum acceptable rate of return for this study was considered to be 100%. Some of the concepts used in the partial budget analysis were gross field benefit (GFB), total variable cost (TVC) and the net benefit (NB);

Gross margin (ETBha^{-1}) = Total revenue (ETB ha^{-1}) – Total Variable Cost (ETB ha^{-1})

NR = GM – TFC; Where NR = Net Return (ETB ha^{-1}) and TFC = Total Fixed Cost (ETB ha^{-1})

TCP = TVC + TFC; Where TCP = Total Cost of Production

Benefit-cost ratio = NR / TCP [17].

RESULT AND DISCUSSION

Soil analysis

Analysis of soil samples before planting was done for the major physical and chemical properties at soil laboratory of Areka agricultural Research Centre. The soil of the experimental site has a proportion of 72% sand, 10% silt and 18% clay (table 2); and it was classified as sandy loam according to the soil triangle texturally.

The organic carbon of the soil was done by Walkely Blacky methods [18] and its value was 0.858%, which was rated as low, [19]. The pH of the experimental site (1:2.5 ration of soil to water suspension) was 5.5, which was implied that the soil of study site was moderately acidic according to [19].

The result of soil analysis indicated that the soil has total nitrogen of 0.074% by Keljdal digestion and distillation followed by titration method; which implied that the soil of experimental site has low level of total nitrogen according to [19-21]. The experimental soil has available Phosphorus of 11.774ppm analysed by Olsen methods which was effective for both alkaline and acidic soil and extracted by 1M $NaHCO_3$, which was medium level according to [22, 23]. The soil analysis result showed that the soil has available potassium of 109.959ppm by using 1N Ammonium acetate solution at pH 7, which implied that the soil has low level of potassium [24].

The soil of experimental site was 0.295ppm of available boron done by dilute HCl methods which was most effective and efficient than that of hot water method and most applicable for acidic, neutral and alkaline soil and more economical than that of hot water methods (only for alkaline soil), which was categorized under low level according to [25] and 8.772ppm of sulphur exist in soil in sulfate (SO_4^{2-}-2) form and which was done by turbidymetric methods of analysis (acidic and non-calcareous soil) and its extractant was calcium chloride dehydrate as sulphate, which showed that the soil has medium level of sulphur as sulfate [26].

Table 2: Some physical and chemical properties of the soil before the experiment

Soil Properties	Composition
Sand (%)	72
Silt (%)	10
Clay (%)	18
Textural class	Sandy loam
pH(H_2O) (1:2.5)	5.5
OC (%)	0.858
TN (%)	0.074
Available P (ppm)	11.774
B (ppm)	0.295
S (ppm) as SO_4	8.772
Available K (ppm)	109.959

Table 3: Growth, yield and yield components of sorghum as influenced by blended fertilizer type

Treatment	PH (cm)	No. till/pl	Pcl L (cm)	Biomass ($kgha^{-1}$)	Yield ($kgha^{-1}$)	TKW (gm)
Control	207.96^{b}	2.4^{b}	20.88^{d}	27718^{b}	3310.3^{b}	26.96^{b}
Recommended NP	220.58^{ab}	2.87^{ab}	21.79^{cd}	42576^{a}	4791.7^{a}	27.36^{ab}
142 $kgha^{-1}$NPS+141 $kgha^{-1}$Urea	209.32^{ab}	2.6^{ab}	22.93^{abc}	45039^{a}	4915.6^{a}	27.44^{ab}
150 $kgha^{-1}$NPSB+141 $kgha^{-1}$Urea	208.09^{b}	2.4^{b}	23.12^{ab}	49649^{a}	5895.8^{a}	27.63^{ab}
197 $kgha^{-1}$ NPKSB+141$kgha^{-1}$Urea	224.53^{a}	2.87^{ab}	22.18^{bc}	45135^{a}	5074.2^{a}	27.06^{b}
160 $kgha^{-1}$NPSZnB+144 $kgha^{-1}$Urea	216.93^{ab}	3.07^{a}	22.39^{abc}	42802^{a}	5159^{a}	28.87^{a}
155 $kgha^{-1}$ NPSZn+141 $kgha^{-1}$Urea	210.16^{ab}	2.8^{ab}	21.76^{cd}	44017^{a}	4924.2^{a}	27.66^{ab}
207 $kgha^{-1}$NPKSZnB+141 $kgha^{-1}$Urea	216.19^{ab}	2.33^{b}	23.49^{a}	48784^{a}	5570.1^{a}	26.67^{b}
$LSD_{(0.05)}$	15.85	0.58	1.23	10646	1172.3	1.71
CV (%)	4.22	12.51	3.15	14.07	13.51	3.55

Means with the same letter shows statistically not significant different. PH (cm): Plant Height in cm, Pcl L (cm): Panicle Length in cm, TKW: Thousands Kernel Weight in gram and No. till/pl: number of tillers per plant

The result was revealed that plant height, number of tiller per plant, panicle length, above ground biomass, grain yield and thousand seed weight of sorghum were influenced by different blended fertilizer type. Growth, yield and yield traits of sorghum were influenced by varied type of blended fertilizer.

Plant height

The highest plant height of 224.53cm was recorded from treatment which receives 197$kgha^{-1}$ NPKSB+141$kgha^{-1}$Urea, but this was in statistical parity with rest treatments except control treatment and treatment that receives 150$kgha^{-1}$NPSB+141$kgha^{-1}$Urea, while the lowest plant height of 207.96cm and 208.09cm was measured from the control treatment and treatment that receives 150$kgha^{-1}$NPSB+141kg ha^{-1}Urea respectively, but these were in statistical parity with rest treatments except treatment that receives 197$kgha^{-1}$NPKSB+141$kgha^{-1}$Urea (table 3). This was in line of agreement with the rate of nitrogen application increased plant heights was also increased, which showed that with increase in rate of nitrogen from 0 to 92 kg N ha^{-1}, plant height increased by 6.49% [27]. Similarly, reported that plant height increases with increment of fertilizer application from nil to blended fertilizer type including NPSZn [13]; furthermore, [15] reported that application of NPKSZn gives the highest plant height over the absolute control treatment. In addition to this, it can be suggested the application of optimum fertilizer nutrients increased the plant growth and biomass and the increased amounts of nutrient increases the production of sorghum [28].

Number of tiller per plant

The highest number of tiller per plant was recorded from treatment that receives 160$kgha^{-1}$ NPSZnB+144$kgha^{-1}$Urea which was in statistical parity with treatment two, treatment three, treatment five and treatment seven, whereas the lowest of 2.33 was measured from treatment that receives 207$kgha^{-1}$NPKSZnB+141$kgha^{-1}$Urea which was in statistical parity with treatment one, four and eight (table 3). The result of this study was in agree with the finding that increased plant growth with optimal nutrient application provides good vegetative cover which resulted in high grain yield of sorghum plant [29].

Panicle length

The longest panicle length of 23.49cm was recorded from treatment that receives 207$kgha^{-1}$ NPKSZnB+141 $kgha^{-1}$Urea, but this was in statistical parity with treatment three, treatment four and treatment six; while the lowest panicle length of 20.88cm was recorded from the control treatment and was in statistical parity with treatment two and treatment seven (table

3). The result was in conformity with the finding reported that tallest panicle length was recorded from the plot treated by NPKSZn fertilizer and the shortest panicle length was recorded from the control [15]. The current result was agree with increasing trend in blended fertilizer and amended with N and P in case of (NPSZn) fertilizer shows a corresponding increment of panicle length as compared with the nil fertilizers [13]. The current finding was disagree with finding reported that panicle length of sorghum did not give significantly different response under fertilized and unfertilized conditions [30].

Biomass

Biomass yield is an important output as farmers are also interested in it for animal feed in addition to grain yield. The highest above ground biomass (49649kgha^{-1}) was recorded from the treatment that receives 150kgha^{-1}NPSB+141kgha^{-1}Urea; but this was in statistical parity with rest treatments except the control treatment, whereas the lowest above ground biomass (27718 kgha^{-1}) was measured from control treatment (table 3). The result was in line of agreement with the finding reported that the highest biomass yield was obtained from the application of blended fertilizer amended with NPSZn which was statistically at par with the application of blended fertilizer NPKSZn; In contrary, the lowest dry above ground biomass of was obtained from the nil fertilizer plots [13]. Similarly, finding reported as application of high nitrogen level results in high amount of biomass yield in sorghum [30]. The current finding was agree with the report plots treated by NPK fertilizer gives highest biomass yield over the control plot as the lowest biomass yield was obtained [15].

Grain yield

The highest grain yield of 5895.8kgha^{-1} was recorded from the treatment that receives 150kgha^{-1} NPSB+141kgha^{-1}Urea; but this was in statistical parity with rest treatments except the control treatment, whereas the lowest grain yield (3310.3 kgha^{-1}) was measured from control treatment (table 3). The current finding was agree with the plots treated by NPKSZn fertilizer gives highest grain yield and the lowest grain yield of sorghum was recorded from control, and showed that NPKSZn increased sorghum grain yield by 136.5%.over the control [15]. Similarly, [13] reported that the maximum grain yield was obtained from the fertilizer types blended NPSZn, while the lowest yield was obtained in unfertilized plots. Additionally, the finding reported that increasing application of fertilizer nutrients such as N, P and K increases the grain yield and biomass weight of sorghum significantly [29]. The present result was agree with total nutrient uptake and fertilizer use efficiency in sorghum variety treated by fertilizer containing primary macronutrients with micronutrients brought significantly higher yield [15]. Additionally, the result was agreed with the finding reported as sorghum yield increase with increase in the rate of nitrogen application till to the optimum rate [27].

Thousand kernel weight

The highest thousand kernel weight (28.87g) was recorded from treatment that receives 160 kgha^{-1}NPSZnB+144 kgha^{-1}Urea, but this was in statistical parity with treatment two, three, four and seven; while the lowest thousand kernel weight (26.67g) was measured from treatment that receives 207 kgha^{-1} NPKSZnB+141 kgha^{-1} Urea, but this was in statistical parity with the rest treatment except treatment six. The present result was in conformity with the finding reported as the highest and the lowest average thousands kernel weight were obtained with application of blended fertilizer amended with N and P, and control respectively, however, there was no significance difference between the recommended DAP and urea, blended fertilizers NPS and blended fertilizer NPKSZn [13]. The present finding was in line of agreement with report application of nitrogen was significantly affects thousand kernel weight of sorghum [27]. Similarly, [15] reported that application of NPS fertilizer gives highest thousand seed weight, while application of nitrogen only gives lowest thousand seed weight and also control.

Economic analysis

Table 4: Partial budget analysis of blended fertilizer type effect experiment on sorghum production

Treatments	Variables				
	Average Yield kgha^{-1}	**10%Adjusted Yield kgha^{-1}**	**Total Return (ETBha^{-1})**	**Total variable cost (TVC) (ETBha^{-1})**	**Net benefit (ETBha^{-1})**
Control (No Fertilizer)	3310.3	2979.27	29792.7	0	29792.7
Recommended NP	4791.7	4312.53	43125.3	6329.89	36795.41
142kgha^{-1}NPS+141kgha^{-1}Urea	4915.6	4424.04	44240.4	9028.29	35212.11
150kgha^{-1}NPSB+141kgha^{-1}Urea	5895.8	5306.22	53062.2	9340.48	43721.72
197kgha^{-1}NPKSB+141kgha^{-1}Urea	5074.2	4566.78	45667.8	10356.92	35310.88
160kgha^{-1}NPSZnB+141kgha^{-1}Urea	5159	4643.1	46431	16288.29	30142.71
155kgha^{-1}NPSZn+141kgha^{-1}Urea	4924.2	4431.78	44317.8	9417.08	34900.72
207kgha^{-1}NPKSZNB+141kgha^{-1}Urea	5570.1	5013.09	50130.9	13836.98	36293.92

10%Adj. Yield= Marketable Yield Adjusted to 10% downward; ETB= Ethiopian Birr

Partial budget analysis of blended fertilizer type effect on sorghum production experiment in Bena Tsemay Woreda was revealed that the highest net return (43721.72 ETBha^{-1}) was obtained in response to application of 150 kgha^{-1} NPSB + 141 kgha^{-1} Urea which showed 31.86% higher return over the nil one (29792.7 ETBha^{-1}); followed by treatment with recommended NP of net return 36795.41 ETBha^{-1}. The lowest net return (29792.7 ETBha^{-1}) was obtained from unfertilized treatment (nil treatment) (table 4).

Dominance and Marginal (MRR) analysis

Table 5: Dominance and marginal analysis, sorghum yield improvement by blended fertilizer type experiment

Treatments	Variables				
	10% Adjusted Yield $kgha^{-1}$	**TVC ($ETBha^{-1}$)**	**Net Benefit ($ETBha^{-1}$)**	**Dominance Analysis**	**MRR (%)**
Control (No Fertilizer)	2979.27	0	29792.7	-	-
Recommended NP	4312.53	6329.89	36795.41	ND	110.63
$142kgha^{-1}$NPS+141 $kgha^{-1}$Urea	4424.04	9028.29	35212.11	D	-
$150kgha^{-1}$NPSB+$141kgha^{-1}$Urea	5306.22	9340.48	43721.72	ND	230.06
$155kgha^{-1}$NPSZn+$141kgha^{-1}$Urea	4566.78	9417.08	34900.72	D	-
$197kgha^{-1}$NPKSB+$141kgha^{-1}$Urea	4643.1	10356.92	35310.88	D	-
$207kgha^{-1}$NPKSZNB+$141kgha^{-1}$Urea	4431.78	13836.98	36293.92	D	-
$160kgha^{-1}$NPSZnB+$141kgha^{-1}$Urea	5013.09	16288.29	30142.71	D	-

Treatments which carries D = Dominated and ND= Non dominated

Dominance analysis of the result was revealed that among the treatments only Recommended NP and 150 kg ha^{-1} NPSB + 141 kg ha^{-1} Urea were un-dominated. This indicated that increase in the total cost of Recommended NP and 150 kg ha^{-1} NPSB + 141 kg ha^{-1} Urea treatments increases the net benefit proportionally; which means benefits were greater than the lower total costs. Treatments were arranged in increasing order of total variable cost recorded for marginal analysis. Recommended NP treatment with MRR of 110.63% and 150 kg ha^{-1} NPSB + 141 kg ha^{-1} Urea treatment with MRR of 230.06% both accepted according to [17] as the minimum acceptable required rate of return which is in between 50% and 100%. However, the highest marginal rate of return (230.06%) was recorded in response to application of 150 kg ha^{-1} NPSB + 141 kg ha^{-1} Urea (table 5).

CONCLUSION AND RECOMMENDATION

The experiment was carried out to evaluate the effect of different blended fertilizer type on improving production of sorghum in Bena Tsemay district, Southwestern Ethiopia. This is because of the low productivity of sorghum in the study area specifically and in region as compared to the crop potential and national average yield; due to depleting soil fertility, inappropriate and imbalanced application of fertilizers including blended fertilizer (which are among main constraints of sorghum production). The result has revealed that sorghum responded well to the application of N, P, K, S, B and Zn than the unfertilized one. Application of $150kgha^{-1}$NPSB+$141kgha^{-1}$Urea resulted in highest grain yield of sorghum, while the lowest grain yield was recorded from the nil. Additionally, the highest net benefit of 43721.72$ETBha^{-1}$ and economic returns/marginal rate of return of 230.06% was obtained in response to application of $150kgha^{-1}$NPSB+$141kgha^{-1}$Urea. Application of $150kgha^{-1}$NPSB+$141kgha^{-1}$Urea gave 43.85% yield increment and 31.86% increment in economic return over the control. Therefore, we recommend application of $150kgha^{-1}$NPSB+$141kgha^{-1}$Urea (92N, 54 P_2O_5, 10.05 S and 1.06B) for farmers and investor's to produce sorghum on the study area and similar agro ecologies, as it was optimum for improving sorghum production. Further studies and investigation should be done on plant nutrient uptake, nutrient use efficiency and optimization.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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