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Effect of NPSB blended fertilizer on yield and yield components of bread wheat (*Triticum aestivum* L.) at rain fed condition on Tsegede district, western Tigray, Ethiopia

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ABSTRACT

Wheat is major grain crops grown in Tsegede district in western Tigray Region for house consumption. However, its productivity is low in general and in the study area in particular due to limited knowledge of balanced or blended fertilizer application rate and low availability of soil nutrients. Since the study was conducted on acidic soils of Tsegede in 2018 to 2019 during the main cropping season to determine economically feasible rate of blended NPSB for better production of wheat. The treatments consisted of seven levels of blended NPSB (0, 50, 100, and 150 kg NPSB ha^{-1}) and with recommended NP fertilizers. The experiment was laid out in a randomized complete block design in a factorial arrangement and replicated three times per treatment having a total of 24 plots. The soil analysis result indicated that, most of the nutrients are below optimum level to support the potential crop production. This may be the effect of low soil pH, which is dominantly leaching of the basic cation exchange capacity of soils. The analysis of variance the experiment indicated that plant height, above ground biomass, grain yield and harvest index were significantly ($p<0.05$) influenced by applied NPSB and recommended NP fertilizers. The highest (74.6cm) plant height was recorded by application of 250 kg of NPSB ha^{-1} and followed (74.2 cm) by 300 kg of NPSB ha^{-1}. On the other hand, the maximum (4564kgha^{-1}) biomass yield, grain yield (2014 kgha^{-1}) and harvest index (44.8%) were recorded in the parameters by application of 250 kg NPSB ha^{-1}. However, spike length, numbers of tillers per plant and numbers of seeds per panicle were not significantly ($p<0.05$) influenced by applied NPSB and recommended NP fertilizers. The partial budget analysis results revealed that the application of 250 kg NPSB ha^{-1}+100 kg Urea ha^{-1} gave b better net benefit and marginal rate of return in the study area. Therefore, application of NPSB at the rate of 250 kg NPSB ha^{-1}+100 kg Urea ha^{-1} was best opportunity to use in the production of bread wheat and economic advantages for the experimental area of wheat production.

Keywords: Nitrogen; Phosphorus; Sulfur; Boron; Blended; NPSB; Bread wheat; Partial budget analysis; Yield.

1. Introduction

Wheat is an important main cereal crop all over the world [1]. It is one of the most important cereals especially for house consumption in Ethiopia [2]. In Ethiopia, approximately 5 million Ethiopian farmers cultivate 1.8 million hectares of land and produce 5.3 million tons of wheat each year [3]. Wheat is one of the major cereal crops in the Ethiopian highlands and is widely grown at an altitude range of 1500 to 3000 meters above sea level [4]. In terms of caloric consumption, it is the greatest important food in the country next to maize and Teff [5]. Wheat is one of the most important cereals cultivated in highlands of Tsegede district and high ranks in area coverage and total production. However, the national yield of wheat is very low as compared to the global average yield mainly due to low soil fertility management, lack of using balanced fertilizer and lack of using improved wheat varieties [6] and due to low soil pH. Thus, addition of nutrients such N, P, S and B to less fertile soil is important to increase wheat yield and yield components of wheat for house consumption or industrial purpose. There are several factors that hindered wheat production in these areas such as low soil fertility and lack of improved management practices, which is resulted an insufficient supply of mineral elements may limit plant growth and development [7]. Balanced fertilization and management of other biotic and abiotic factors are very important for higher productivity of wheat [8]. For many years, Ethiopian agriculture depended exclusively on imported fertilizer products; only urea and Di-ammonium phosphate (DAP), as sources of N and P, respectively. However, recently it is observed that the production of such high protein cereals like wheat can be limited by the deficiency of S and other micronutrients like B, Zn As well as Cu [9]. Then shifting from blanket recommendations for fertilizer application rates to recommendations that are adapted based on soil type and crop in Ethiopia [9]. Recent studies have indicated that elements like N, P, K, S and Zn levels as well as B and Cu are becoming depleted and deficiency symptoms are being observed on major crops in different areas of the country including the district of Tsegede [10]. Micronutrients are essential for plant growth and play a vital role in increasing crop yields as they develop plant nutrition and increase soil efficiency [11]. Except blanket recommendation of nitrogen and phosphorus, the effect of other fertilizers on yield components of bread wheat is unknown in the study areas, even though new blended fertilizers such as NPSB are currently available. Moreover, the response of wheat plant to application of fertilizer varies with rainfall, soils, agronomic practices, predictable yield. Thus, there is as well as rate of balanced fertilizer on wheat. However, no information is presented on response of NPSB blended fertilizer in situation of study area. Then detailed study on Effect of NPSB blended fertilizer on yield and yield components of bread wheat at specific study area in Tsegede is necessary.

1.1. Study Objectives

Therefore, this study was undertaken the research field with the following objectives:

(i) To assess the effect of rates of blended NPSB on yield and yield components of bread wheat, and

(ii) To estimate economically feasible rates of blended NPSB for bread wheat production.

2. Materials and Method

2.1. Description of the Study Site

The experiment was conducted on farm field in 2018 and 2019 cropping seasons under rain fed conditions at Tsegede district, on the site of Humera agricultural research center. The site of the experiment is located at latitude of 13°18' 40"- 13°22' 0" N, longitude of 37°16'0" to 37°30'0" E (Figure 1) and at an altitude of 2520 meters above sea level in Western Zone of Tigray Region.

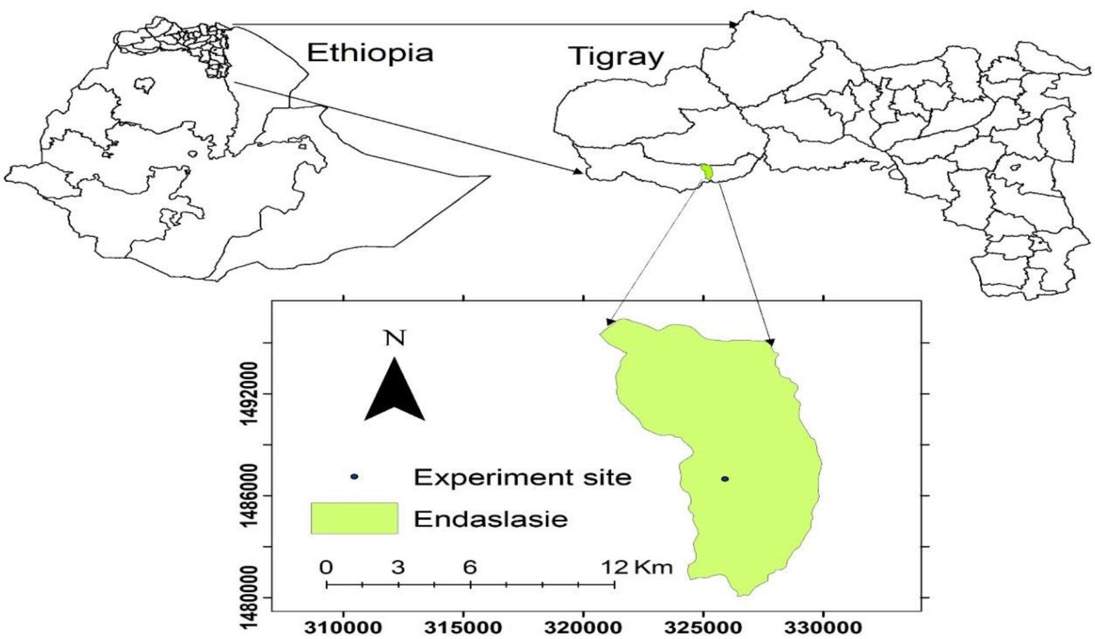

Figure 1. Map of study area

The climatic condition of the area is a humid moist condition highland, and it receives about 2,320 mm of rainfall per year with mean annual temperature of 15°C [12]. The major soil type of the study area is Dystric-Cambisol. The study area was known by production of cereal crops such as Wheat, Barley, Teff, and Sorghum. Blended NPSB (18.9% N, 37.7% P2O5, 6.95% S and 0.1% B), and urea were used as fertilizer sources.

Nitrogen fertilizer obtained from urea (46% N) was applied uniformly to the all treatments except for the control treatment. Fertilizer rate formulated by four blended fertilizer rates including kg ha^{-1} (Control, Recommended NP, 50NPSB+100Urea, 100NPSB+100Urea, 150NPSB+100Urea, 200NPSB+100Urea, 250NPSB+ 100Urea and 300NPSB+100Urea) of Eight (8) treatments. The experiment was laid out in randomized complete block design (RCBD) with three replications. The size of each experimental plot was 2.5 m x 3m (7.5 m^2). The space between blocks and plots were separated by 1m apart from each other. The outermost two rows from each side of a plot and 0.2 m on both ends of each row considered as border and were not included for recording the data. Thus, the net plot size was 2.3m x2.8 m (6.44 m^2).

2.2. Experimental Procedure, Management and Data Collection

The experimental field was ploughed by oxen three times and prepared before planting, a field layout was made, and each treatment was assigned randomly to the experimental plots within a block. The whole amount of NPSB blended fertilizers were applied at sowing time whereas, urea was applied in two splits (half at planting and the remaining half at knee height). The entire blended NPSB fertilizer was applied as per the treatments at a full dose at sowing, whereas N was applied in two splits (½ at sowing and ½ at tillering about 30 days after sowing) in the form of urea (46% N). Weeding and all necessary agronomic managements as per the recommendation practice will be undertaken. A soil sample was collected in which 1 Kg composite soil sample from each location for reprehensive of all experimental plots before planting. Collected soil samples were air-dried at room temperature, grounded using mortar and pistil, and passed through a 2 mm diameter sieve for the analyses of selected physic-chemical soil properties using conventional laboratory methods. However, a 0.5 mm sieve was used for analysis of organic carbon (OC). The bulk density of undisturbed soil sample was determined by core method [13]. The Bouyoucos hydrometer method was used for the determination of soil particle size (soil texture) [14]. Soil pH-H_2O was measured using a pH meter equipped with combined glass electrode [15] and Organic carbon (OC) was determined by the wet acid dichromate digestion method [16]. Available P was determined using the Bray II method of extraction [17] using ascorbic acid as a reductant in the presence of antimony and determined spectrophotometric ally. The cation exchange capacity (CEC) was determined by replacing exchangeable cations with ammonium acetate (NH_4OAc) 1 M leaching at pH 7, removal of excess sodium (Na) by alcohol, and determining Na and K concentration by flame photometry [18] and Ca2+ and Mg2+ in the filtrates were determined by Versenate titration (DTPA) (Page, et. al., 1982). Exchangeable acidity was determined by saturating soil samples with potassium chloride solution and titrating with sodium hydroxide as described by [19].

Plant height: Ten plants were randomly selected and tagged from the net plots area of each experimental unit. Then the height was measured from the selected plant from the ground to the tips of spike using of ruler and the mean value was determined in respective to each plot.

Spike length: determined by taking ten effective tillers randomly from each plot at the time harvesting and can be measured from the bottom of spike to the tip of the panicle. Then, the mean value was determined for each plot experimental unit from the recorded data in centimeter.

Number of tillers per plant: number of tillers per plant was measured by taking of ten plant samples randomly from each plot at full tillering stage of crops by counting the total number of tillers and then the mean value was determined.

Number of productive tillers: number of productive tillers was determined by counting all spikes, which can bear kernels from the ten plant samples randomly selected at full tillering of the crop, and the mean value was calculated from the recorded value.

Dry biomass: was measured from the plant parts (stems, leaves and grain seeds) harvested from the net plot area for each treatment after sun drying for about 3 to 4 days and it's expressed in tons per hectare (tons/ha).

Grain yield: was determined for each treatment by harvesting and threshing of crops separately from the net plot area and then weighted by electronic balance. Then the grain yield was expressed by adjusting of it is to 12.5% of moisture content as:

Harvest index: was computed as the ratio of adjusted grain yield to total above ground dry biomass yield for each treatment in experimental plot and finally expressed in percent as: HI (%) = (Grain yield/Above ground dry biomass) *100.

2.3. Data Analysis and Economic Analysis

The collected data were subjected to analysis of variance "(ANOVA) using R Software version R-3.6.2. Means were separated using the p-value test at 5% level of significance. The partial budget analysis was done as described by [20]. In this experiment, the costs that vary were calculated by adding costs of fertilizer and labor for fertilizer application. However, other management and fixed costs were assumed equal for all and not included in the calculation. The costs of blended NPSB and recommended NP were 1600 birr and 1500 birr, respectively. Price of grain was 30 birr/kg and the straw was 3.3birr/kg. The average GY and SY were adjusted by 10%. Following the CIMMYT partial budget analysis methodology, total variable costs (TVC), gross benefits (GB), and net benefits (NB) were calculated. To identify treatments with maximum return to the farmer's investment marginal analysis was performed on non-dominated treatments. For a treatment to be considered as a worthwhile option to farmers, the marginal rate of return (MRR) needs to be at least between 50% and 100% [20]. However, other researchers suggested a MRR of 100% as realistic [21] Marginal rate of return (MRR) (percentage) was calculated by dividing change in net benefit by change in total variable cost.

3. Results and Discussion

3.1. Physico-Chemical Properties of the Experimental Soil before Planting

Laboratory analysis result of selected soil Physico-chemical properties before planting was indicated in table 1 below. The textures of the soils in experimental sites were relatively high in sand, but moderate in silt and clay content and the soil textural class of experimental site were found to be clay loam according to [14] (31% clay, 33%

silt and 36% sand). The soil texture or the proportions of sand silt and clay in the soil indicates the degree of weathering, aeration, nutrient and water holding capacity of the soil. The pH of the soil was 5.51 which categorized as strongly acidic [22]. This value falls in the pH range of low pH (strong acid) could be due to the high rainfall distribution in the study area that increased leaching of the basic cations from the soil surface. Similarly, many studies in different parts of Ethiopia reported very low pH for acid soils [23]. The organic carbon% and total nitrogen content% of the soil were 2.88% and 0.19% respectively. According to [24] organic carbon% and total nitrogen content % of the soil was medium/moderate. The available P content soil was 4.73m kg^{-1} which is very low because of the domination of the Al and Feoxides [25]. The cation exchange capacity of 8.8Cmolc kg^{-1} and rated as low according to [26] and this is leaching and running of the basic cations from surface of top soils [27].

Table 1. Soil physicochemical properties of the experimental site before sowing

Properties	**Values**	**Rating**	**Sources**
Clay (%)	31		14
Silt (%)	33		
Sand (%)	36		
Textural class	Clay loam		
pH: H_2O	5.51	Strongly acidic	27
Organic Carbon (%)	2.88	Medium	24
Organic Matter (%)	4.95	Medium	24
Total nitrogen (%)	0.19	Medium	24
Available P ($mgkg^{-1}$)	4.73	Low	16
Bulk density (gcm^3)	0.29		
Exchangeable-Al (Cmolc kg^{-1})	0.48		
Exchangeable acidity (Cmolc kg^{-1})	4		
CEC (Cmolc kg^{-1})	8.8	Low	26

3.2. Effect of NPSB blended fertilizer rate on Yield and Yield Components

3.2.1. Plant height, Spike length, Numbers of tillers per plant and Numbers of seeds per panicle

The mean yield and yield component of wheat results are depicted in (Table 2). The result of analysis of variance indicated that application of blended fertilizer rates were significantly ($P<0.05$) influenced the mean plant height of the bread wheat. The results showed that the tallest mean plant height was obtained by application of 250 kg of NPSB (74.6 cm) which was statistical at similarity with application of 50 kg NPSB (69cm), 100 kg NPSB (67.9cm), 200 kg NPSB (71.9cm), 300 kg NPSB (74.4) and with application of blanket (68.8cm), while the shortest mean plant height was recorded from (54.4 cm) unfertilized plot which followed by 150 kg NPSB (65.5cm). The results of this study depicted that, spike length was significantly ($p \leq 0.05$) not affected by the application of blended fertilizer rates. As a result, increasing plant height at the highest level of NPSB fertilizer could be attributed to a rising supply of nitrogen, phosphorus, and sulphur nutrients, which aided in high vegetative growth and development of the plant. This finding is consistent with the findings of [28], who found that increasing blended fertilizer rates increased wheat plant height. The results showed that the highest mean value for spike length was recorded from the plot treated with 250 kg NPSB ha^{-1} (7.2cm) but statistical at par with plots applying blended NPSB fertilizers rest other blended fertilizer rates except unfertilized plot (control). The lowest spike length (5.5cm) obtained from the control treatment that was not fertilized; and this could be due to low levels of fertilizer nutrients in the area.

The result of the analysis of number of branches per plant of Wheat as affected by blended fertilizer rates showed that did not significantly ($p<0.05$) affect by the interaction of the applied blended fertilizer. The result indicated that maximum (3.8) number of branches per plant was recorded from the application of 300kg NPSB, which was statistically similar with other treatments and the minimum (3.0), was obtained from the untreated plot. The application of different rates of NPSB fertilizers had not a significant impact on numbers of seeds per panicle. In comparison to the control, the different fertilizer of NPSB and application the blanket recommendation kinds generate a considerable had not difference in numbers of seeds per panicle. As the result showed that, highest numbers of seeds (38cm) were obtained when application of 300kg of NPSB fertilizer and the highest number of seeds [30] recorded from the control.

Table 2. Effect of Fertilizer Rate on plant height (cm), Spike length (cm), numbers of tillers per plant, numbers of seeds per panicle, above Ground Biomass ($Kgha^{-1}$), Grain Yield ($Kgha^{-1}$) and Harvest index (%)

Treatment	**PH(cm)**	**PL(cm)**	**NTP**	**NSP**	**BM($Kgha^{-1}$)**	**GY($Kgha^{-1}$)**	**HI(%)**
Control (0)	54.4^{e}	5.5^{de}	3.0^{bcde}	29.6^{b}	1345^{f}	406.3^{f}	39.6^{ab}
Rec.NP(46kgN+46kg P_2O_5)	68.8^{abc}	7.0^{ab}	3.5^{abc}	31.2^{ab}	3442^{abcd}	1456^{abcd}	40.0^{ab}
50NPSB+46kg P_2O_5	69.0^{abc}	6.7^{abc}	3.4^{abcd}	32.6^{ab}	3340^{bcde}	1308^{bcde}	36.2^{abc}
100NPSB+46kg P_2O_5	67.9^{abc}	6.8^{abc}	3.4^{abc}	33.4^{ab}	3697^{ab}	1368^{bcd}	32^{bc}
150NPSB+46kg P_2O_5	65.5^{bcd}	6.8^{abc}	3.5^{ab}	32.7^{ab}	3622^{abc}	1439^{bcd}	40.4^{ab}
200NPSB+46kg P_2O_5	71.9^{a}	7.1^{ab}	3.8^{a}	36.3^{ab}	4089^{a}	1735^{abc}	40.4^{ab}
250NPSB+46kg P_2O_5	74.6^{a}	7.2^{a}	3.7^{ab}	38.5^{a}	4573^{a}	2014^{a}	44.8^{a}
300NPSB+46kg P_2O_5	74.2^{a}	6.9ab	3.8^{a}	37.6^{a}	4564^{a}	1936^{ab}	39.6^{ab}
Mean	68.28	6.7	3.48	34.0	3584.08	1457.89	39.1
P -value	0.002	0.19	0.45	0.61	0.007	0.02794	0.6

PH= plant height, PL=Spike length, NTP= numbers of tillers per plant, NSP= numbers of seeds per panicle, BM= above Ground Biomass, GY= Grain Yield and HI= Harvest index.

3.2.2. Above Ground Biomass, Grain Yield and Harvest index

Application of NPSB fertilizer was significantly ($P<0.05$) influenced grain weight, biomass yield and harvest index of Wheat as compared to the previous blanket recommended NP fertilizer and none fertilizer plots applied in the field experiment. The grain yield obtained from applying fertilizer at 300 kg NPSB (1936 kg), 250 kg NPSB (2014 kg) and 200 kg NPSB (1735kg) fertilizer rates applications was statistically non-significant from each other but there was significant difference from the recommended NP (1456 kg), 50 kg NPSB (1308), 100 kg NPSB (1368), 150 kg NPSB (1439kg) and control (406.3kg). Similarly, [29] reported that application of nutrients like K, S, Zn, Mg and B significantly increased grain yield and yield component of Bread wheat as compare to the no fertilized plot (control). The full yield has 79.8% yield increment over control and 27.3% over the blanket recommendation of NP fertilizer. The minimum result obtained from (406.3 kgha^{-1}) from the control treatment. [30] reported that wheat grain yield increases with NPSB. This result also agrees with [31] who reported that 4207 kgha^{-1} was achieved with 250 kg NPSB and recommended urea.

The highest grain yield (2803kg ha^{-1}) weighed down the national average yield (1664 kg ha^{-1}) [32]. This could be due to the combined effect of nutrients like N, P, S and B in blended fertilizer, which might have enhanced growth and development of crop, compared to the rest of the treatments.

The maximum above ground biomass (4573kgha^{-1}) was reached by applying 250kg of NPSB ha^{-1}, although there is no statistical difference compared to other treatments except 50kg of NPSB ha^{-1} and control. The minimum result obtained from the control treatment. This result is similarity agreed with [30] compound fertilizer application had a significant impact on aboveground biomass, grain yield and straw yield. In addition, [33] found that significantly higher biomass yield was obtained with the application of 250 kg NPSB ha^{-1} on and the lowest biomass yield was obtained from without application of external fertilizer. This might be due to increase in number of tillers per plant, increase length of leaves and due to increase in vegetative growth of the plants. The application of treatments using 250 kg ha^{-1} NPSB produced the highest harvest index (44.8%), though no significant effect with other treatments (Table 2) whereas the treatment using 100 kg ha^{-1} NPSB produced the lowest harvest index (32%).

3.3. Effects of Blended NPSB Fertilizer Rates on Economic Feasibility of Wheat Production

The most important step in performing partial budget analysis is the proper identification of data on the costs and benefits associated with the alternative technologies. In this study the biological yield is considered as main factor to evaluate or to estimate economic feasibility. The maximum net benefit of ETB 51069 ha^{-1} with marginal rate of return 849 % and value to cost ratio ETB 12.8 per unit of investment of bread wheat was obtained with application of 250 kg blended NPSB ha-^{1} with urea whereas the lowest net benefit ETB 11224 ha^{-1} was obtained from unfertilized plot (control) (Table 3). The second and the third net benefit ETB 44281 and 38348 with marginal rate of return 905 and 469% and with value to cost ratio 13.8 and 25.7 per unit of investment of bread wheat production respectively was obtained by application of 200 kg NPSB and recommended NP respectively. Based on the [CPT, 1988] suggestion, the minimum acceptable marginal rate of return should be more than 100%. In line with this result, [34] reported that “application of 250 NPSB ha^{-1} gave higher net return of ETB 54068 ha^{-1} with marginal rate of return 395and value to cost ratio of 7.58 EB followed by application of 250/100 and 150/100 kg urea/NPSB ha. [35] also reported that N application at 69 kg ha^{-1} is effective in attaining higher grain yield and economic benefit of wheat in southern part of Ethiopia. Therefore, application of 250 kg NPSB provided relatively economical and recommended for production of Bread wheat in the study area and other areas with similar agro ecological condition.

Table 3. Effects blended NPSB fertilizer rates on economic feasibility of wheat production

NPSB Levels (Kgha-^{1})	GY	BY	SY	AGY	ASY	Income (ETB)		GFB	TVC	NB	MRR%
						GY	SY	(ETBha$^{-1)}$	(ETBha^{-1})	(ETBha^{-1})	
0	406.3	1345	938.7	365.67	844.83	10970	253	11224	0	11224	0
50 NPSB	1308	3340	2032	1177.2	1828.8	35316	549	35865	800	35065	2980
Urea& DAP	1456	3442	1986	1310.4	1787.4	39312	536	39848	1500	38348	469
100 NPSB	1368	3697	2329	1231.2	2096.1	36936	629	37565	1600	35965	D
150 NPSB	1439	3622	2183	1295.1	1964.7	38853	589	39442	2400	37042	135
200 NPSB	1735	4089	2354	1561.5	2118.6	46845	636	47481	3200	44281	905
250 NPSB	2014	4573	2559	1812.6	2303.1	54378	691	55069	4000	51069	849
300 NPSB	1936	4564	2628	1742.4	2365.2	52272	710	52982	4800	48182	D

GY=grain yield (Kgha^{1}), BY= biomass yield (Kgha^{1}), SY=straw yield (Kgha^{1}), AGY=adjusted grain yield (Kgha^{1}), ASY=adjusted straw yield (Kgha^{1}), TVC=total variable cost, NB=net benefit and MRR= marginal rate of return.

4. Conclusion

Pre-planting fertilizer applications soil samples were taken and analyzed for Physico-chemical contents of the experimental site. And the results showed that texturally high in sand, moderate in silt and clay in content, with pH of 5.51 (strong acid), medium organic carbon content of 2.88%, moderate total N (0.19%) and low available P (4.73%), low CEC of 8.8 (Cmol kg^{-1}). Application of integrated use of urea and blended NPSB fertilizer rate were significantly improved growth, yield and yield components of bread wheat. Application of different rates of NPSB had significantly improved all agronomic traits of bread wheat. The highest 2014 kg ha^{-1} and lowest 406.3 kg ha^{-1} mean grain yield of bread wheat was obtained with application of 250 kg NPSB ha^{-1} blended fertilizer rates and unfertilized plot (control) respectively. The highest net benefit ETB 51069 ha^{-1} with marginal rate of return of 849% and value to cost ratio of ETB 12.8 per unit of investment for bread wheat production was obtained from application of 250 kg NPSB ha^{-1} on particular study area. Therefore, application 250 NPSB ha^{-1} was economically profitable and it can be recommended for farmers in study area. However, it is difficult to make definite conclusion based on the experiment of only one season and one location. Therefore, to give conclusive recommendation, the optimum blended NPSB fertilizer rates for the production of bread wheat in the study area further research over location and years should be conducted for soundness and fruitful research finding.

Declarations

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Competing Interests Statement

The authors declare no competing financial, professional, or personal interests.

Consent for publication

The authors declare that they consented to the publication of this study.

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