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Impact of Blended Fertilizer Rates on Bread Wheat (*Triticum aestivum* L.) and Economic Viability in Northern Ethiopia

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Authors' contributions

This work was carried out in collaboration among all authors. Authors BM, AT and YG contributed to the data collection, data management, analysis, and preparation of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The aim of this study was to evaluate the yield and yield responses of bread wheat to different amounts of blended fertilizer in two different locations: Hatsebo and Ahferom in northern Ethiopia. The experiment, conducted during the 2021 and 2022 growing seasons, included seven treatments for both locations. The research followed a randomized complete block design with three replications.

In Hatsebo, results showed that application of 250 and 300 kg ha-1 NPSB resulted in the highest above-ground biomass (10,000 and 10,853 kg ha-1) and grain yield (3,768 & 3,899 kg ha-1). However, the optimal economic yield of 307,747.3 Eth-birr per hectare with a marginal return of 8,404.3% was achieved with the application of 100 kg ha-1 NPSB.

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The results at Ahferom showed that the NPKSZnB rate significantly influenced the yield and related traits of bread wheat. The highest grain yield (4,163 kg ha-1) and an economic return of 678,631.8 Eth-birr per hectare with a marginal return of 7,135.6% were achieved with the application of 150 kg ha-1 NPKSZnB. The different yields of different fertilizer treatments in different soils show how important a soil-specific fertilization strategy is for increasing production. However, the partial budget analysis showed that treating the soils of the different sites (Hatsebo and Ahferom) with 100 kg NPSB and 150 kg NPKSZnB ha-1, respectively, achieved the maximum net benefit and marginal return. Therefore, it is recommended to use 100 kg ha-1 NPSB in Hatsebo District and 150 kg ha-1 NPKSZnB in Ahferom District and similar agroecological areas, taking into account economic indicators in addition to yield response.

Keywords: Blended fertilizers; bread wheat; economic profitability; Northern Ethiopia; wheat yield.

1. INTRODUCTION

One of the main cereals that form the basis of Ethiopia's agricultural and food economy is wheat (*Triticum aestivum*), which is grown together with teff (*Eragrostis teff Zucc*), maize (*Zea mays*), sorghum (*Sorghum bicolor*) and barley (*Hordeum vulgare*) [1]. The potential yield (Yp = 9.6 t ha^{-1}), the water-limited potential yield (Yw = 8.3 t ha^{-1}) and the global average yield (4.39 t ha^{-1}) are all significantly higher than the current one national average wheat yield (2.97 t ha^{-1}) (http://www.yieldgap.org/Ethiopia). For this reason, millions of households suffer from chronic food insecurity every year and rely on food assistance from humanitarian organizations to survive [2].

Therefore, in order to enable the nation to become self-sufficient through soil management, intensification, extensive irrigation, and agricultural mechanization in partnership with the private sector, the Ethiopian government recently announced that it will close the yield gap [3] and reduce wheat imports from 1.7 million metric tons in 2019 to zero in 2023 [4]. In addition, balanced doses of the most important nutrients must be applied in order to maximize output while minimizing nutrient losses; fertilization must then be adjusted to the specific soil chemical conditions and crop needs of the area [2].

Depletion of soil nutrients and inadequate use of mineral fertilizers are among the main reasons for low yields in smallholder farming systems in Africa [5]. Micronutrients such as B, Fe, Mn, Zn and Cu play a crucial role in plant growth even in small amounts [6]. Thus, a comprehensive approach is possible that takes into account all essential plant nutrients in fertilizer sources and strategies essential for improving nutrient utilization efficiency and ultimately improving yields [7]. Furthermore, various studies have highlighted the importance of tailoring fertilizer rates and combinations based on specific soil types to optimize the yield of different crop species [8]. Therefore, tailored soil test-based fertilizer recommendations containing key nutrients such as S, B, Zn and others are preferable to blanket recommendations [9].

According to Elias et al. [2] low wheat yield levels in Ethiopia can be attributed to the deficiencies caused by inadequate and unbalanced fertilizer application. Traditionally, Ethiopian agriculture has heavily relied on urea and di-ammonium phosphate (DAP) as sources of nitrogen (N) and phosphorus (P), respectively. However, there is growing recognition that the production of high-protein cereals such as wheat can be limited by the lack of other nutrients like sulfur (S) [10]. Including nutrients such as zinc, boron, sulfur, and potassium in fertilizer formulas, especially in deficient soils, can significantly enhance fertilizer efficiency and crop profitability [11].

In the Tigray region, wheat covers about 107,929.86 hectares of the total grain crop area of approximately 769,670.80hectares.The Hatsebo (Lailay-Maichew) and Ahferom within the central zone of Tigray are known as potential wheat-growing regions in Ethiopia. Soil fertility, soil organic matter, and insufficient knowledge regarding appropriate rates of blended fertilizer application and agronomic practices have been identified as key factors contributing to low productivity and fluctuating bread wheat production in Tigray [12]. Specifically, the farmers in the central zone lack understanding of the optimal rate of blended fertilizer application, resulting in reduced wheat yield and quality. Therefore, this study aims to determine the most suitable rate of blended fertilizer based on soil test recommendations and to estimate economically viable rates for bread wheat production.

2. MATERIALS AND METHODS

2.1 Study Area Description

The study was conducted over two consecutive rain-fed cropping seasons (2021 and 2022) in Hatsebo and Ahferom. Hatsebo is positioned at longitude 38^0 46.17’403’’ and latitude 14^0,6’28.015’’ , with an elevation of 2148 meters above sea level. The average annual rainfall in this area ranged from 500 to 782.8 mm, with daily average minimum and maximum temperatures of 12.6°C and 25.51°C, respectively. The soil at the site is clay type, with a pH of 7.19. Ahferom is positioned at longitude 39^0 04’40.2’’ and latitude 14^0,6’28.015’’, with an elevation of 2200 meters above sea level °C.

2.2 Experimental Materials and Design

Different types of blended fertilizers were used at each location based on site-specific recommendations: NPSB at Hatsebo and NPKSZnB at Ahferom. The experiment included seven treatments: a control with recommended Nitrogen fertilizer, six levels (50, 100, 150, 200, 250, and 300 kg ha^{-1} NPSB) at Hatsebo, and six levels (50, 100, 150, 200, 250, and 300 kg ha^{-1} NPKSZnB) at Ahferom. Additionally, all treatments received 100 kg ha^{-1} of urea as a top-dressing. The nutrient levels in 100 kg of NPSB were found to contain 18N - 36P2O5 + 7S + 0.71B, while NPKSZnB contained 13N - 26.1 P2O5 – 13.7K2O + 5.6 S + 1.7 Zn + 0.5B. The planting material used was a bread wheat variety called Ogolcho, chosen for its adaptability to the agro-ecological conditions of the experimental areas. The experiment was set up using a Randomized Complete Block Design (RCBD) with three replications. Each plot had dimensions of 2.5 m x 2 m, with 10 rows spaced 20 cm apart, resulting in a total plot size of 5 m^2. The spacing between plots was 0.5 m, and 1 m between blocks. Data collection took place in the middle eight rows, excluding the outer rows on both sides.

2.3 Soil Sampling and Analysis

Soil samples were taken in a zig-zag pattern before and after sowing from each field, at a depth of 20 cm from the top soil layer, in each location. Forty-two soil samples were collected after harvest, while two soil samples were taken prior to sowing. These samples were then composited to produce representative samples, with each composite sample weighing approximately 1 kg. The samples were air-dried at room temperature, thoroughly mixed, and prepared for physico-chemical analysis. The soil samples were analyzed for various characteristics, including pH, texture, total Nitrogen, available Phosphors, electrical conductivity, cation exchange capacity, organic matter, and organic carbon contents. Soil pH was determined using a potentiometric test method, while soil texture was determined using the spindle mixer method. The other analyses were conducted using appropriate apparatus and methods.

2.4 Data Collection

Data were collected on eight agronomic parameters, both on individual plants and on a plot basis.

2.5 Phonological Traits

Days to 50% heading: Counted the number of days from seedling emergence to when 50% of the plants in the plot started to head their panicles' tips.
Days to 90% maturity: Recorded the number of days from seedling emergence to when 90% of the plants reached physiological maturity.

2.6 Agronomic Traits Data

Plant height (PH): Measured from the ground surface to the tip of the panicle at maturity using a tape measure. Measurements were taken from 5 randomly sampled plants.

Spike length (SL): Measured from the bottom of the spike to the tip of the spike (excluding the awns) using 5 randomly tagged spikes from the designated plot.

Grain yield (kg ha^{-1}): Harvested from the middle eight rows of each plot, sun-dried, and separately threshed manually. The resulting grain was weighed using a sensitive electronic balance.

Above-ground biomass: Harvested from the designated plot area, including leaves, stems, and seeds. The harvested biomass was sun-dried until a constant weight was achieved, then weighed and expressed in kg ha^{-1}.

Harvest index (%): Calculated as the ratio of dried grain weight to the dried total above-ground biomass weight, multiplied by 100.

2.7 Data Analysis

All data analyses were performed using the software package GenStat 18 edition to detect significant differences in treatment effects by utilizing the least significance difference (LSD) test at a 5% probability level.

2.8 Economic Analysis

To assess the economic viability of the blended fertilizer, the method of CIMMYT [13] was used. This included calculating costs and benefits per hectare in Birr. The partial budget analysis considered factors such as the average yield for each treatment, the straw yield benefit, and the price and application cost of blended fertilizers. The marginal rate of return (MRR) was determined by dividing the change in net benefit (NB) by the change in total variable cost (TVC) at different levels. The net benefit was determined by subtracting the total variable costs from the gross field benefit.

To account for the discrepancy between the experimental yield and the yield achievable by farmers on the same field size, the actual yield was revised downwards by 10%. Return on investment per unit of fertilizer investment was calculated as the percentage MRR between any two non-dominated treatments. An MRR of 100% means that for every birr output for a given variable input, one birr will be returned.

3. RESULTS

Pre-planting analysis of the soil's physical and chemical properties in the experimental fields yielded the following findings (refer to Tables 1 and 2):

Hatsebo soil texture: clay textured with a particle size distribution of 50% clay, 34% silt, and 16% sand. Ahferom soil texture: silt textured with a particle size distribution of 24% clay, 48% silt, and 28% sand. The soil also had a high silt proportion (48%). Soil pH: Hatsebo 6.82, Ahferom 6.58. The pH range (4 to 8) recommended by FAO [14] for most crops and productive soils was met.

Both experimental soils were non-saline, as indicated by the EC values falling below the recommended range of 2 to 16 (mScm^{-1}). Soil organic carbon content was low in both sites (0.609 for Hatsebo and 0.634 for Ahferom). Total nitrogen content was very low (0.055% for Hatsebo and 0.052% for Ahferom). Available phosphorous content was also rated as very low (4.5 mg kg^{-1} for Hatsebo and 10.6 mg kg^{-1} for Ahferom) according to EthioSIS [12] classifications. CEC values indicated that both experimental sites had a very high capacity to hold exchangeable cations (52.20 meq/100 g of soil for Hatsebo and 45.40 meq/100 g of soil for Ahferom) according to Landon [15] classifications.

3.1 The Combined Mean of Yield and Yield Related Traits of Bread Wheat as Influenced by Rates of Blended Fertilizer (NPSB) at Hastebo Location

The analysis of variance combinedly demonstrated that the influence of NPSB blended fertilizer rates on bread wheat exhibited a statistically significant variance ($P < 0.05$) across various yield and yield components, excluding days to heading (DH) (Table 3).

The outcome indicated that higher NPSB rates resulted in increased plant height. As indicated in Table 3; the blended fertilizer rate of 250 kg ha^{-1} of NPSB produced the tallest plant height (84.05 cm), while the control plot yielded the shortest plant (70.2 cm). Similarly, the application of NPSB led to an increase in spike length, with the rate of 200 kg ha^{-1} of NPSB producing the longest panicle length (10.27 cm), whereas the rate of 0 kg ha^{-1} NPSB resulted in the shortest length (8.3 cm).

The aboveground biomass was significantly impacted ($p<0.05$) by the application of blended fertilizer rates (Table 3). The greatest aboveground biomass (10583 & 10000 kg ha^{-1}) was observed at blended fertilizer application rates of 250 & 300 NPSB kg ha^{-1}, respectively. Conversely, the control or unfertilized plot showed the lowest aboveground biomass (5667 kg ha^{-1}). Different rates of blended fertilizers exhibited a significant effect ($p<0.05$) on grain yield (Table 3). The grain yield on application of 100 kg ha^{-1} NPSB was lower (33553 kg ha^{-1} but statistically at par with the GY (3768 kg ha^{-1}) of NPSB application of 250 kg ha^{-1} NPSB. In contrast, the control plot yielded the lowest grain yield (2133 kg ha^{-1}). The application rate of 100 kg ha^{-1} NPSB yielded the maximum harvest index (0.41).

3.2 Economic Analysis of NPSB Rates at Hatsebo Location

Table 4 summarizes the partial budget and marginal rate of return analysis of the blended fertilizer rate of NPSB. The application of 100 kg/ha of NPSB blended fertilizer yielded the highest net return of 307,747.3 Eth-birr ha^{-1} with a marginal rate of return of 8404.3%. Conversely, the unfertilized plot resulted in the lowest net benefit. Therefore, based on economic indicators, it is advisable for farmers in the Hatsebo area and similar agro-ecological zones with comparable soil conditions to utilize 100 kg/ha of NPSB blended fertilizer for improved bread wheat production.

At Ahferom site; the application of NPKSZnB blended fertilizer at different rates significantly ($P < 0.05$) influenced the yield and yield components of bread wheat (Table 5). By increasing the NPKSZnB rate from 50 to 300 kg/ha, there was an increase in various yield parameters such as plant height (87.90 cm), spike length (8.9 &8.7cm), and the duration of heading and maturity. This is attributed to the enhanced vegetative growth facilitated by higher NPKSZnB rates.

The use of blended fertilizer NPKSZnB significantly influenced aboveground biomass, grain yield, and harvest index. The highest aboveground biomass (11,292 kg ha^{-1}) was recorded when applying 150 kg ha^{-1} of NPKSZnB blended fertilizer. On the other hand, the control plot with no fertilizer application exhibited the lowest aboveground biomass (8938 kg ha^{-1}). The maximum grain yield (4163 kg ha^{-1}) was achieved with the application of 150 kg ha^{-1} of NPKSZnB blended fertilizer. Conversely, the control plot yielded the lowest grain yield (2291 kg ha^{-1}). Furthermore, the application of NPKSZnB fertilizer at a rate of 150 kg ha^{-1} resulted in a maximum harvest index (0.37), indicating greater grain yield due to efficient allocation of dry matter to the grain.

Table 1. Pre-planting soil physicochemical properties of Hatsebo experimental site

No	Soil characters	Values	Rating	Reference
1.	Soil texture:			
	Sand (%)		16	
	Clay (%)		50	
	Silt (%)		34	
Textural Class	**Clay**			**FAO [14]**
2	pH	6.82	Neutral	Ethiosis [12]
3.	Organic carbon (%)	0.61	Low	Landon [15]
4.	Total Nitrogen (%)	0.052	Very low	EthioSIS [12]
5.	CEC (meq/100 g of soil)	52.2	Very high	Landon [15]
6.	Available phosphorous (mg kg^{-1})	4.5	Very low	EthioSIS [12]
7	EC (mmh)	0.450	Salt free	EthioSIS [12]
8	Organic matter (%)	1.05	Low	EthioSIS [12]

Table 2. Pre-planting soil physico-chemical properties of Ahferom experimental location

No	Soil characters	Values	Rating	Reference
1.	Soil texture:			
	Sand (%)		30	
	Clay (%)		22	
	Silt (%)		48	
Textural class	**Loam**			**FAO 1990**
2.	pH	6.6	Neutral	EthioSIS [12]
3.	Organic carbon (%)	0.634	Low	Landon [15]
4.	Total Nitrogen (%)	0.055	Very low	EthioSIS [12]
5.	CEC (meq/100 g of soil)	45.40	Very high	Landon [15]
6.	Available phosphorous (mg kg^{-1})	10.602	Very low	EthioSIS [12]
7	Ec (mmh)	0.652	Salt free	EthioSIS [12]
8	Organic matter (%)	1.094	Low	EthioSIS [12]

Table 3. Combined (two season) mean performance of NPSB at Hatsebo location

Trts	DH	DM	PH	PL	BM (kg ha-^{1})	GY (kg ha-^{1})	HI
0	67.0	115.5b	70.2d	8.3b	5500.0d	1791e	0.33c
50	67	110.3 a	73.50 cd	9.60 a	6958 c	2569 d	0.37abc
100	64.67	111.2 a	78.33 bc	9.600 a	8750 b	3353bc	0.41a
150	66.50	111.3 a	79 ab	9.933 a	8625 b	3260c	0.38abc
200	65.33	111.2 a	80.45 ab	10.267 a	8167 b	3201 c	0.39ab
250	65.33	111.2a	84.05 a	10.150 a	10583 a	3768 ab	0.36bc
300	64.5	111.0 a	81.27 ab	10.100 a	10000 a	3869a	0.39abc
Mean	65.81	111.67	78.11	9.7	8369	3116	0.38
LSD (5 %)	ns	3.13	5.3	0.7	1207.2	454.7	0.048
CV (%)	3.4	2.4	5.3	6.2	12.3	12.4	10.8

Trts; treatments, DH; days to heading, DM; days to maturity, PH; plant height, PL; panicle length, BM; biomass yield, GY; grain yield, HI; harvest index

Table 4. Combined MRR of Analysis, NPSB wheat at Hatsebo, 2010-2011

TRT	Actual yield (kg ha-^{1})	Adjusted yield (kg ha-^{1})	Gross Field Benefit	Biological yield	Adjusted yield (kg ha-^{1})	Gross Field Benefit	Total Gross Field Benefit	Total variable cost (ETB ha^{-1})	Net benefit (ETB ha^{-1})	MRR%
0	1791	1611.9	30626.1	5500	4950	158400	189026.1	0	189026.1	
50	2569	2312.1	43929.9	6958	6262.2	200390.4	244320.3	824.5	243495.8	6606.3
100	3353	3017.7	57336.3	8750	7875	252000	309336.3	1589	307747.3	8404.
150	3260	2934	55746	8625	7762.5	248400	304146	2383.5	301762.5	D
200	3201	2880.9	54737.1	8167	7350.3	235209.6	289946.7	3088	286858.7	D
250	3768	3391.2	64432.8	10583	9524.7	304790.4	369223.2	3892.5	365330.7	4212.6
300	3869	3482.1	66159.9	10000	9000	288000	354159.9	4657	349502.9	D

Table 5. Combined mean performance of NPKSZnB at Ahforom

TRT	DH	DM	PH (cm)	PL (cm)	BM (kg ha-[1])	GY (kg ha-[1])	HI
0	64.75 ab	102.2 a	82.55b	8.2 b	8938 c	2291 d	0.257c
50	66.33 b	103.2 ab	83.17b	8.4 ab	9583 bc	3217 bc	0.35 ab
100	65.33 ab	105.2 c	85.58ab	8.56 ab	9592 bc	3129 c	0.327 b
150	64.17 ab	107.2 d	85.70 ab	8.7 ab	11292 a	4163a	0.37a
200	63.50 a	105.7 cd	87.20a	8.9 a	11125 ab	3860 abc	0.35ab
250	64.50 ab	105 bc	86.90a	8.48 ab	10850 ab	3790 ab	0.35 ab
300	64.08 ab	105.8 cd	87.67a	8.5 ab	11000 ab	3922 ab	0.34 ab
Mean	64.7	104.9	85.5	8.5	10340	3482	0.33
LSD (5%)	2.02	1.86	3.4	0.51	1550	748.5	0.041
CV(%)	2.7	1.5	3.42	5	12.4	13.7	10.5

Where; Trts; treatments, DH; days to heading, DM; days to maturity, PH; plant height, PL; panicle length, BM; biomass yield, GY; grain yield, HI; harvest index, cm; centimeter, kg ha-[1]; kilogram per hectare

Table 6. MRR of Analysis, NPkSZnB at Ahferom, 2010-2011

trt	Actual yield (kg ha-[1])	Adjusted yield (kg ha-[1])	Gross Field Benefit	Biological yield	Adjusted yield (kg ha-[1])	Gross Field Benefit	Total Gross Field Benefit	Total variable cost (ETB ha^{-1})	Net benefit (ETB ha^{-1})	MRR%
0	2291	2061.9	39176.1	8938	8044.2	482652	521828.1	0	521828.1	
50	3217	2895.3	55010.7	9583	8624.7	517482	572492.7	824.5	571668.2	6044.88
100	3129	2816.1	53505.9	9592	8632.8	517968	571473.9	1559	569914.9	d
150	4163	3746.7	71187.3	11292	10162.8	609768	680955.3	2323.5	678631.8	715.66
200	3860	3474	66006	11125	10012.5	600750	666756	3088	663668	d
250	3790	3411	64809	10850	9765	585900	650709	3852.5	646856.5	d
300	3922	3529.8	67066.2	11000	9900	594000	661066.2	4647	656419.2	d

Based on the yield response and economic indicators, the most favorable outcome was observed when applying 150 kg ha^{-1} of NPKSZnB blended fertilizer, resulting in a net return of 678,631.8 Eth-birr ha^{-1} and a MRR of 7135.6% (Table 6). Therefore, it is recommended to adopt this fertilizer application rate (150 kg ha^{-1}) in Ahferom district and areas with similar soil conditions and agro-ecology.

4. DISCUSSION

As shown in Table 3; the control treatment showed a notable distinction from the other treatments, although there was no substantial disparity between the treatments. This divergence could be attributed to the utilization of blended fertilizer in contrast to the non-blended plot. Rut et al. [16] supported this outcome, reporting that excessive application of N-fertilizer leads to delayed crop maturity due to disturbances in photosynthesis supply during the reproductive phase.

The growth parameters exhibited enhancement proportionate to the application rate of NPSB, likely due to the significant impact of nitrogen, which facilitates stem elongation and vegetative growth in wheat. Berhan [17] and Teshome [18] also support the significant effect of blended fertilizer application on panicle length, as it aids in photosynthesis assimilation. These findings are backed by Rut et al. [16] who recorded the tallest plant height (95.5 cm) with the application of 300 kg of NPSB. Abebe et al. [19] noted a similar trend, observing the highest plant height (85.57 cm) with the application of 237 kg/ha NPS + 102 kg/ha urea, along with a maximum spike length (8.85 cm) achieved using the same fertilizer combination. The increase in plant height at higher levels of NPSB fertilizer can be attributed to the increased supply of nitrogen, phosphorus, and sulfur nutrients, which facilitate robust vegetative growth and development of the plant. Several authors, namely Dewal and Pareek [20], Gupta et al. [21], Arif et al. [22], Melkamu et al. [23], Sofonias et al. [24], and Chaltu et al. (2022) have also reported that the application of macro and micronutrients through fertilizers can positively influence plant height, spike length, number of tillers, and kernel count, when using varied doses and combinations. Bereket et al. [25] found that the application of macronutrients and micronutrients (Nitrogen, Phosphorous with Sulfur, and Boron) through fertilizers can lead to an increase in plant height, spike length, tiller count, and kernel count with higher doses and combinations.

The influential effect of blended fertilizer on aboveground biomass yield can be attributed to the improved root growth and enhanced nutrient uptake, which foster superior growth and delayed leaf senescence, prompted by the synergistic effect of nutrients. Consistent with this result, Regassa et al. [26] emphasized the significant effect of blended fertilizer rates on aboveground biomass yield. The findings also align with Woubshet et al. [27] who found that the application of 150 kg ha^{-1} NPSB blended fertilizer with compost increased biomass yields by 11.5 t ha^{-1}. The positive impact of sulfur in enhancing chlorophyll formation and promoting vegetative growth, combined with the role of boron in facilitating nitrogen absorption, contributes to these results. The ultimate objective in crop production is to maximize economic yield, which stems from the response of individual yield components to optimal input rates. Mesfin and Tadesse [28] identified a highly significant increase in biomass (11.5 t ha^{-1}) with the use of NPSB blended fertilizer. The incorporation of Sulfur promotes chlorophyll formation and vegetative growth, while Boron aids in nitrogen absorption.

The maximum grain yield attained with the highest blended fertilizer rate can be attributed to the presence of micronutrients (S and B), in addition to N and P, which play critical roles in metabolic processes, nutrient utilization, enzyme activation, as well as enhancing photosynthesis and assimilate transportation from sources to sinks during the growth period. This outcome is consistent with the findings of Seifu et al. [29] who recorded the highest grain yield (4330 kg/ha) with the application of 175 kg/ha NPSB, while the lowest yield was observed in the unfertilized plots. Abebe et al. [19] also reported that the maximum grain yield (3796 kg/ha) of wheat was achieved with the application of 237 kg/ha of blended fertilizer, whereas the lowest (1466 kg/ha) was obtained from the unfertilized plot. Usman et al. [30] and Melkamu et al. [31] further support these findings, noting that the application of nutrients such as K, S, Zn, and B significantly increased grain yield and yield components in bread wheat in comparison to the control (no fertilizer). The application of 100 kg ha^{-1} blended fertilizer gives the highest harvest index; this indicates a higher grain yield for crops since it facilitates the assimilation of dry matter stored in different plant parts. Amanullah &

Inamullah [32] reported that a high amount of P + Zn enhances the accumulation and allocation of total dry matter to reproductive plant parts (panicles), resulting in a higher harvest index. Similar findings were reported by Regassa et al. [26], Seifu et al. [29], Abebe et al. [19], Melkamu et al. [31], and Chaltu et al. (2022) regarding the positive effect of increasing blended fertilizer on bread wheat yield and yield attributes. Recent studies on potassium (K) and NPS [33] demonstrate that higher levels of NPS and K can enhance agronomic efficiency in wheat cultivation up to a certain threshold. Therefore, the results suggest that the application of balanced nutrients, including NPS and K up to a certain level, positively contributes to nutrient uptake efficiency, ultimately translating into improved yield and yield traits. This finding aligns with the research conducted by Tilahun and Tamado [34] on the response of bread wheat to NPS and nitrogen in the nitisols of southern Ethiopia.

Since farmers prefer low-cost methods with high income, conducting a marginal rate of return analysis and examining dominated treatments becomes crucial [13]. Grain and straw yields were adjusted by 10% for partial budget economic analysis in order to account for the discrepancy between the experimental yield and the yield that farmers would typically receive from the identical treatment. As a result, every treatment generated a bigger positive net benefit (NB) than the control. Applying extra soil nutrients instead of just di-ammonium phosphate (DAP) alone resulted in the highest net benefit from applying NPSB mixed fertilizer; as a result, bread wheat productivity increased. Thus, in the Hatsebo area, applying the suggested soil-specific mixed fertilizer (100 kg ha^{-1} NPSB), and in Ahferom district and areas with similar soil conditions and agro-ecology, applying (150 kg ha^{-1} NPKSZnB) will pave the road for wheat self-sufficiency. Furthermore, as mentioned by Seifu et al. [29], greater employment prospects in agricultural value chains will result from such investment in the national wheat sector [35-39].

5. CONCLUSION

In the year 2021 and 2022 cropping seasons, a field experiment was carried out at Hatsebo and Ahferom districts to assess the impact of different rates of blended fertilizers on the growth of bread wheat. At the Hatsebo site, the use of NPSB fertilizer and varying rates had a significant influence on the yield and yield components of bread wheat. The highest grain yield of 3869 kg per hectare was achieved when applying 300 kg per hectare of NPSB. However, based on economic analysis, the highest marginal rate of return of 8404.3% was obtained from the application of 100 kg per hectare of NPSB, which proved to be the most economically viable option. Therefore, farmers can maximize profitability by utilizing a fertilizer rate of 100 kg per hectare in their wheat cultivation. Moving on to the Ahferom district, the application of NPKSZnB on bread wheat also showed a statistically significant difference in yield and yield components. The highest grain yield of 4163 kg per hectare was obtained using 150 kg per hectare of NPKSZnB. Based on economic analysis, the acceptable marginal rate of return of 7135.7% was also observed with the application of 150 kg per hectare of NPKSZnB. Therefore, a fertilizer rate of 150 kg per hectare is recommended not only for the study area but also for other regions with similar soil types.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

No generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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