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Original Research Article

Evaluation of Balanced Fertilizer Types and Validation of Soil Fertility Map-Based Fertilizer Recommendation for Bread Wheat Production in Bale Highland Southeastern Ethiopia

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Abstract: The optimal and appropriate fertilizer recommendation packages for all crops considering the improvement in productivity of small-scale farmers in the country. To evaluate the impact of blended fertilizer on wheat output, a field experiment using a five-treatment, three-replicate RCBD design was carried out during the 2020–2023 cropping season at Bale Highland southeastern Ethiopia to evaluate balanced fertilizer types and validation of soil fertility map-based fertilizer recommendation for Bread Wheat production The treatment 1Control (without fertilizer)2 (100 kg/ha^{-1} Urea)3 (100 kg /ha^{-1} NPS plus 100 kg of urea)4(100 kg /ha^{-1} NPSB plus 100 kg of urea) 5(100 kg /ha^{-1} NPSZnB plus 100 kg of urea). The plot size was 3m by 3 m (9 m^2) and the spacing between plots and blocks was 1m and 1m, respectively in comparison to the control, The application of 100 kg ha^{-1} NPSZnB + 100 kg ha^{-1} urea in Bale Highland produced the highest and most significant yields of grains (5257.51 kg ha^{-1}) the least amount of grain (3006.51 kg $^{ha-1}$) in Bale Highland at the same time. To improve the production of wheat in the study area, farmers in Bale Highland must apply NPSZnB, with a similar agroecology.

Keywords: Fertilizer, Bread Wheat, Grain Yield, NPS and Biomass.

INTRODUCTION

Ethiopia's highlands are primarily home to wheat (*Triticum spp.*) cultivation (Efrem *et al.*, 2000). Although it is most suited to rich, well-drained silt and clay loam soils, it can be produced successfully in a variety of soil types (Bekele *et al.*, 2000). It comes in third place in terms of cereal grain production (15.17% (4,642.96 million t)) in Ethiopia, behind maize and teff, and fourth in terms of the total area covered by cereal grains (1.69 million ha) (CSA, 2018). Ethiopian agriculture depends heavily on wheat despite its long history, high production area cover, productivity, and significance. However, the country's average yield of 2.74 t ha-1 (CSA, 2018) is still far below the global average of 3.0 t ha-1 (FAOSTAT, 2013). Together with other biotic and abiotic factors, low soil fertility may be the cause of the low wheat yield and decline in productivity (Tesfaye, 1988). The biggest obstacles to increasing Ethiopia's output of bread wheat are inadequate agronomic and soil management, as well as a low degree of technology creation and dissemination. Conversely, low soil fertility and the resulting slow development of wheat with long-lasting resistance to pests, diseases, and weeds are thought to be the main factors limiting Ethiopia's production of bread wheat (Demeke and DiMarcantonio, 2013).

According to Teklu and Hailemariam (2009), improving soil fertility necessitates applying inorganic and organic nutrient sources equitably. According to Sanchez *et al.*, (1997), inorganic fertilizers have improved food production globally and have proven to be useful in addressing issues related to soil fertility. Stewart *et al.*, (2005) estimate that the use of commercial fertilizers contributes between 30 and 50 percent of the increase in crop yield.

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Adequate amounts of essential nutrients are necessary for plants to produce more effectively (Alloway, 2003). But for a long time, Ethiopian farmers only used urea and di-ammonium phosphate (DAP) to produce crops. (ATA, 2016) states that in addition to nitrogen and phosphorus, low levels of sulfur, potassium, boron, zinc, and copper have been found in Ethiopian soil and must be addressed to address the main nutrient deficiencies. The majority of the soil in Bale Highland also lacked the aforementioned nutrients (ATA, 2016). The soil fertility map covering over 150 districts indicates that most Ethiopian soils lack roughly seven nutrients (N, P, K, S, Cu, Zn, and B). The study area's soil is deficient in some major macronutrients like nitrogen and phosphorus, secondary macronutrients like sulfur, and some micronutrients, especially boron.

Maintaining soil health and producing crops in a sustainable manner both depend on balanced fertilization. The lack of alternatives for managing soil fertility and the application of balanced fertilizer types resulted in a decrease in bread wheat yield in the study area. The application of balanced fertilizers is essential for enhancing soil fertility and raising bread wheat yield in the study area since there is a dearth of research on the precise balanced fertilizers that are advised based on the ATA soil fertility map.

Nutrient types that are balanced must be used to improve soil fertility and increase bread wheat production in the research area. However, there is a huge knowledge vacuum regarding soil testing for bread wheat cultivars that maximizes grain production and quality based on balanced blended fertilizer treatment levels. The purpose of this study was to evaluate a soil fertility map based on various balanced fertilizer applications for the production of bread wheat in the study area and to suggest an alternative balanced fertilizer type to maximize the production of bread wheat in the study area.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The study was carried out in the districts of Sinana, Goba, and Agarfa in the Bale Zone, situated in the southeast of Ethiopia, during the primary cropping season of 2020–2023. The highlands in the center represent the Bale Zone, which receives a lot of rain and is distinguished by two types of rainfall. Two cropping seasons are observed in the area: the first, known as Bona, lasts from March to July, and the second, known as Ganna, runs from the second half of July to September. Clay soil is the most common type of soil in every place.

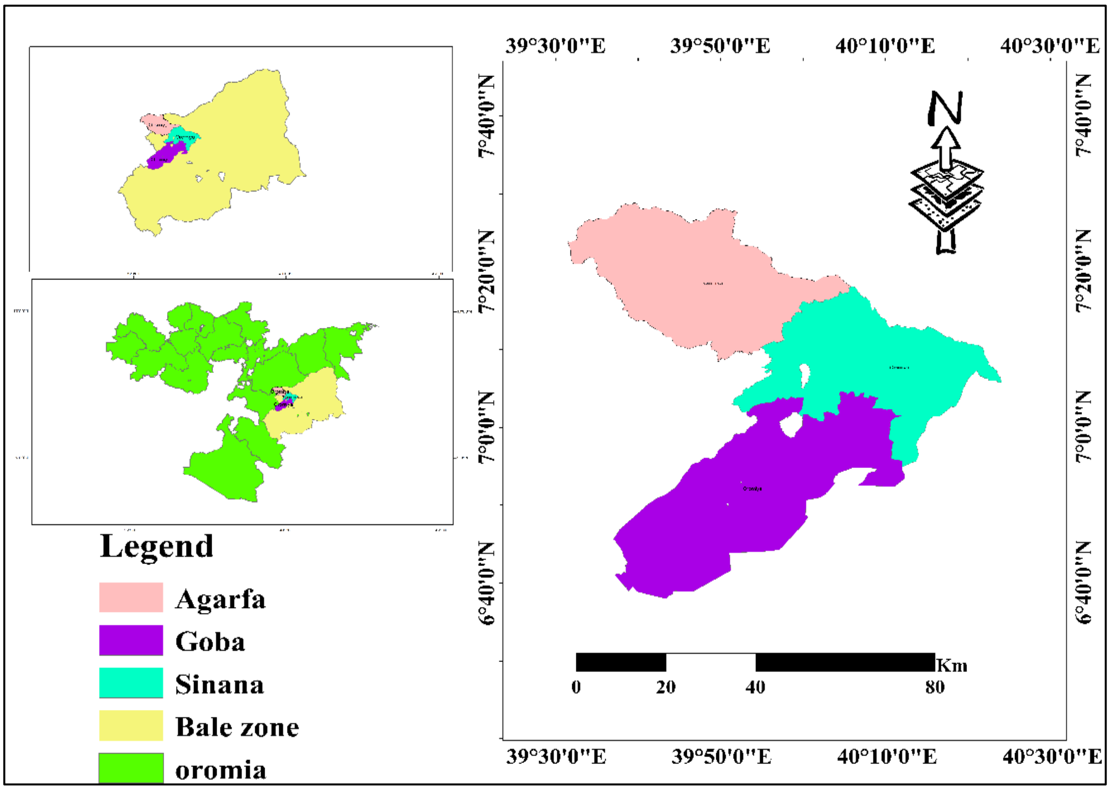

Figure 1: A map representing the research area

2.2 Experimental design and treatments

The experiment was conducted in 2020-2023 at Bale Highland. Three replications of each treatment were used in the trial, which was set up using a Randomized Complete Block Design (RCBD) and based on treatments available from ATA mapping for Bale high (Sinana, Agrafa, and Goba). Each treatment was repeated three times, resulting in 15 plots being filled by five different treatments. At planting time, a full dosage of NPS, NPSB, and NPSZnB was put in the rows mixed with soil. On the other hand, nitrogen was applied twice, once at planting and once 35 days later. Mandoyu variety for the experiment, an improved variety of wheat was selected, and all management techniques were implemented by wheat research recommendations. Following the suggested techniques, all relevant agronomic and soil data were collected all over the appropriate crop growth at various stages.

The experiment consists of five treatments

T 1= Control (without fertilizer)
T2 = 100 kg/ha Urea
T3 = 100 kg /ha NPS+100 kg/ha Urea
T4 = 100 kg /ha NPSB+100 kg/ha Urea
T5 = 100 kg /ha NPSZnB+100 kg/ha Urea

2.3 Data collection and soil sampling

Several methods were used to acquire data on yield and its parts. Five plants at random from each plot's center rows were chosen to measure the height of the plants. After that, these plants' average values were recorded. Harvesting the complete net plot area and converting it to kg per hectare allowed researchers to calculate the grain yield and biomass. A sensitive balance was used to randomly select one thousand kernels from the total grain production, which were then weighed and expressed in grams. The length of the spikes, the number of seeds per spike, and the number of tillers per plant were also noted. Soil samples were taken at a depth of 0–20 cm from the experimental field both before and after planting, using a random sampling technique. A 2 mm sieve will be used to crush, air dry, and screen the composite soil sample that was collected; the organic matter, on the other hand, was subjected to standard laboratory procedures for analysis at the Sinana Agricultural Research Center.

2.4. Soil sample analysis

The Walkley and Black oxidation technique (Walkley and Black, 1934) was used to calculate the amount of organic carbon. The micro-Kjeldhal digestion procedure using sulfuric acid was used to determine the total nitrogen content (Jackson, 1962). After saturating the soil with 1 N ammonium acetate (NH4OAc) and replacing it with 1 N NaOH, the total amount of exchangeable cations a soil can contain and its cation exchange capacity was calculated (Chapman, 1965) Using a spectrophotometer, Olsen's technique (Olsen *et al.*, 1954) was used to determine the amount of available phosphorus. A soil-to-water ratio of 1:2.50 was used to determine the pH of the soil (Van Reeuwijk, 1992). The hydrometer technique developed by Bouyoucous in 1951 was used to assess soil texture. cation exchange capacity (CEC) was analyzed and reported (Hesse, 1972). Lastly, established ratings or critical levels for various classes of the relevant soil parameters were compared with the values or concentrations of the relevant parameters obtained from the laboratory analyses (both physical and chemical properties) to determine the fertility statuses of the soils in the experimental fields (study areas).

2.5. Data Analysis

According to the experiment's design, R-Software an analysis of variance (ANOVA) on the acquired data. At significance levels of (p0.05), the Least Significant Difference (LSD) was applied to separate the means. To identify linear relationships between agronomic factors, Pearson correlations were used. Descriptive statistics will be used to summarize the results of the soil analysis, and the soil nutrient interpretation guideline was used to further categorize the results.

3. RESULTS AND DISCUSSION

3.1. Soil Fertility Status Before Planting

Before planting composite surface soil (0–20 cm) samples were collected, and specific physico-chemical characteristics of the soil were identified (Table 1). As a result, the clay fraction dominates the texture of the soil at the experimental location. The clay texture shows how much weathering there was during geological epochs as well as how much water and nutrients the soil could hold. Table 1 displays the pH values of the soil at both locations, which ranged from 60.1 to 6.7. Jones (2003) classified the soil's pH status as neutral. These findings indicate that since most plants prefer a pH range of 5.5 to 7.0, the pH value is ideal for most crop production. The values of Soil Organic Matter for the experimental sites' soils varied between 1.45 and 2.56 for both locations (Table 1). According to the Tekalign (1991) rating system, soil organic matter content is divided into two categories: moderate and low. The range of soil total nitrogen values across all sites was 0.15 to 0.18. The experimental site's soil total nitrogen was rated as low, following Landon's (1991) recommendations. Accessible Phosphorus values ranged from 1.18 to 5.92 for each of the two locations (Table 1). Based on Cottenie's (1980) rating system, all of the investigated soils have low phosphorus contents. According to Hazelton's 2007 cation exchange rating system, the study sites' soil had a high to moderate rating.

Table 1: Physico-chemical soil properties of the study area

Location	**Textural**	**PH (H_2O)**	**OM (%)**	**P(mg/kg)**	**CEC (cmol kg-1)**	**TN%**
Sinana	Clay	6.2-6.7	1.45-1.93	1.18-4.45	49.24	0.18
Gobba	Clay	6.01	1.61	5.92	39.38	0.16
Agarfa	Clay	6.02-7.05	1.80-2.56	3.88-5.72	37.38	0.15

3.2. Growth Parameters

3.2.1. Plant Heigh

The findings of the analysis of variance revealed that the blended fertilizer types and rates applied had a significant ($P<0.05$) impact on the wheat plant height. The application of 100 kg NPSB + 100 kg urea per hectare in Bale Highland produced the greatest plant height (92.27 cm), The control plots in Bale Highland had the lowest plant height measured at 84.87 cm, and while the other treatments did not differ significantly from one another statistically (Tables 2). The increased plant height may be the result of N being used more extensively during wheat's elongation and vegetative development. On the other hand, insufficient soil fertility in the experimental plots may have contributed to the minimum plant height in the control plots. According to Sofonyas *et al*., (2021), who also observed a similar outcome, the application of 300 kg of NPSZn-blended fertilizer per ha-^{1} considerably increased bread wheat plant height as compared to unfertilized treatments. According to Haji *et al*., (2020), the administration of 200 kg NPS ha^{-1} blended fertilizer resulted in the highest plant height (118.06 cm), whereas control treatments produced the lowest plant height (86.2 cm).

3.2.2. Spike Length

When compared to the unfertilized plot, the blended fertilizer types and rates administered had a significant ($P<0.05$) impact on the length of the wheat spike. The application of 100 kg NPSZnB + 100 kg urea ha^{-1} from Bale Highland, resulted in maximum spike lengths of 7.13 cm while the minimum spike lengths of 6.27 cm were recorded from the control plot in Bale Highland (Tables 2). A non-significant variation was found within the blended fertilizer that was used nevertheless. Similar to this outcome, Haji *et al*., (2020) observed that the 200 kg NPSB ha^{-1} blended fertilizer produced the longest spikes (9.37 cm), whereas the control (unfertilized) treatment produced the shortest spikes (6.14 cm). According to Berhan (2012), the spike length augmentation with the mixed fertilizer treatment may provide greater photo assimilation. The author also noted that the grain per spike increased with spike length, resulting in a better yield.

3.3. Yield and Yield Components

3.3.1. Number of Tillers per Plant

The number of tillers per plant was significantly ($P\leq0.05$) altered by the application of blended fertilizer types and rates when compared to unfertilized treatments. In Bale Highland, the application of a blended fertilizer consisting of 100 kg NPSB + 100 kg urea ha-1 produced the highest number of tillers per plant in 4.09. On the other hand, Table 2 shows that the study area's unfertilized plots had the fewest tillers per plant (3.13). This result is in line with Seyoum's (2017) investigation, which showed that the combination application of 200 kg NPS + 92 kg N ha-1 produced the greatest number of tillers per plant of bread wheat, highlighting the advantageous impact of the ideal rate of nitrogen for tillering.

3.3.2. Number of Seeds per Spike

The analysis of variance results showed a statistically significant (P 0.05) difference in the number of seeds per spike among the blended fertilizer types and rates that were applied. Tables 2 show that in Bale Highland, the plot treated with 100 kg NPSZnB+ 100 kg-1 urea produced the most seeds per spike (42.38) while the control treatment produced the fewest seeds per spike (38.84). The highest rate of NPSZnB+ blended fertilizer increased the number of seeds per plant by 62% over the control treatments. Consistent with this observation, Abebual *et al*., (2019) discovered that following the application of NPSZnB kg ha-1 fertilizer, the control plot produced the highest number of seeds (50.47) and the smallest number of seeds per spike of wheat (32.73).

3.3.3. Thousand kernel weight

The analysis of variance revealed that the various blended fertilizer types and rates had no statistically significant effect on thousand kernel weight ($P < 0.05$). In both experimental locations, the 100 kg NPSB yielded the highest thousand kernel weight (Table 2), which is approximately 27% greater than the yield from the unfertilized plot. This outcome is consistent with Dinkinesh *et al*., (2020), who observed that an unfertilized plot had the lowest weight (37.2 g) and a fertilized plot had the highest weight (44.8 g) of 1000 kernels.

3.3.4. Above Ground Biomass

Applying a combination of fertilizer types affected the aboveground biomass more significantly ($P < 0.05$) than leaving the plot unfertilized. Whereas the control group in the study areas recorded the lowest aboveground biomass of 9080.98 kg ha-1, the application of 100 kg NPSB + 100 kg urea in Bale Highland produced a maximum aboveground biomass of 14054.67 kg ha-1 (Tables 2). The amount of aboveground biomass increases by 64.61% when 100 kg NPSB + 100 kg urea is applied compared to the unfertilized control.

Better root development and increased nutrient uptake, which result in better growth and tillering, may be the cause of the increase in aboveground biomass, according to Dinkinesh *et al*., (2020). Similar findings were made by Abebual *et al*., (2019), who discovered that the application of NPSZnB produced the highest total biomass (14290 kg ha-1), while the control treatment produced the lowest (3390 kg ha 1).

3.3.5. Grain yield

The results of the analysis of variance showed that the various blended fertilizer types significantly ($P<0.05$) affected the production of grain yield (Table 2). The study revealed that the plots maintained by 100 kg NPSZnB+ 100 kg urea treatment in the Bale highland produced the highest grain yield of 5257.57 kg ha^{-1}. The minimum amounts of 3006.51 kg ha^{-1} were obtained from unfertilized plots in Bale Highland (Tables 2).

Applying 100 kg NPSZnB plus 100 kg urea ha-1 to an unfertilized plot in the Bale highland increases the production of grain by 57.2%, specifically in wheat grain yield. Similar results were reported by Abebual *et al*., (2019), who found that the application of NPSZnB kg ha-1 produced the highest grain yield (5770 kgha-1) and the lowest was observed from unfertilized plots. Similar to the previous example, when compared to the control, the wheat grain yield in treatments increased with combined fertilizers containing 183 kg ha-1 NPSB (Dinkinesh *et al*., 2020). 200 kg of NPSZnB fertilizer was applied to the unfertilized plot to attain the maximum wheat grain yield of 3580.2 kg ha-1, according to the findings of Sofonyas *et al*., (2021).

Table 2: Mean wheat yield and yield components in Bale Highland as the result of blended fertilizer types

Trt (Combined)	**PH (cm)**	**SL (cm)**	**SPS (cm)**	**NT**	**BM (kg)**	**GY (kg)**	**TKW**
Control	**84.87^{b}**	**6.27**	**38.84c**	**3.13**	**9080.98**	**3006.51^{e}**	**30.11**
100 kg Urea	**89.22^{a}**	**7.07**	**39.82^{bc}**	**3.42**	**9607.42**	**3838.87^{d}**	**32.89**
100 kg NPS +100 Urea	**92.11^{a}**	**6.58**	**40.82^{ab}**	**4.00**	**11701.27**	**4593.89^{c}**	**32.69**
100 kg NPSB +100 Urea	**92.27^{a}**	**6.71**	**40.27^{bc}**	**3.96**	**14054.67**	**5005.38^{b}**	**33.07**
100 kg NPSZnB +100 Urea	**91.20^{a}**	**7.13**	**42.38^{a}**	**4.09**	**12054.27**	**5257.51^{a}**	**32.69**
Mean	**89.93**	**6.75**	**40.43**	**3.72**	**11299.72**	**4340.43**	**32.89**
LSD (0.05%)	**4.0**	**NS**	**1.7**	**NS**	**1212**	**232.4**	**NS**
CV (%)	**10.96**	**13.64**	**10.65**	**20.62**	**15.82**	**12.89**	**12.65**

NB. *Means with the same letter are statistically not significant at a 5% level of significance, CV=Coefficient of variation, LSD= Least significance difference, PH= Plant height, TKW= Thousand Kernel weight SL= Spike length, SPS= seed per spike, NT= number of tiller, BM =biomas GY=grain yelied*.

3.4. Correlation analysis

Shows the findings of the investigation conducted to ascertain the relationship between the growth and yield components of bread wheat as influenced by the application of blended fertilizers. Grain yield and the other yield factors were found to have a significant and positive correlation. It appears that enhancing those characteristics will consistently raise the bread wheat's grain yield. Table 3 shows a significant and positive correlation between grain yield (r= 0.31*, 0.41*, 0.33*, 0.30*, and 0.07*) and the following variables in the Bale highland: plant height, number of tillers per plant, spike length, number of seeds per spike, above-ground biomass, and weight of thousand kernels.

The result demonstrated that the fertilizers applied had a significant and positive effect on the yield of bread wheat. The most recent study by Abebual *et al*., (2019) found a significant and positive correlation between the yield of grain on bread wheat and the number of tillers per plant, plant height, spike length, number of seeds per spike, above-ground biomass, and thousand seed weight.

Table 3: Average agronomic characteristics of bread wheat produced in the Bale highlands with blended fertilizers and their correlation coefficients

	TKW	**BM**	**GY**	**SL**	**SPS**	**NT**	**PH**
TKW	1						
BM	0.006*	1					
GY	0.07*	0.53**	1				
SL	0.08*	0.20*	0.33*	1			
SPS	0.17*	0.20*	0.30*	0.18*	1		
NT	0.14*	0.41**	0.31*	0.22*	0.20*	1	
PH	-0.16*	0.43**	0.41*	0.33*	0.23*	0.15*	1

Note*: NT- Number of tillers plant-1, PH- Plant height, SL-Spike length, SPS- seed peer spike-1, BM- Aboveground biomass, GY-Grain yield, TKW- Thousand seed weight, NS- non-significant and *, ** stands for significantly different at 5%, 1%, respectively*.

4. CONCLUSION AND RECOMMENDATIONS

The results of the study showed that the application of the NPSZnB Bale highland balanced fertilizer types had the highest significant difference among the 5 fertilizer types applied (p<0.05). The yield and yield components of wheat were significantly higher in these two fertilizer types compared to the other three fertilizer types using NPSZnB (combination of Zn and B with macronutrients NPS) fertilizers for improving wheat production in Bale Highland.

Low and/or unbalanced use of inorganic fertilizers is important Reasons for low crop yields and nutrient depletion floor. Replenish missing fertilizers based on nutrients Soil testing is a good strategy for improving crop yields and sustainably increasing productivity.

In the recent past (last five to eight years), ATA (Agricultural Transformation Agency) identified nutrients that were lacking in the country's soil and formulated different types of fertilizers for the country, helping farmers move away from the use of urea and diammonium phosphate More balanced/mixed fertilizers (macro and micro fertilizers). nutrients). According to some recent reports, major crops across the country have shown symptoms of shortage due to the depletion of nutrients like K, S, Ca, Mg, and micronutrients like Cu, Mn, B, Mo, and Zn.

With the higher rate of blended fertilizer, the highest grain production and biomass were recorded. The findings of this study suggest that applying fertilizer is an effective method to increase crop production and biomass in the study area. The production of wheat increased when nitrogen fertilizer was applied, however, it decreased when phosphorus and potassium fertilizers were applied. The results of this study demonstrate that the ideal fertilizer application rate has to be adjusted for various soil types and crop species. Generally, to improve the production of wheat in the study area, farmers in Bale Highland must apply NPSZnB, which is compatible with blended fertilizers. Other agroecology with a similar composition can also benefit from this type and rate of blended fertilizer.

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Conflicts of Interest: Authors have declared that no competing interests exist.

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