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Influence of NPSB and Lime Rates on Yield and Yield Components of Bread Wheat (*Tritcum aestivum* L.) at Guji Highland

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ABSTRACT

Background and Objective: A significant cereal crop in Ethiopia and the research region is bread wheat. However, due to the insufficient utilization of better cultivars, weeds, disease, low soil fertility, acidity and a lack of location-specific fertilizer recommendations, its yield is constrained. This study was conducted with the objective to assess the impact of blended NPSB fertilizer and lime rates on grain yield and yield components of bread wheat. **Materials and Methods:** A field experiment was carried out at the Bore Agricultural Research Center during the main cropping season including four levels of NPSB (0, 50, 100 and 150 kg NPSB ha^{-1}) and four levels of lime rates (0, 1.57, 3.14 and 4.713 t ha^{-1}). A factorial arrangement was used in three replications and the experiment was set up using a randomized complete block design. The plot size was 2.6×3 m (7.8 m^2). **Results:** The combined application of 150 kg NPSB ha^{-1} and 3.14 t lime ha^{-1}, the highest grain yield (4201 kg ha^{-1}), number of grains per spike (53.62), number of tillers per plant (2.64) and plant height (85.91 cm) were measured. However, the results of the economic study showed that the combined application of 100 kg NPSB and 3.14 t ha^{-1} of lime produced an economic benefit of 115166.88 Birr ha^{-1} with an acceptable marginal rate of return of 1779.17. **Conclusion:** Therefore, the application of 100 kg NPSB and 3.14 t lime ha^{-1} is the best economic rate and recommended for the production of bread wheat in the study area and other areas with similar agro-ecologies.

KEYWORDS

Grain yield, interaction effect, NPSB, economic benefit, lime rates, bread wheat

INTRODUCTION

In Ethiopia, wheat is an essential staple crop in terms of both production and consumption. It is the second-most significant food in the nation in terms of calorie intake after maize[1]. The majority of Ethiopia's wheat is farmed in the highlands, which are located between 6-16°North and 35-42°East, at elevations between 1500 to 2800 m above sea level and at mean minimum temperatures between 6 to 11°C[2,3]. Despite an expansion in the country's production area, the yields being achieved are poor when compared to crop potential and the national. This may be caused by a variety of factors, including insufficient soil fertility, acidity in the soil, improper fertilizer type and rate, disease, etc.

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There was not much information available to farmers in the majority of the nation and in the Bore District in particular, about the effects of NPSB rates combined with liming except general recommendations of N and P[4]. However numerous studies revealed that lime and NP fertilizer boost yield and yield components and improve physico-chemical characteristics of acid soil[5]. The reactivity of the soil has a significant impact on how well-suited it is as a medium for crop growth and development. By increasing its pH and precipitating exchangeable aluminum, liming acid soil improves the soil environment for crops and associated microbes while also increasing the concentration of vital nutrients[6]. At intermediate pH levels, when organic matter breaks down and releases key nutrients like N, P and S, biological activity and availability of nutrients are typically at their highest.

The highlands of Ethiopia, which make up virtually all of its regional states and 40.9% of the nation's total acreage, are significantly affected by acidic soil[7,8]. Around 27.7% of this are made up primarily of soils with pH values between 4.5 and 5.5, which are moderately to strongly acidic and approximately 13.2% are composed primarily of very acidic soils (KCl pH 4.5), including the highlands of the Guji Zone, which have a pH range of 5.04-5.13[9,10]. In such acidic soil, micronutrient deficiency and inadequacy such as N, P, K, Ca and Mg are common. Numerous negative effects are seen as a result of these conditions, including a loss of crop diversity, a reduction in yield of crops, a lack of response to fertilizers like ammonium phosphate and urea, a complete failure of cropping, poor plant vigor, uneven pasture and crop growth, poor nodulation of legumes, stunted root growth, the persistence of acid-tolerant weeds, an increase in disease incidence, poor plant growth, nutrient deficiencies and imbalance[11]. Due to its potent ability to neutralize acid and effectively eliminate any existing acid, lime is the main tool for reducing soil acidity[12]. Although the total amount of fertilizers used in the nation is gradually rising, low and uneven application rates per unit of land, primarily focusing on urea and DAP fertilizers with low fertilizer efficiency[4] and limited use of improved seeds[13] have still remained major obstacles for small farmers to get the best results from the input. The soils in the south, where Guji is located and the Southwest, where Sidamo, Ilubabor and Keffa are located, have high N contents and low P contents, respectively[14]. This is due to the fixation of P in acidic soil. Thus, enhancing soil organic N and P mineralization in acid soils and speeding up the uptake efficiency of applied fertilizers through liming is very important. Even though this is the problem in the study area, no research was done on liming and other acid soil management practices. Therefore, this study was conducted to determine the optimum rates of NPSB and lime for the production of wheat in the Guji highland, Oromia, Ethiopia.

MATERIALS AND METHODS

Study area: The experiment was conducted at the highland of Guji, Bore District on the Bore Agricultural Research Center experimental field and farmer field for three consecutive years (2019-2021) during the main cropping season. Bore District is situated at a distance of about 383 km from Addis Ababa in the Southern Direction. It is found at a Longitude of 038°37'54.1"E and a Latitude of 06°1'06.7"N. The Altitude of the district ranges from 1450 to 2900 m.a.s.l (meters above sea level) with a rugged topography.

Experimental materials

Plant material: Bread wheat variety Huluka (ETBW5496) was served as the test crop. Kulumsa Agricultural Research Center released the variety during the 2012 growing season. According to Ferede[3], variety has a producing potential of 3.8 to 7.0 t ha^{-1}. Variety was chosen because of its adaptability to the environment and better performance.

Fertilizer materials: Blended NPSB (18.9% N, 37.7% P_2O_5, 6.95% S and 0.1% B) was used as the source of fertilizers and Guder lime was used as a liming material.

Treatments and experimental design: The treatments consisted of four lime levels (0, 1.57, 3.14 and 4.713 t ha^{-1}) and four levels of blended NPSB (0, 50, 100, 150 kg ha^{-1}) fertilizer. The levels of lime were determined based on lime requirement i.e. lime requirement, 50% above and 50% below requirement whereas the levels of NPSB are based on blanket recommendation (blanket recommendation, one level above and one level below).

The experiment was set up using a randomized full-block design with three replications and a 4×4 factorial layout, totaling 16 treatment combinations. The distance between adjacent plots and blocks was 0.5 and 1 m, respectively, while the overall size of each plot was 2.6 and 3 m (7.8 m^2) with thirteen rows.

Eleven rows made up the net plot, which measured 2.2 by 3 m (6.6 m^2). To prevent border effects, the outermost row on both sides of each plot, together with the 20 cm on either side of each row, were deemed border plants and were not used for data collection.

Soil sampling and analyzing: Before planting, soil samples were randomly collected using an auger in a zigzag pattern from 15 different sites over the experimental field at a depth of 0 to 30 cm. The samples were then composited. The samples were then air-dried at ambient temperature under the shade and crushed to pass through a 2 mm sieve, except for organic carbon (OC) and nitrogen, which pass a 1mm sieve. A working sample (1 kg) was taken from the prepared sample/composite and analyzed at Horticoop Ethiopia's soil and water analysis lab for physico-chemical characteristics, primarily soil texture, soil pH, cation exchangeable capacity (CEC), organic carbon, total N, available P, S and B.

The total nitrogen was evaluated using the Kjeldhal method[15] and organic carbon was determined using the Walkley and Black oxidation method[16]. The pH of the soil was determined at 1:2.5 (weight/volume) soil-to-water dilution ratio using a glass electrode attached to a digital pH meter. After saturating the soil with 1N ammonium acetate (NH_4OAC) and replacing it with 1 N sodium acetate, the cation exchange capacity was determined[17]. The Mehilich 3 method and the Bray method[18], were used to calculate available phosphorus. The turbid metric approach was used to determine the amount of available S[19]. The Mehlich 3 was used to determine the availability of boron.

Experimental procedures and field management: The experimental field was four times tiled by the tractor and oxen and the plots were manually levelled. A field layout was created in accordance with the plan and each treatment was randomly assigned to the experimental units within a block. Bread wheat seeds were manually drilled into rows with 20 cm spacing at the recommended seed rate of 150 kg ha^{-1}. While NPSB fertilizer was applied at sowing. Lime was applied one month prior to planting. Manual harvesting, threshing and weeding were all done as needed.

Data collection and measurement

Crop phenology and growth parameters

Days to 50% heading (DTH): Days to headings were calculated visually by counting the days between the date of planting and the day when each plot's plants had grown to 50% of their original height.

Days to 90% physiological maturity (DTM): Measured as the number of days between the time of sowing and the point at which 90% of the straw turned yellow. When the plants' glumes and peduncles lost their green color or when it was difficult to break the grains with the thumb nail, it was noted.

Plant height (cm): The height of 10 randomly tagged plants from the net plot area was measured from the soil surface to the tip of the spike, with awns excluded.

Spike length (cm): The length of 10 randomly selected spikes from the net plot was measured from the base of the spike to the tip of the spike, omitting the awns.

Yields component and yield

Number of tillers per plant: After removing the soil surrounding the tillers, the number of tillers per plant was counted from 10 tagged plants per net plot at physiological maturity.

Number of productive tillers: The number of productive tillers was counted from the net plot at physiological maturity by counting all spikes-bearing tillers.

Thousand seed weight (g): The weight of 1000 kernels was calculated using an electronic sensitive balance and automatic seed counter to count and weigh a sample of 1000 kernels taken from the grain yield of each net plot. The weight was then modified to have a moisture content of 12.5%.

Grain yield (t ha^{-1}): After harvesting and threshing, grain yield from the net plot area was measured. In order to achieve the desired yield at 12.5% moisture content:

$$\text{Adjusted grain yield} = \frac{(100 - \text{MC}) \times \text{fresh grain yield}}{100 - 12.5}$$

Where, MC is the moisture content of bread wheat seeds at the time of measurement and 12.5 is the standard moisture content of bread wheat in percent. Finally, yield per plot was converted to per hectare basis and the yield was reported in t ha^{-1}.

Statistical data analysis: Using GenStat (18th edition) software, the Analysis Of Variance (ANOVA) approach was used for all gathered data[20]. Using Fisher's protected Least Significant Difference (LSD) test at a 5% threshold of significance, comparisons between treatment means with significant differences for assessed characteristics were conducted.

Partial budget analysis: The economic analysis was carried out using market prices that were in force at the time of planting and harvest using the methodology described in CIMMYT[21]. Every cost and benefit was calculated per hectare in Birr. The terms used in the partial budget analysis were the mean grain yield for each treatment, the gross benefit (GB) ha^{-1} (mean yield for each treatment) and the field price of fertilizers (the expenses). Since the local farmers do not use straw yield, it was not taken into account when calculating the benefit. By dividing the net increase in bread wheat yield brought on by the application of each fertilizer rate, the marginal rate of return which refers to the net revenue obtained by incurring a unit cost of fertilizer and its application was determined. Using the formula, NB = (GY×P)-TCV. The net benefit (NB) was computed as the difference between the gross benefit and the total cost that fluctuates (TCV). The GY is the adjusted grain yield per hectare and P is the field price per unit of the crop. While, 10% of the actual grain yield was deducted.

From the range of treatments examined, several were chosen using the dominance analysis method as indicated in CIMMYT[21]. Using this method, the rejected and chosen treatments were referred to as dominated and undominated, respectively. The marginal rate of return (MRR) was computed for each pair of ranking treatments using the following formula[21]:

$$\text{MRR (\%)} = \frac{\text{Change in NB } (NB_b - NB_a)}{\text{Change in TCV } (TCV_b - TCV_a)} \times 100$$

Where,

NB_a = NB with the immediate lower TCV

NB_b = NB with the next higher TCV

TCV_a = Immediate lower TCV

TCV_b = Next highest TCV

The return on fertilizer investment was calculated as the percentage MRR between any two undominated treatments. Changes in NB (increased benefit) divided by the % MRR were used to compute these returns. The price of each fertilizer for NPSB (Birr 49.80 kg^{-1}) during the sowing period was calculated. When harvesting began in January, 2022, the cost of applying NPSB and lime was Birr 600 ha^{-1} and the open market price of bread wheat was Birr 33 kg^{-1}.

RESULTS AND DISCUSSION

Physical and chemical characteristics of the soil at the test site: A study of a few of the soil's physico-chemical characteristics before sowing was mentioned in Table 1. The experimental soil's analysis results showed that it belongs to the clay textural class, with a particle size distribution of 43 clay, 30 silt and 27% sand. The soil at the test site is therefore appropriate for growing wheat. According to El-Shakweer[22], the soil had a pH of 5.1, which is classified as severely acidic. According to FAO[1], the ideal pH values for the majority of crops and productive soils are 4 to 8. According to Lawlor[23], the ideal pH range for the growth of wheat is between 4.1 and 7.4. The pH of the test soil was therefore within the acceptable range for productive soils. However, cultivating wheat at a pH below 6.0 frequently causes magnesium insufficiency, delayed organic nitrogen mineralization, reduced phosphorus availability and increased risk of aluminum and manganese toxicity. Lime is utilized in this experiment because of this.

The CIMMYT[21] noted that the experimental site's soil organic carbon level (3.1%) was high. The analysis also revealed that the soil contains a high level of total nitrogen (0.33%), according to CIMMYT[21] assessments. According to CIMMYT[21], the analysis results also showed that the soil has a low available phosphorus level (6.8 mg kg^{-1}). According to Moritsuka[24], the experimental soil had values of 15.01 mg kg^{-1} for available sulfur, which is considered low. According to Lawlor[23], the experimental soil exhibited values of 0.29 mg kg^{-1} for accessible Boron, which is considered low.

According to Landon[25], the soil sample's CEC value is medium (23.12 [Cmol (+) kg^{-1} soil]), indicating that the soil has a significant potential to retain exchangeable cations.

Some soil physico-chemical characteristics of the study site after harvesting: As shown in Table 2, the differences were observed between the treatments. The application of lime and NPSB fertilizer brought a change in pH at the end of this field experiment. The soil pH varied from 5.76 to 7.12. The highest lime and NPSB rates (4.713 t lime $ha^{-1}$and 150 kg ha^{-1}) increased the pH from 5.79 to 7.12. Generally, soil pH increased in a linear fashion with increasing lime rate. The increase was highest with applications of the maximum rate (4.713 t lime ha^{-1}) of lime. When lime is added to acid soils that contain high Al^{3+} and H+concentrations, it dissociates into Ca^{+2} and OH-ions forming Al^{3+} hydroxide and water, thereby increasing soil pH in the soil solution. In comparison to the control treatment, treatment plots that got the

Table 1: Selected physical and chemical characteristics of the soil at the experiment site before planting

Parameter	Result	Rating	Reference
Soil texture			
Clay (%)	43		
Sand (%)	27		
Silt (%)	30		
Textural class	Clay		
pH (1: 2.5 H_2O)	5.1	Strongly acidic	El-Shakweer *et al.*[22]
Total N (%)	0.33	High	El-Shakweer *et al.*[22]
Organic carbon (%)	3.10	High	El-Shakweer *et al.*[22]
Cation exchange capacity [Cmol (+) kg^{-1} soil]	23.12	medium	London[25]
Available phosphorus (mg kg^{-1})	6.8	Low	El-Shakweer *et al.*[22]
Available sulfur (mg kg^{-1})	15.01	Low	Moritsuka *et al.*[24]
Available boron (mg kg^{-1})	0.29	Low	Moritsuka *et al.*[24]

Table 2: Some physico-chemical properties of soil experimental site after harvesting

Treatments									
NPSB (kg ha^{-1})	Lime rate (t ha^{-1})	pH-H_2O	OC (%)	OM (%)	TN (%)	P (mg kg^{-1}) (ppm)	S (mg kg^{-1}) (ppm)	B (mg kg^{-1}) (ppm)	CEC (Meq/ 100 g soil)
150	4.713	7.12	2.65	4.57	0.37	3.29	7.42	0.35	24.10
150	3.142	6.75	2.76	4.76	0.30	3.54	7.49	0.37	21.83
100	4.713	6.65	2.78	4.79	0.30	2.24	1.86	0.58	23.62
50	0	5.98	2.59	4.47	0.31	3.08	1.86	0.36	22.39
100	1.571	5.89	2.72	4.69	0.31	1.40	1.87	0.55	22.94
100	3.142	6.32	2.80	4.83	0.31	5.20	7.42	0.44	24.89
0	1.571	6.08	2.88	4.97	0.31	1.92	7.42	0.77	20.65
50	1.571	5.88	2.66	4.59	0.31	3.33	3.75	0.66	22.51
50	4.713	6.78	2.71	4.67	0.27	1.39	7.42	0.44	22.64
0	3.142	6.60	2.78	4.79	0.30	4.14	6.78	0.52	22.83
0	4.713	6.83	2.67	4.60	0.30	2.22	2.42	0.32	21.86
150	1.571	6.15	2.82	4.86	0.31	1.39	7.42	0.47	21.84
150	0	5.76	2.61	4.50	0.30	2.77	4.29	0.49	21.26
50	3.142	6.33	2.53	4.36	0.30	2.44	1.25	0.62	20.29
100	0	6.00	2.47	4.26	0.30	3.33	4.97	0.37	23.60
0	0	5.79	2.68	4.62	0.31	1.72	8.72	0.27	22.11

OC: Organic carbon, OM: Organic matter, TN: Total nitrogen, P: Phospurus, S: Sulfur, B: Boron and CEC: Cation exchange capacity

required quantity of lime and fertilizer generally had higher PH values. This finding was consistent with that reported by Chimdi *et al.*[26], who noted that lime had an ameliorative impact in reducing soil acidity by raising soil pH, decreasing the activity of aluminum ions in soil solution and reducing exchangeable acidity. Available boron increased across all treatments except the control which ranged from 0.32 up to 0.66 (Table 2). These are low according to the rating of Buchholz[24] even though there is an increment. Similarly, total nitrogen increased at the highest rate of NPSB and lime rate by 10.8%. Cation exchange capacity also increased at the some/highest rate of lime and blended NPSB while it decreased at control treatment.

Contrary to the conclusions reported by Alemu *et al.*[27] and Dinkecha and Tsegaye[28], accessible phosphorus in this investigation showed a declining tendency with an increase in the amount of lime applied. This might be because the P concentrations in the environment were higher than Selassie *et al.*[29] threshold limit. This result, however, was consistent with Haynes[30] observations that the precipitation of insoluble calcium phosphates has the ability to lower P availability at high soil pH and low Al concentration values. Since the soils only contain trace amounts of exchangeable Al, when a large amount of lime is applied, Ca may fix free accessible. Organic carbon and sulfur availability both declined.

Phenological and growth parameters

Days to 50% heading: The results of the analysis of variance showed that neither the main effects nor the interactions of the NPSB and lime rates had a significant ($p<0.05$) impact on the number of days to 50% heading. Given that the crop's variety is the same for all treatments, this might be a genetic effect of the crop (Table 3). Lack of significance could be caused by a genotype's genetic makeup having a significant influence on how the crop heads. This result was in line with the findings of Beketa *et al.*[31], who reported a non-significant for heading on different blended fertilizer rates.

Days to 90% physiological maturity: According to the analysis of variance, neither the main effects nor the interactions between NPSB and lime rates had a significant ($p<0.05$) impact on the number of days to 90% maturity. This may be due to the genetic effect of the crop since the variety is the same for all treatments (Table 4). The lack of significance might be due to the maturity of the crop is mainly controlled by the genetic makeup of a genotype.

Table 3: Mean squares of ANOVA for growth, yield and yield component parameters of bread wheat at highland of Guji

SV	DF	DTM	DTH	TKW (g)	GY (kg ha^{-1})	PH (cm)	SL(cm)	NTPP	NPTPP	NKPS
Rep	2	26.00	0.260	22.52	2496272	78.88	0.103	0.4287	0.34190	116.59
NPSB	3	4.76^{ns}	7.278^{ns}	30.08*	3383341**	148.67**	0.907^{ns}	2.5284**	1.54437**	301.54**
Lime	3	1.51^{ns}	2.417^{ns}	3.75^{ns}	2281247**	28.16^{ns}	2.179^{ns}	0.8295**	1.26249**	276.63**
L×NPSB	9	0.83^{ns}	3.898^{ns}	6.73^{ns}	1543673**	38.01*	0.754^{ns}	0.1975*	0.26875*	131.92**
Error	78	94.16	4.579	10.44	379489	28.52	1.306	0.1147	0.09797	35.42
CV (%)		6.2	2.5	8.3	17.7	6.7	15.5	14.4	16.2	14.1

SV: Source of variation, DF: Dgree of freedom, DTH: Days to heading, DTM: Days to maturity, TKW: Thousand kernels weight, GY: Grain yield, PH: Plant height, SL: Spike length, NTPP: Number of tiller per plant, NPTPP: Number of productive tiller per plant, NKPS: Number os kernels per spike, CV: Coefficient of variation, *p<0.05, **p<0.01 and ns: Non-significant

Table 4: Number of days takes bread wheat to reach 50% heading and 90% maturity

	Days to heading				Days to maturity			
	Lime rate (t ha^{-1})				Lime rate (t ha^{-1})			
NPSB (kg ha^{-1})	0	1.57	3.14	4.713	0	1.57	3.142	4.713
0	83.33	82.67	83.00	82.33	167.00	166.00	167.00	167.00
50	83.33	82.33	82.67	82.67	165.30	166.30	167.00	165.00
100	82.67	83.00	83.00	83.00	165.00	165.30	165.30	165.30
150	83.00	83.00	82.33	82.33	167.00	168.30	165.30	166.70
Mean	82.78				166.19			
LSD (0.05)	ns				ns			
CV (%)	0.70				1.10			

Means with the same letter (s) in the columns and rows are not significantly different at a 5% level of significance, CV (%): Coefficient of variation, ns: Non-significant and LSD: Least significant difference at a 5% level

Plant height: Plant height was strongly ($p<0.01$) impacted by the NPSB and lime rate interactions. However, the main effect of NPSB had a high ($p<0.05$) impact on plant height While this parameter did not significantly respond to the major influence of lime rate.

Although, there was no statistically significant difference between 150 and 100 kg NPSB ha^{-1}, the results showed that wheat plant height increased as the NPSB rate increased (Table 5). The tallest plant (85.91 cm) measured at 3.14 t ha^{-1} and 150 kg NPSB ha^{-1} while the control treatment (0 kg NPSB ha^{-1}+0 t lime ha^{-1}) produced the shortest plant (80.91 cm). The findings of this study were in agreement with those of Abdeta *et al.*[32], who noted that maize plants grew to their peak plant heights when blended NPSB and lime were applied together. Thus, compared to the control plot that did not receive any fertilizer or lime, the application of lime and NPSB increased the height of bread wheat.

Spike length: The results of the analysis of variance showed that there was no significant difference ($p<0.05$) between the main effects and the interaction of NPSB and lime rates on the spike length (Table 3). Since we utilize the same variety for all treatments, this might be because of the genetic makeup of the wheat crop. This result was consistent with that of Demissie *et al.*[33], who found that the barley plant reached its maximum height (95.33 cm) following the application of lime (611 kg ha^{-1}), NPSB (150 kg ha^{-1}) and compost (5 t ha^{-1}).

Yield-related traits and grain yield of bread wheat

Number of tillers per plant: The number of tillers produced per plant was highly significantly ($p<0.01$) impacted by the interactions between NPSB and lime rates. On the number of tillers produced per plant, the major effects of NPSB and the lime rate were also significant ($p<0.05$) (Table 3).

With higher NPSB fertilizer and lime rates, the number of tillers per plant increased dramatically. Wheat tiller production was considerably impacted by the interactions between NPSB and lime rates. The plots treated with the greatest rates of NPSB and lime (150 kilogram NPSB ha^{-1}+4.713 t lime ha^{-1}) produced

Table 5: Effect of NPSB fertilizer and lime rates in combination on bread wheat spike length and plant height

	Plant height (cm)				Spike length (cm)			
	Lime rate (t ha^{-1})				Lime rate (t ha^{-1})			
NPSB (kg ha^{-1})	0	1.57	3.142	4.713	0	1.57	3.142	4.713
0	80.91^{abcd}	78.05^{bcde}	77.69^{cde}	74.33^{e}	6.528	7.611	7.609	7.276
50	80.11^{abcde}	77.72^{cde}	76.28^{de}	77.92^{bcde}	7.47	7.414	7.109	6.799
100	77.47^{cde}	81.33^{abcd}	83.94^{ab}	78.25^{bcde}	7.221	7.553	7.748	7.194
150	82.69^{abc}	80.44^{abcde}	85.91^{a}	83.39^{abc}	7.276	7.554	8.442	7.249
G. Mean	79.78				7.38			
LSD (0.05)	6.14	ns						
CV (%)	6.7	15.50						

Means with the same letter (s) in the columns and rows are not significantly different at a 5% level of significance, CV (%): Coefficient of variation, ns: Non-significant and LSD: Least significant difference at a 5% level

Table 6: Number of tillers and productive tillers per plant of bread wheat as affected by the interaction of NPSB fertilizer and lime rates

	Number of tillers per plant				Number of fertile tiller per plant			
	Lime rate (t ha^{-1})				Lime rate (t ha^{-1})			
NPSB (kg ha^{-1})	0	1.57	3.14	4.713	0	1.57	3.142	4.713
0	1.513^{g}	2.08^{f}	2.213^{def}	2.077^{f}	1.065^{g}	1.895^{cdef}	2.005^{cde}	1.672^{ef}
50	2.067^{f}	2.577^{bcde}	2.243^{def}	2.243^{def}	1.595^{f}	1.842^{cdef}	1.785^{def}	1.895^{cef}
100	2.19^{ef}	2.247^{cdef}	2.577^{bcde}	2.633^{abc}	1.875^{cdef}	2.005^{cde}	2.115^{bcd}	2.395^{ab}
150	2.58^{bcd}	2.577^{bcde}	2.877^{ab}	2.987^{a}	1.895^{cdef}	2.062^{bcd}	2.642^{a}	2.172^{bc}
Mean	2.35				1.93			
LSD (0.05)	0.39				0.36			
CV (%)	4.90				5.30			

Means with the same letter (s) in the columns and rows are not significantly different at a 5% level of significance, CV (%): Coefficient of variation and LSD: Least significant difference at a 5% level

the most tillers per plant (2.987), followed by 150 kg NPSB+3.14 t lime ha^{-1}. In contrast, the control plots that received no lime or fertilizer produced the fewest tillers per plant (1.53) (Table 6). The quick conversion of produced carbohydrates into protein and the subsequent increase in the quantity and size of developing cells may be the cause of the maximum number of tillers at the highest rates of NPSB and lime[33]. The increase in the overall number of tillers seen after the administration of NPSB may be attributable to the P present in NPSB's role in the development of emerging radical and seminal roots during the establishment of wheat seedlings[34]. In general, all of the treated plots had significantly more tillers per plant than the unfertilized plots (Table 6). Similar to this finding, Demissie *et al.*[33] reported the application of blended NPSB, lime and compost in the acidic soil of West Shewa resulted in the maximum number of barley tillers.

Number of productive tillers: The number of bread wheat productive tillers was significantly ($p<0.01$) impacted by the interaction between NPSB and Lime rates. This parameter was also considerably impacted by the major effects of lime and NPSB (Table 3).

The number of fertile tillers increased when NPSB and lime application rates were increased. Thus, the rate of 150 kg NPSB ha^{-1} and 3.14 t lime ha^{-1} produced the maximum number of productive tillers (2.64) whereas the control treatment produced the fewest (1.06) (Table 6). This outcome was consistent with what Demissie *et al.*[33] discovered.

Thousand kernels weight: A thousand wheat kernels' weight of weight was significantly ($p<0.05$) impacted by the major effect of NPSB. However, the weight of a thousand bread wheat kernels was not significantly impacted by the main effect of lime or the two-factor interactions (Table 3).

Table 7: Impact of NPSB fertilizer and lime rate on thousand kernel weight of bread wheat

NPSB (kg ha^{-1})	TKW (g)
0	37.61^{b}
50	38.37^{ab}
100	39.65^{a}
150	40.02^{a}
Mean	38.91
LSD (0.05)	1.80
CV (%)	8.10
Lime rate (t ha^{-1})	
0	38.9
1.57	38.36
3.14	39.13
4.713	39.25
Mean	38.91
LSD (0.05)	ns
CV (%)	8.4

Means with the same letter (s) in the columns and rows are not significantly different at a 5% level of significance, CV (%): Coefficient of variation, ns: Non-significant and LSD: Least significant difference at a 5% level

Table 8: Interaction effect of NPSB fertilizer and lime rate on grain yield and number of kernels per spike of bread wheat

	Grain Yield				Number of kernels per spike			
	Lime rate (t ha^{-1})				Lime rate (t ha^{-1})			
NPSB (kg ha^{-1})	0	1.57	3.14	4.713	0	1.57	3.14	4.713
0	2414^{e}	3161^{cd}	3483^{bcd}	3084^{cde}	32.01^{g}	32.39^{fg}	40.89^{de}	42.23^{de}
50	3565^{abc}	3098^{cde}	3412^{bcd}	3098^{cde}	39.11^{def}	49.28^{abc}	42.62^{cde}	42.39^{de}
100	2837de	3976^{ab}	4071^{ab}	4003^{ab}	42.28^{de}	42.12^{de}	43.08^{cde}	50.01^{ab}
150	3396^{bcd}	3987^{ab}	4201^{a}	3791^{abc}	39.39^{de}	38.06^{efg}	53.62^{a}	45.06^{bcd}
Mean	3473.63				42.16			
LSD (0.05)	708.071				6.84			
CV (%)	17.70				4.50			

Means with the same letter(s) in the columns and rows are not significantly different at a 5% level of significance, CV (%): Coefficient of variation, ns: Non-significant and LSD: Least significant difference at a 5% level

Even though there was no discernible difference between 150 and 100 kg NPSB ha^{-1}, greater NPSB rates led to an increase in thousand kernels weight of bread wheat (Table 7). The application rate of 150 kg NPSB ha^{-1} produced the highest weight per thousand kernels (40.02 g), followed by 100 kg ha^{-1} (Table 7). On the other side, the control (0 kg NPSB ha^{-1}) showed the smallest thousand kernel weight (37.61 g). This might be due to the improvement of seed quality and size due to nitrogen and the synergic effect of nutrients in the NPSB.

Number of kernels per spike: The main effects of NPSB and lime, as well as their interaction, were significant ($p<0.01$) for the number of kernels per spike, according to the analysis of variance (Table 3).

The two variables strongly interacted to affect the quantity of bread wheat kernels per spike (Table 8). Thus, even though it was inconsistent, increasing the rates of NPSB and lime generally increased the amount of kernels generated in each spike. In general, the highest rate of NPSB fertilizers (150 kg NPSB ha^{-1}) and the needed lime rate (3.14 t ha^{-1}) generated the highest number of kernels per spike (53.62), whereas the lowest number of kernels per spike (32.01) was produced under the control treatment (Table 8). This showed that NPSB increased the amount of kernels per spike, which may be because P is necessary for the development of seeds and fruit. This also might be due decrement of soil acidity by lime through neutralization and an increase in soil nutrient availability by enhancing mineralization. These additionally demonstrated how the two elements worked together synergistically to boost the number of kernels produced per spike and grain yield. This finding was in line with that of Demissie *et al.*[33], who noted that barley had a larger number of kernels per spike (50.66) when lime, compost and NPSB were all used in conjunction.

Grain yield: The grain yield of bread wheat was highly ($p<0.01$) impacted by the main impacts of NPSB and their interactions. Similarly, grain yield was considerably ($p<0.05$) impacted by lime's major influence (Table 3).

Grain yields greatly increased when NPSB and lime rates were increased (Table 8). As a result, the combined rates of 150 kg NPSB ha^{-1}+3.14 t lime ha^{-1} produced the highest grain yield (4201 kg ha^{-1}) which was statistically equivalent to 100 kg NPSB ha^{-1}+3.14 t lime ha^{-1} with grain yield of 4071 kg ha^{-1} (Table 8). The combination of 0 kg NPSB+0 t lime ha^{-1} (control treatment) had the lowest grain yield (2414 kg ha^{-1}). The highest grain production at the highest NPSB and lime rates may have resulted from higher root development, faster nutrient uptake and better growth favored by the interaction/synergistic effect of the three nutrients which improved yield components and yield. It also might be due to the availability of nutrients and increased nutrient uptake as soil acidity/toxicity decreased due to lime application[26]. In general, the highest grain yield obtained from fertilizer and limed exceeded the grain yield from the control plots by about 42.5% i.e. application of lime and combinations of fertilizers significantly increased bread wheat yield over untreated (control).

In line with the result of this study, Beketa[31] reported that raising the NPSB rate and liming rate boosted the grain yield of maize, with the application of 100 kg NPSB ha^{-1}+necessary lime having around 74.83% more grain yield than the control plots. According to Haileselassie *et al.*[35], bread wheat grain yield increased by roughly 6.8% when the P rate was raised from 46 to 69 kg P2O5 ha^{-1}. Similarly, by applying lime, NPSB and compost, Demissie *et al.*[33] obtained a maximum yield of 5385.6 kg ha^{-1}. High grain production (4813 kg ha^{-1}) of wheat was also recorded by Erekul *et al.*[36] at a combined application of 210 kg N and 40 kg S ha^{-1}. Similar to this, Järvan *et al.*[37] reported that adding 100 kg N and 10 kg S to winter wheat resulted in a yield of 5.88 t ha^{-1} whereas adding 100 kg N and 6 kg S with increased grain protein content resulted in a yield of 5.73 t ha^{-1}. This shows that the nutrients work together to increase wheat yield and quality. Similar to this, Hayat *et al.*[38] got the maximum grain yield of wheat (4463.5 kg ha^{-1}) at 140 kg N ha^{-1} and 20 kilogram S ha^{-1}, respectively, at sowing and a thesis.

Partial budget analysis: Table 9 shows the analyzed result of the net benefits, total variable expenses that vary and marginal rate of return. For farmers to adopt technical innovation, knowledge of the costs and advantages of treatments is a requirement. In order to produce suggestions from the agronomic data, the research evaluated the financial advantages of the treatments. This enhances the selection of the right combination of resources by farmers in the study area. According to the study's findings, applying lime and NPSB fertilizer together produced larger net benefits than the unfertilized and limed/control treatments (Table 9).

According to Table 9, the combined application of 100 kg NPSB ha^{-1}+3.14 t lime ha^{-1} produced the maximum net benefit (Birr 115166.88 ha^{-1}) followed by 100 kg NPSB ha^{-1}+1.571 t lime ha^{-1} (112498.13 Birr ha^{-1}) and the control treatment produced the lowest net benefit. The minimum acceptable rate of return should range from 50 to 100% when using the marginal rate of return (MRR%) as a foundation for fertilizer recommendations[20]. The largest economic benefit in this study was 115166.88 ha^{-1}, with a marginal rate of return of 1779.17%, from the application of 100 kg NPSB ha^{-1}+3.14 t lime ha^{-1}. For the production of bread wheat in the research area and other places with similar agroecological circumstances, the combined application of 100 kg NPSB ha^{-1} and 3.14 t lime ha^{-1} is, therefore, the best and most cost-effective. Thus this treatment was recommended for the study area.

Table 9: Analysis of the partial budget and marginal rate of return for the bread wheat as influenced by NPSB and lime rates

Treatments		Adjusted grain yield downwards by 10% (kg ha^{-1})	Gross benefit (Birr ha^{-1})	Total variable cost (Birr ha^{-1})	Net return (Birr ha^{-1})	MRR (%)
NPSB (kg ha^{-1})	Lime rate (t ha^{-1})					
0	0	2172.92	71706.25	0.00	71706.25	0.00
0	1.571	2844.79	93878.13	300.00	93578.13	7290.6
0	3.142	3134.38	103434.38	450.00	102984.38	6270.83
0	4.713	2776.04	91609.38	600.00	91009.38	D
50	0	3208.33	105875.00	2640.00	103235.00	11.44
50	1.571	2788.54	92021.88	2940.00	89081.88	D
50	3.142	3070.83	101337.50	3090.00	98247.50	D
50	4.713	2788.54	92021.88	3240.00	88781.88	D
100	0	2553.54	84266.88	5280.00	78986.88	D
100	1.571	3578.13	118078.13	5580.00	112498.13	315.07
100	3.142	3663.54	120896.88	5730.00	115166.88	1779.17
100	4.713	3603.13	118903.13	5880.00	113023.13	D
150	0	3056.25	100856.25	7920.00	92936.25	D
150	1.571	3588.54	118421.88	8220.00	110201.88	D
150	3.142	3781.25	124781.25	8370.00	116411.25	47.13
150	4.713	3411.46	112578.13	8520.00	104058.13	D

MRR (%): Marginal rate of return, D: Dominated treatment and Control: Unfertilized and unlimed

In line with this result, Beketa *et al.*[31] reported higher grain yield and economic benefit of wheat in the Southern part of Ethiopia. Similarly, Demissie *et al.*[33] recommended the integrated use of lime, NPSB, compost and Kcl for the production of barley in the Wolmera District, West Shewa zone.

CONCLUSION

Analysis of the data showed that all parameters were significantly ($p<0.05$) affected by the interaction and main effects of the factors with the exception of the date to DTH, DTM and SL. This shows how the factors play a role in the productivity and production of bread wheat. Generally speaking, all measurements taken over treated plots were higher than those taken over control plots. Thus, yield and yield components of bread wheat improved by utilizing lime and NPSB fertilizer. The combined applications of 100 kg NPSB ha^{-1} and 3.14 t lime ha^{-1} provided the best economic benefit with acceptable MRR, according to the partial budget analysis. Therefore, for the research region and other places with similar agro ecologies, the use of 100 kg NPSB ha^{-1} and 3.14 t lime ha^{-1} can be advised for the production of bread wheat. In addition, lime combination with other blended fertilizers and acid soil management practices should also be done in the future.

SIGNIFICANCE STATEMENT

This study determined the effect of inorganic (NPSB) and lime rates on yield component, yield and soil physical and chemical properties of soil. This research indicated using of NPSB and lime increased yield, yield traits and soil pH of the experimental site. Thus, the combined use of NPSB and lime is important for the production and productivity of bread wheat.

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