Daagu International Journal of Basic and Applied Research 8(1) (2026): 874-889
doi: 10.20372/dijbar309.v8i1.2026

Research Article

Effect of NPS and NPSB blended fertilizers application on newly released barley varieties (*Hordeum vulgare* L.) in Degu'a Tembien district, Tigray, Ethiopia

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Received: October 21, 2025 Revised: February 03, 2026 Accepted: February 17, 2026

Abstract

Barley is an important food and beverage crop in the highlands of Tigray, Ethiopia, where soil nutrient depletion and low-yielding varieties have contributed to declining productivity. A field experiment was conducted during the 2017 and 2018 rainy seasons in Degua Tembien Woreda to evaluate the effects of blended NPSB fertilizer rates on the yield and yield components of two food barley (*Hordeum vulgare* L.) varieties, Illala-1 and Illala-2. The treatments consisted of five fertilizer rates (control, 100 kg NPS + 46 kg N ha^{-1}, 50 kg NPSB + 23 kg N ha^{-1}, 100 kg NPSB + 46 kg N ha^{-1}, and 150 kg NPSB + 69 kg N ha^{-1}) and two barley varieties arranged in a factorial RCBD with three replications. Results showed that grain yield and yield components were significantly ($P < 0.01$) affected by fertilizer application. The highest grain yields were obtained from 150 kg NPSB + 69 kg N ha^{-1}, producing 4,257 kg ha^{-1} and 4,148 kg ha^{-1} for Illala-1 and Illala-2, respectively. This treatment also generated the highest net returns, with ETB 56,722 ha^{-1} for Illala-1 and ETB 55,332 ha^{-1} for Illala-2. Based on agronomic and economic performance, the application of 150 kg NPSB ha^{-1} combined with 69 kg N ha^{-1} is recommended for Illala-1 barley production in Degua Tembien and similar agro-ecological areas.

Keywords: Barley varieties, blended fertilizer, economic analysis, nitrogen, yield.

1. INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the most staple foods and economically important cereal crop in Ethiopia which ranked fifth next to tef, maize, wheat, and sorghum [Central Statistical Agency (CSA, 2014)]. It is a crop with a wide adaptation (Dawson et al., 2015), more drought and disease resistant crop than wheat and is also more productive under adverse conditions (Brahmi et al., 2023). The average yield of barley in Ethiopia is lower (2.18 t ha^{-1}) compared to the world

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average (2.89t ha^{-1}) and its potential yield, which is 6t ha^{-1} (Shawl et al., 2021). Though numerous factors are responsible for low yields, low soil fertility is the most limiting factor that affects plant growth and grain yield. Production of barley in Ethiopia fall under low fertility soils (Yihenew, 2002). Sinebo et al. (2003) reported that about 65% of grain yield variability in barley was attributed to N stress. Similarly, Cantero-Martínez *et al*. (2003) reported that yields of barley under N and P stresses are reported to be less than 50%. In Ethiopia, fertilizer use trend has been focused mainly on the use and application of N and P fertilizers in the form of Di-ammonium phosphate (DAP) (18-46-0) and urea (46-0-0), a blanket recommendation for the major food crops. Moreover, nutrient mining due to sub-optimal fertilizer use in one hand and unbalanced fertilizer (only N and P) uses on the other hand have favored the emergence of multi-nutrient deficiency in Ethiopian soils (Wassie *et al*., 2011). Recently acquired soil inventory data revealed that Ethiopian soils lack seven soil nutrients (N, P, K, S, Fe, Zn and B) [Ethiopian Soil Information System, (Ethio-SIS, 2016)]. Therefore, different fertilizer materials would be required to ensure balanced fertilizer use involving all or most of the nutrients required by crops for sustainable farming.

Barley is a strategic crop in the rain fed highlands of Tigray, because of its usefulness in farmers' strategy for risk aversion and as a dependable catch crop at the end of the rainy season in which food is usually scarce. However, farmers are still following their traditional varieties and crop management practices to alleviate the persisting production constraints. There is no information on the application of blended fertilizer rates in the study area. Therefore, this study was conducted to evaluate the response of newly released barley varieties to different rates of NPSB blended fertilizer. The study is particularly important because it assesses the effects of sulfur (S) and boron (B), newly introduced nutrients in the blended fertilizer recommendation for barley production in the study area. The findings are expected to contribute to improved fertilizer recommendations, leading to increased barley grain and straw yields, thereby enhancing food production and livestock feed availability for farmers. Specifically, the study aimed to address the following research questions: (1) What is the optimum rate of blended fertilizer adjusted with nitrogen for barley in the study area and other similar areas? and (2) Do the Illala1 and Illala2 barley varieties differ in their response to the blended fertilizer rates?

2. MATERIALS AND METHODS

2.1. Description of the experimental site

The experiment was conducted in Degu'a Tembien Woreda, South Eastern Zone of Tigray, during 2017 and 2018 cropping seasons. The site is located from 13º36'30" N to 13º42"30" N and 39º 2" 30" E to 39º 11' 30" E (Figure1). The soil of the experimental site is Vertisols with a textural class of clay loam (45%) Rowell (1994). According to the rating of Tekalign (1991), the soil reaction (pH) was slightly alkaline (7.7), organic carbon (OC) content was very low (0.49%); and the total N content was very low (0.01%). According to the rating of Cottenie (1980), the available Phosphorus content was low (100 ppm). Based on the rating of Hazelton and Murphy (2007), the cation exchange capacity (CEC) of the soil was high (37.8 cmol (+) kg^{-1} soil).

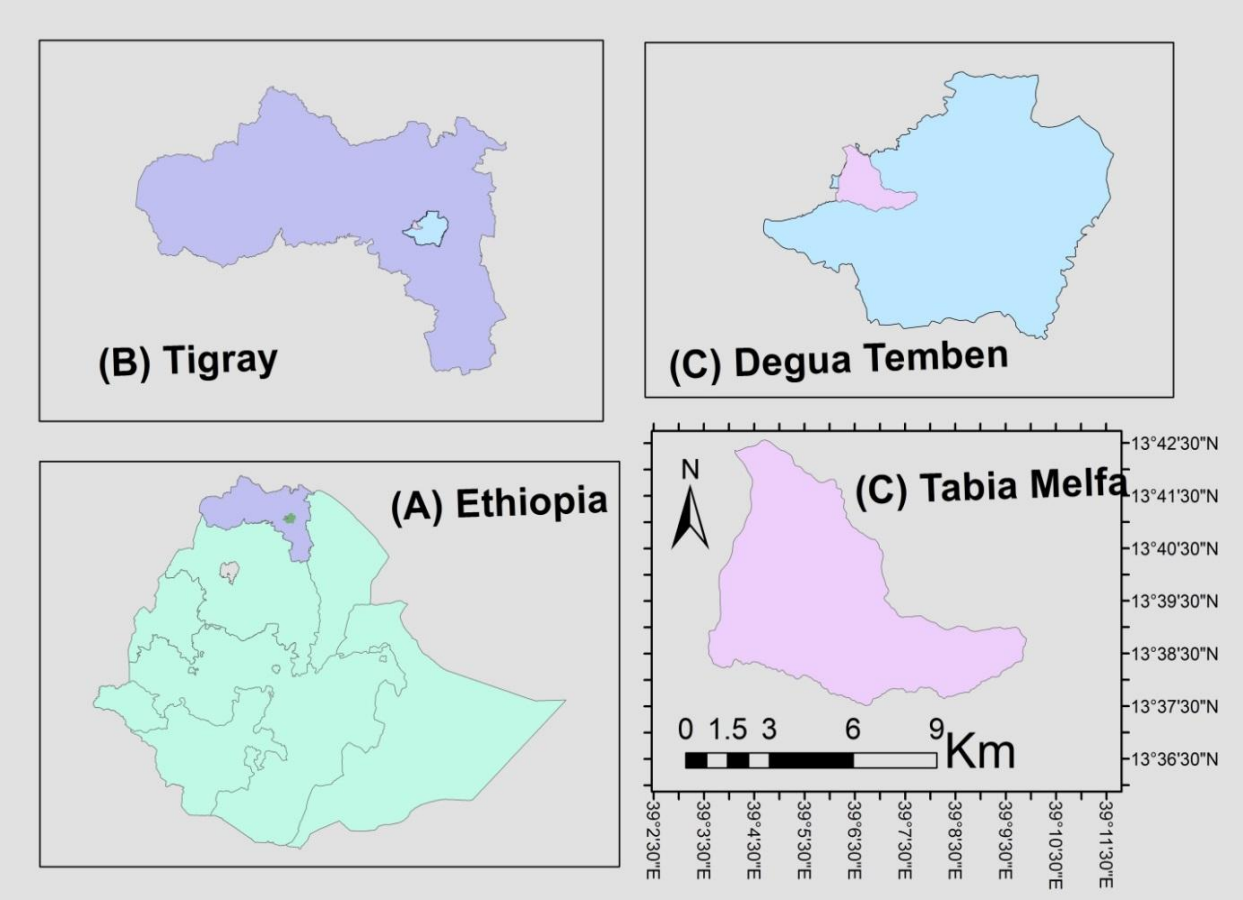


Figure 1. Map showing Douga Temben district with selected study area

2.2. Treatments, experimental design and procedure

The experiment consisted of ten treatment combinations comprising five fertilizer rates: control (no fertilizer), 100 kg NPS + 46 kg N ha^{-1}, 50 kg NPSB + 23 kg N ha^{-1}, 100 kg NPSB + 46 kg N

ha^{-1}, and 150 kg NPSB + 69 kg N ha^{-1}; and two barley varieties (Illala-1 and Illala-2). Treatments were arranged in a factorial Randomized Complete Block Design (RCBD) with three replications. According to Ethio-SIS (2016), NPS fertilizer contains 19% N, 38% P_2O_5, and 7% S, whereas NPSB contains 18.1% N, 36.1% P_2O_5, 6.7% S, and 0.71% B. Urea (46% N) was used as the nitrogen source.

The experimental field was plowed three times using ox-drawn implements and prepared manually before planting. All NPS and NPSB fertilizers, together with half of the nitrogen from urea, were applied at sowing, while the remaining nitrogen was top-dressed at the tillering stage. Barley seeds were hand-drilled at a rate of 100 kg ha^{-1}. Each plot measured 3 m × 3 m (9 m^2), with row, plot, and block spacings of 0.20 m, 1.0 m, and 1.5 m, respectively. Recommended agronomic practices were followed throughout the growing season, and harvesting was carried out manually using hand sickles.

2.3. Soil sampling and analysis

Before planting, surface soil samples were collected from the 0–20 cm soil layer at twelve randomly selected points across the experimental field. The samples were composited and analyzed for selected physicochemical properties using standard laboratory procedures. The 0–20 cm sampling depth was chosen because it corresponds to the plow layer commonly used for cereal crop production and represents the soil zone with the highest root concentration and nutrient uptake. In barley, approximately 65% of the total root length is concentrated within this depth, making it the most relevant layer for assessing soil fertility and nutrient availability.

2.4. Data collection and measurement

Growth and yield parameters were measured from the net plot area to minimize border effects. Plant height, spike length, and number of seeds per spike were recorded from ten randomly selected plants in each plot at physiological maturity. Grain yield and aboveground biomass data were collected from the central 13 rows of each plot. The harvested biomass was sun- and air-dried for three days before weighing. Grain yield (kg ha^{-1}) was determined after threshing the harvested plants and adjusted to a standard moisture content of 12.5%. Harvest index (HI) was calculated as the ratio of grain yield to total aboveground dry biomass yield. Thousand-kernel weight was determined by counting and weighing 1,000 randomly selected seeds from each plot.

2.5. Data analysis

All collected data were subjected to statistical analysis using the Statistical Analysis System (SAS) software version 9.2. Analysis of variance (ANOVA) was performed, and whenever treatment effects were significant, mean comparisons were conducted using the Least Significant Difference (LSD) test at the 5% probability level. Economic analysis was carried out to assess the profitability of the treatments. In addition, Pearson's correlation analysis was used to determine the relationships among barley yield, growth parameters, and fertilizer treatments. **2.5.1.** ***Partial budget analysis***

Economic analysis was conducted using the partial budget procedure developed by the International Maize and Wheat Improvement Center (CIMMYT, 1988). The analysis was based on the prevailing market prices of inputs at planting and outputs at harvest. During the 2018 production season, the average market prices of barley grain and straw were ETB 15.00 kg^{-1} and ETB 0.55 kg^{-1}, respectively. The costs of NPSB fertilizer and urea were ETB 19.30 kg^{-1} and ETB 11.00 kg^{-1}, respectively.

To reflect the yield levels expected under farmers' conditions, grain and straw yields were adjusted downward by 10% before economic calculations. Gross benefit (GB) was calculated from the adjusted yields, while net benefit (NB) was obtained by subtracting the total variable cost (TVC) from the gross benefit. The marginal rate of return (MRR) was computed as the ratio of the change in net benefit to the change in total variable cost and expressed as a percentage.

3. RESULTS

3.1.1. Effect on phenological parameters of Barley

The study results showed that days to heading and maturity were significantly influenced ($P < 0.01$) by the main effects of variety, fertilizer rate, and year of cultivation, as well as by the interaction between fertilizer and year (Tables 1 and 4). The control plots recorded significantly greater days to heading (63.7) and maturity (90.3) compared with the lowest values observed in plots receiving NPSB100 + N 46 kg ha^{-1}, which had 59.4 days to heading and 88.42 days to maturity.

Regarding varietal effects, Illala2 exhibited a longer growth period to reach physiological maturity than Illala1, exceeding it by approximately 6.2%.

Table 1. Mean days to heading, days to maturity and plant height as influenced by fertilizer, variety and year and their interaction.

Year* fertilizer

Fertilizers rate (kg ha^{-1})	Days to heading			Days to maturity			Plant height (cm)		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
NPSB0 +N 0	64.1a	63.0b	63.5^{a}	93.87c	82.67d	88.27b	74.6^{c}	57.0^{c}	65.8^{e}
NPSB100+N46	63bc	60.f	61.4^{b}	95.67bc	82.2d	88.92b	99.6^{a}	83.9^{a}	97.72^{a}
NPS 100 +N 46	62.6cd	55.8h	59.2^{c}	95.67^{bc}	82.3d	88.97b	91.3^{b}	83.1^{ab}	87.17^{c}
NPSB50 +N23	62.3d	56.4g	59.3^{c}	98.37^{a}	82.2d	90.27a	86.1^{b}	77.8^{b}	81.93^{d}
NPSB150 N69	61.3e	61.1^{e}	61.2^{b}	96.67^{ab}	83.97d	90.32a	104.7^{a}	82.6^{ab}	93.63^{b}
P value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0.0000
LSD	0.4076	0.4076	0.2459	2.1190	2.1190	1.2781			0.4836
Variety									
Illala 1	61.07a	58.53^{b}	59.8^{b}	92.6^{b}	80.7^{d}	86.65^{b}	89.99^{b}	77.3c	83.65b
Illala 2	64.20b	61.27a	62.7^{a}	99.5^{a}	84.6^{c}	92.035^{a}	92.50^{a}	76.4d	84.45a
P value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LSD	0.2063	0.2063	0.1098	1.0726	1.0726	0.5709	0.4059	0.4059	0.2160
Year									
2017			62.6^{a}			96.05a			91.24^{a}
2018			59.9^{b}			82.65b			76.85^{b}
P value			0.0000			0.0000			0.0000
LSD			0.1098			0.5709			0.2160
CV (%) all	4.0	4.0	4.0	3.6	3.6	3.6	5.8	5.8	5.8

*LSD = least significant difference; CV = coefficient of variation, ** Significant, ns= not significant, Means in a column followed by the same letters are not significantly different at ($P \leq 0.05$)

A significant fertilizer × year interaction was also observed. In 2017, the highest values for days to heading (64.1, control) and maturity (98.4, NPSB100 + N46) were recorded, whereas the lowest values were observed in 2018, with 55.8 days to heading in plots treated with NPSB100 + N46 and 82.2 days to maturity under the same fertilizer treatment. Overall, the absence of fertilizer delayed barley development, increasing days to heading and maturity by about 14.9% compared with fertilized treatments, while fertilizer application in 2017 accelerated both phenological stages.

3.2. Growth parameters of barley

Plant height of barley was significantly affected ($P < 0.01$) by the main effects of fertilizer rate, variety, and year of cultivation, as well as by the interaction between year and fertilizer. However, the three-way interaction (year × fertilizer × variety) and the two-way interaction between variety and fertilizer were not statistically significant (Table 1).

The tallest plants were recorded under NPSB100 + N 69 kg ha^{-1} (97.7 cm), followed by NPSB150 + N 46 kg ha^{-1} (93.6 cm). These treatments increased mean plant height by approximately 48.5% and 42.2%, respectively, compared with the control.

Plant height also responded significantly to the fertilizer × year interaction. The maximum plant height (104.7 cm) was obtained in 2017 with the application of NPSB150 + N 69 kg ha^{-1}. This treatment increased plant height by 40.4% relative to the corresponding unfertilized control. The

greater plant height observed in 2017 may be attributed to more favorable rainfall conditions, which enhanced nutrient uptake and promoted vegetative growth. In addition, sulfur (S) contributes to chlorophyll formation and vegetative growth, while boron (B) facilitates nitrogen uptake, jointly improving plant development.

Spike length was also significantly influenced ($P < 0.01$) by the main effects of fertilizer, variety, and year, as well as by the fertilizer × year and variety × year interactions. In contrast, the fertilizer × variety and three-way interactions were not significant. The longest spike length (8.1 cm) was recorded in plots treated with NPSB150 + N 69 kg ha^{-1}, followed by NPS100 + N 46 kg ha^{-1}, whereas the shortest spikes were observed in the control plots. The variety Illala-2 produced longer spikes than Illala-1, with an average increase of about 5%.

Spike length was further influenced by the variety × year interaction, with the highest value (9.0 cm) recorded in 2017 for Illala-2. This represented a 46% increase compared with Illala-1 grown in 2018 (Table 1).

3.3. Yield and yield components of Barley

Number of kernels per spike

The number of kernels per spike in barley was significantly influenced ($P < 0.01$) by the main effects of fertilizer rate, variety, and year of cultivation, as well as by the fertilizer × year and variety × year interaction effects. In contrast, the fertilizer × variety and the three-way interaction (year × fertilizer × variety) were not statistically significant.

The highest number of kernels per spike (22.8) was recorded under the application of NPSB100 + N 46 kg ha^{-1}, followed by NPSB150 + N 69 kg ha^{-1}. These treatments increased kernels per spike by approximately 24% and 21%, respectively, compared with the unfertilized control (Table 2).

Varietal differences were also significant ($P < 0.01$), with Illala-2 producing a greater number of kernels per spike than Illala-1. Accordingly, Illala-2 exceeded Illala-1 by about 9.7% in kernels per spike.

Table 2. Mean spike length, kernels per spike and thousand seed weight as influenced by fertilizer, variety and year and their interactions.

Year* fertilizer

Fertilizer rates	Spike length(cm)			Seeds per spike(no)			Thousand seed weight (g)		
(kg ha^{-1})*	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
NPSB0N0	7.8d	5.3h	6.55^{e}	19.21c	16.38^{d}	17.8^{d}	49.74a	44.67e	47.2b
NPS100N46	9.0b	6.5ef	7.75^{b}	22.81^{a}	21.44^{ab}	22.12^{a}	48.04b	45.98c	47.01b
NPSB50N23	8.8b	6.3fg	7.55^{c}	22.11^{a}	19.81^{bc}	20.96bc	49..45a	45.5c0	47.49b
NPSB100N46	8.4c	6.1g	7.25^{d}	22.21^{a}	18.04^{cd}	20.12^{c}	49.12a	47.28b	48.2a

NPSB150N69	9.5a	6.7e	8.10[a]	23.21[a]	19.84bc	21.52[ab]	47.87b	44.9de	48.38c
P value	0.0000	0.0000	0.0019	0.0000	0.0000	0.0000	0.0000	0.000	0.0000
LSD	0.2636	0.2636	0.1590	1.8930	1.8930	1.1418	0.8154	0.8154	0.4918
Variety									
Illala1	8.4b	6.15c	7.27[b]	20.03[b]	18.51[c]	19.27[b]	48.16[b]	45.11d	45.95[b]
Illala2	9.0a	6.22c	7.61[a]	23.79[a]	19.69[b]	21.19[a]	49.54[a]	46.22c	47.88[a]
P value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LSD	0.1334	0.1334	0.0710	0.9582	0.9582	0.5100	0.4127	0.4127	0.2197
Year									
2017			8.68[a]			22.91[a]			48.16[a]
2018			6.19[b]			19.10[b]			45.67[b]
P value			0.0000			0.0000			0.0000
LSD			0.0710			0.5100			0.2197
Fertilizer *Variety	NS								
Variety*year*fertilizer	Ns								
CV (%) all	5.6	5.6	5.6	6.0	6.0	6.0	4.9	4.9	4.9

SL= spike length, SPS= seeds per spike, TSW= thousand seed weight, LSD = least significant difference; CV = coefficient of variation, NS= not significant, Means in a column followed by the same letters are not significantly different at ($P \leq 0.05$)

A significant year effect was observed, with the highest mean number of kernels per spike (22.91) recorded in 2017, which was approximately 20% higher than that obtained in the 2018 cropping season (Table 2).

3.3.1. Total aboveground biomass yield

Biomass yield was significantly ($P < 0.01$) affected by the main effects of fertilizer application, variety, and year, as well as by the interactions between variety × fertilizer and fertilizer × year. However, it was not significantly influenced by the fertilizer × variety interaction, nor by the three-way interaction of fertilizer × year × variety (Tables 3 and 4).

Increasing fertilizer rates significantly enhanced the total aboveground biomass of barley. The highest biomass yields were recorded for Illala-1 (10,016 kg ha^{-1}) and Illala-2 (10,072 kg ha^{-1}) under the application of 150 NPSB + 69 kg N ha^{-1}. The application of 100 NPSB + 46 kg N ha^{-1} also produced yields that were statistically similar. In contrast, the lowest biomass yields were observed in the unfertilized control plots, with 3,702 kg ha^{-1} for Illala-1 and 3,493 kg ha^{-1} for Illala-2. Overall, the highest fertilizer rate increased total aboveground biomass by approximately 186% and 172% over the control for Illala-1 and Illala-2, respectively.

Table 3. Mean grain yield, biomass yield and harvest index as influenced by fertilizer, variety, year of cultivation and their interaction.

Year* fertilizer

Fertilizers	Grain yield kg ha$^{-1.}$			Biomass yield kg ha$^{-1.}$			Harvest index%		
(rate kg ha^{-1})*	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
NPSB0N0	1912[e]	1556[d]	1734[d]	4000[d]	3194[d]	3597[d]	0.48d	0.49[d]	0.48b
NPS100N46	3492[b]	3631[b]	3562[b]	7435[b]	9201[b]	8318[b]	0.55b	0.38[fg]	0.46c

NPSB50N23	3084[c]	3852[b]	3468[b]	6343[c]	9628[b]	7985[b]	0.52c	0.57a	0.55a
NPSB100N46	2735[d]	2997[c]	2866[c]	5889[c]	6786[c]	6338[c]	0.37g	0.33h	0.35e
NPSB150N69	3999[a]	4406[a]	4203[a]	8676[a]	11412[a]	10044[a]	0.46e	0.46e	0.42d
P value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011
LSD (0.05)	70.698	70.698	70.698	17.852	17.852	17.852	0.0148	0.0148	0.0089
Year									
2017			3044.4b			6468.5b			0.48a
2018			3288.5a			8044.4a			0.43b
P value			0.0000			0.0000			0.0000
LSD (0.05)			4.8093			4.8093			0.0039
Variety									
Illala1	2985d	3158b	3071.5b	6307d	7900.9a	7104b	0.48a	0.42c	0.45b
Illala2	3104c	3419a	3261.4a	6630c	8188b	7409[a]	0.47a	0.44b	0.46a
P value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LSD	35.786	35.786	19.046	9.0367	9.0367	4.8093	0.0075	0.0075	0.0098
CV (%) all	7.0	7.0	7.0	8.4	8.4	8.4	7.9	7.9	7.9
Variety*Fert.	NS								
Year*var*Fert	NS								

Means in a column followed by the same letters are not significantly different at ($P \leq 0.05$) LSD = least significant difference; CV = coefficient of variation, ns= not significant, **=significant

Biomass yield also showed a significant ($P < 0.01$) fertilizer × year interaction. Higher total biomass yield (11,412 kg ha^{-1}) was recorded in 2018 under the application of 150 NPSB + 69 kg N ha^{-1}, compared with 8,676 kg ha^{-1} in 2017. In 2018, this treatment increased aboveground biomass by about 31% relative to the same treatment in 2017 (Table 4).

3.3.2. Grain yield

Grain yield of barley was significantly ($P < 0.01$) influenced by the main effects of fertilizer application, variety, and year of cultivation, as well as by the interaction effects of fertilizer × variety and fertilizer × year. However, it was not significantly affected by the fertilizer × variety interaction or the three-way interaction of year × fertilizer × variety (Tables 3 and 4).

The highest grain yields were recorded for Illala-1 (4,297 kg ha^{-1}) and Illala-2 (4,108 kg ha^{-1}) under the application of 150 NPSB + 69 kg N ha^{-1}. These represent yield increases of approximately 150% and 135%, respectively, compared with the unfertilized control.

Similarly, grain yield showed a significant ($P < 0.01$) fertilizer × year interaction. The highest grain yield (4,537 kg ha^{-1}) was obtained in 2018 under the application of 150 NPSB + 69 kg N ha^{-1}, compared with 4,278 kg ha^{-1} recorded in 2017 under the same treatment. This corresponds to an increase of about 6.1% in 2018 relative to 2017 (Table 4).

Table 4. Interaction effect of fertilizer by year on yield and yield components of barley varieties at Degua Tembien

Year*fertilizer

Fertilizer rates by year (Kg ha^{-1})*	DTH (d)	DTM (d)	PTH (cm)	SPL cm)	TSW (g)	HI %	BYLD Kg ha^{-1}	GYLD Kg ha^{-1}
Y1(NPSB0+N0)	64.1a	93.9c	74.6h	7.8d	49.7a	0.48d	4000i	1912i
Y1 NPS100+N46	63.0bc	95.7bc	99.6b	8.8b	49.5a	0.55b	6343g	3492e
Y1 NPSB50+N23	62.6cd	95.7bc	91.3c	8.4c	49.1a	0.52c	5889h	3084f
Y1 NPSB100+N46	62.3d	98.4a	86.1d	9.0b	48.0b	0.37g	7435e	2735h
Y1 NPSB150+N69	61.4e	96.7ab	104.7a	9.5a	47.9b	0.46e	8676d	3999b
Y2 NPSB0+N0	63.0b	82.7d	57.0i	5.3h	47.3b	0.49d	3194j	1556.1j
Y2 NPS100+N46	59.8f	82.2d	83.9e	6.5ef	46.0c	0.38fg	9628b	3631.1d
Y2 NPSB50+N23	55.8h	82.3d	83.1ef	6.1g	45.5cd	0.57a	6786f	3852.1c
Y2 NPSB100+N46	56.3g	82.2d	77.8g	6.3fg	44.9de	0.33h	9201c	2997.1g
Y2 NPSB150+N69	61.1e	84.0d	82.6f	6.7e	44.7e	0.39f	11412a	4406.1a
P value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CV (%)	4.0	3.6	5.8	5.6	4.9	7.9	8.4	7.0
LSD	0.4076	2.1190	0.8018	0.2636	0.8154	0.0148	17.852	70.698

Y1= year 1(2017), Y2= year 2(2018), DTH= days to heading, DTM= days to maturity, PTH= plant height, SL= spike length, SPS= GYLD= grain yield, BYLD = biomass yield, TSW= thousand seed weight, HI= harvest index, CV = coefficient of variation, ns= not significant

Overall, grain yield was higher in 2018 than in 2017, which may be attributed to improved grain filling duration and more favorable growth conditions that enhanced crop development. Across both seasons, the pattern of response to fertilizer application remained consistent, with the highest and lowest yields recorded under the highest fertilizer rate and the control, respectively. Relative to the control, grain yield increased by about 109% and 183% in the respective years. This yield improvement with increasing fertilizer rates is likely due to the essential role of nutrients in enhancing physiological processes such as leaf expansion, photosynthetic activity, and dry matter accumulation.

3.3.3. Harvest Index

Harvest index (HI) of barley was significantly affected by the main effects of fertilizer, variety, and year, as well as by most interaction effects, except for the variety × fertilizer and year × fertilizer × variety interactions (Tables 3 and 4). The HI values ranged from 0.33 to 0.57, with the highest value recorded in 2018 under the control treatment. This suggests that at higher nitrogen application rates, a smaller proportion of biomass was partitioned into grain. The relatively higher HI observed in 2018 may be attributed to more efficient translocation of assimilates to the grains during that season.

3.4. Correlation of fertilizer with barely parameters

A positive correlation was observed between fertilizer application and grain yield, biological yield, spike length, number of seeds per spike, and plant height (Table 5). The correlation analysis showed that fertilizer had significant positive relationships with grain yield (r = 0.69), biological yield (r = 0.77), and plant height (r = 0.51). In contrast, fertilizer application showed negative correlations with harvest index, thousand-seed weight, and days to heading (Table 5).

Table 5. Correlations coefficient of fertilizer and other yield and yield components of barely

	Fert	GY	By	HI	SL	SPS	TSW	DTH	DTM	PTH
Fert	1									
GY	0.6889	1								
By	0.7691	0.821	1							
HI	-0.413	-0.0346	-0.5938	1						
SL	0.2641	0.2452	0.0125	0.2498	1					
SPS	0.2724	0.4669	0.2761	0.1131	0.758	1				
TSW	-0.0304	-0.1544	-0.1991	0.0789	0.727	0.6244	1			
DTH	-0.2985	-0.2955	-0.3507	0.1835	0.481	0.447	0.5595	1		
DTM	0.0998	-0.0147	-0.1759	0.2163	0.8886	0.7365	0.864	0.7185	1	
PTH	0.5125	0.6823	0.4209	0.1633	0.8326	0.7438	0.4008	0.0483	0.5594	1

GY = Grain yield, Biological yield = BY, HI= harvest index, SL= spike length, number of grains per spike =SPS, TSW = Thousand seed weight, DTH = number of days to heading, DTM= number of days to physiological maturity and PTH = plant height.

3.5. Partial budget analysis

The economic analysis revealed that the highest net benefits of 56,722.20 ETB ha^{-1} and 55,332.40 ETB ha^{-1} were obtained from the application of 150 NPSB + 69 kg N ha^{-1} for Illala-1 and Illala-2, respectively (Tables 6 and 5).

For Illala-1, the marginal rates of return (MRR) from the application rates of NPSB50 + 23 kg N ha^{-1}, NPSB100 + 46 kg N ha^{-1}, and NPSB150 + 69 kg N ha^{-1} were 1,041%, 663%, and 1,102%,

respectively. Corresponding values for Illala-2 were 1,409%, 612%, 9,242%, and 267% for NPSB50 + 23 kg N ha⁻¹, NPSB100 + 46 kg N ha⁻¹, and NPSB150 + 69 kg N ha⁻¹, respectively. Overall, the economic analysis indicated that the application of 150 NPSB + 69 kg N ha⁻¹ provided the highest net benefit and acceptable marginal rate of return, making it the most economically viable treatment. Illala-1 also recorded an 8.6% higher net benefit than Illala-2, which can be attributed to its higher yield performance (Table 6).

Table 6. Effects of blended fertilizers on economic profitability of barley, Degua Tembien

Variety by fertilizer rates (kg ha^{-1})	Adjusted grain yield (kg ha^{-1})	Grain yield Benefit (ETB ha^{-1})	Adjusted Straw kg ha^{-1}	Straw yield benefit (ETB ha^{-1})	Gross Benefit (ETB ha^{-1})	TVC ETB ha^{-1}	Net benefit (ETB ha^{-1})	MRR	MRR (%)
Illala-1 NPSB0N0	1582.2	23733	1749.6	962.28	24695.3	0	24695.3	-	-
Illala-1 NPS100N46	3018.6	45279	4022.1	2212.15	47491.2	2385	45106.2	6.6333	663.33
Illala-1 NPSB50N23	2460.6	36909	2974.5	1635.97	38545.0	1213	37332.0	10.4177	1041.77
Illala-1 NPSB100N46	2928.6	43929	4217.4	2319.57	46248.6	2428	43820.6	D	
Illala-1 NPSB150N69	3831.3	57469.5	5183.1	2850.70	60320.2	3598	56722.2	11.0270	1102.70
Illala-2 NPSB0N0	1539.0	23085	1604.7	882.58	23967.6	0	23967.6	-	-
Illala-2 NPS100N46	3223.8	48357	4108.5	2259.67	50616.7	2385	48231.7	6.119	611.852
Illala-2 NPSB50N23	2698.2	40473	3274.2	1800.81	42273.8	1213	41060.8	14.092	1409.167
Illala-2 NPSB100N46	3483.0	52245	4343.4	2388.87	54633.9	2428	52205.9	92.423	9242.326
Illala-2 NPSB150N69	3733.2	55998	5331.6	2932.38	58930.4	3598	55332.4	2.673	267.256

TCV= total cost that vary, NB= net benefit, ETB= Ethiopian Birr and MRR = Marginal rate of return.

4. DISCUSSION

Consistent with our findings, Abdisa et al. (2023) reported that reducing NPSB fertilizer application significantly prolonged the days to heading in barley across all application rates. They observed the highest number of days to heading (85 days) in the control treatment (0 kg NPSB ha⁻¹), while the lowest value (76.55 days) was recorded at the highest application rate of 200 kg NPSB ha⁻¹.

The authors concluded that the reduction in days to heading with increasing rates of blended fertilizer may be attributed to the role of phosphorus and the synergistic effects of NPSB nutrients in promoting plant growth and dry matter partitioning, thereby enhancing crop development.

In contrast to the present findings, Shimels and Kefale (2021) reported a higher number of days to maturity with increasing nitrogen rates compared with lower rates. They attributed this response to the role of nitrogen in promoting vegetative growth, which in turn delayed crop maturity.

Similarly, Tehulie and Yimer (2021) found that days to heading and physiological maturity were significantly influenced by variety, but not by the combined application of NP with S, B, and K fertilizers, nor by their interaction with varieties.

Regarding plant height, Shimels and Kefale (2021) also observed an increase in barley plant height as fertilizer application rates increased. However, in contrast, Tehulie and Yimer (2021) reported that plant height was significantly affected by the main effect of malt barley varieties, while neither blended fertilizers nor their interaction with varieties had a significant effect.

Consistent with the present study, Tehulie and Yimer (2021) reported highly significant differences in number of kernels per spike, thousand-kernel weight, aboveground biomass, and grain yield due to blended fertilizer rates and varieties in the Mekdela district of South Wollo. They further observed that, compared with the recommended NP fertilizers, the application of blended fertilizers such as NPSBK (70 kg N ha^{-1}, 46 kg P_2O_5 ha^{-1}, 150 kg K_2O ha^{-1}, 21 kg S ha^{-1}, and 2.1 kg B ha^{-1}) and NPS (70 kg N ha^{-1}, 46 kg P_2O_5 ha^{-1}, and 7 kg S ha^{-1}) significantly increased both straw and grain yields.

Similarly, Melkamu et al. (2019) reported a significant effect of blended fertilizers on barley yield and yield components in the Hulla district of southern Ethiopia, with the highest aboveground biomass, straw yield, and grain yield obtained from the application of 200 kg ha^{-1} NPSB fertilizer. In addition, Woubshet et al. (2017) found that the combined application of 150 kg ha^{-1} NPSB fertilizer with compost increased grain yield up to 4.8 t ha^{-1}.

The higher yield observed in 2018 in the present study may be attributed to better soil moisture availability, which likely enhanced nutrient uptake by plant roots, resulting in improved photosynthetic activity and vigorous plant growth (Kibe et al., 2006). However, excessive vegetative growth at the expense of reproductive development may reduce grain formation and yield, potentially due to increased lodging, as reported by Tripathi et al. (2003).

In agreement with our findings, Tehulie and Yimer (2021) also reported that harvest index was significantly influenced only by blended fertilizer rates in the Mekdela district.

5. CONCLUSION

A field experiment was conducted during the 2017 and 2018 main cropping seasons at Tahtai Melfa village in Degua Tembien District, South Eastern Zone of the Tigray National Regional State, Ethiopia. The study aimed to evaluate the response of barley to three rates of NPSB blended fertilizer, compared with an NPS treatment combined with urea, on the yield and yield components of Illala-1 and Illala-2 barley (Hordeum vulgare L.) varieties.

Data on phenological traits, yield, and yield components were collected and analyzed. The results showed that number of grains per spike, spike length, thousand-seed weight, plant height, grain yield, and aboveground biomass increased with increasing rates of NPSB blended fertilizer combined with nitrogen application. In contrast, days to heading and physiological maturity generally decreased as fertilizer rates increased.

Correlation analysis revealed positive relationships between NPSB fertilizer application and grain yield, biological yield, and plant height. However, negative correlations were observed between fertilizer application and harvest index, thousand-seed weight, and days to heading.

The highest fertilizer rate (150 NPSB + 69 kg N ha^{-1}) consistently produced superior biomass and grain yields for both Illala-1 and Illala-2 across the two seasons, whereas the lowest yields were recorded in the unfertilized control plots. Economic analysis further indicated that the same treatment (150 NPSB + 69 kg N ha^{-1}) provided the highest net benefits for both varieties. Although Illala-2 produced slightly higher grain and biological yields, Illala-1 showed a higher net economic return, indicating greater overall profitability.

Therefore, Illala-1 combined with 150 NPSB + 69 kg N ha^{-1} can be recommended for Vertisols in the study area and similar agro-ecological zones with comparable soil conditions.

Finally, further studies are recommended across different soil types, agro-ecologies, slope classes, and under both rainfed and irrigated conditions in Tigray. In addition, since the NPSB blend contains multiple nutrients (N, P, S, and B), future research should disentangle the individual contributions of each nutrient to yield improvement for more precise fertilizer recommendations.

ACKNOWLEDGEMENTS

The Authors thank Mekelle Agricultural Research Center for providing the necessary resources (Financial and Material) to conduct the study. The authors wish to express their appreciation to Soil Fertility Laboratory case team members of Mekelle Soil Research Center for their unreserved collaboration and assistance during soil analysis. We also thanks to Mr. H/Mariam Abreha for providing the study area map.

Ethics approval and consent to participate

The study was conducted in rainy season command owned by a farmer. We leased the land for two consecutive years. To do so, a contract agreement that comply with legal requirements between the famer and Mekelle Research Center (represented by the first author) was signed. Moreover, permission to conduct the study in the said place was granted by the district authority as no study is allowed without getting legal permission.

Ethics and consent to participate

The plants used in this study are cultivated plants. The regional and national guidelines in place in the country allows their collection, cultivation, harvesting and processing. Moreover, the sampling of plant materials was in a way that meet the standards for field study.

Funding Information

This study was financially supported by Mekelle Agricultural Research Center (Tigray National Regional State Government) in Tigray Agricultural Research Institute (TARI).

Declaration of Interest Statement

The authors declare that they have no conflict of interest

REFERENCES

Abdisa M., Ashagre, H., & Chala, G. (2023). Effect of blended NPSB fertilizer rates on performance of food barley (*Hordeum vulgare* L.) varieties in central highland of Ethiopia. *World Journal of Agricultural Sciences, 19*(3), 94–103.

Brahmi, W., Ltifi, A., & Haouala, F. (2023). Effects of drought stress on growth and yield of barley. *Biochemistry & Pharmacology, 12*, 001.

Cantero-Martínez, C., Angás, P., & Lampurlanés, J. (2003). Growth, yield and water productivity of barley (*Hordeum vulgare* L.) affected by tillage and N fertilization in Mediterranean semiarid rainfed conditions of Spain. *Field Crops Research, 84*, 341–357.

Central Statistical Agency (CSA). (2013). *Agricultural sample survey: Results on area, production and yield of major crops by sector and season*. CSA.

Central Statistical Agency (CSA). (2014). *Agricultural sample survey: Report on area and production of major crops*. CSA.

CIMMYT (International Maize and Wheat Improvement Center). (1988). *From agronomic data to farmers' recommendations: Economics training manual* (Rev. ed.). CIMMYT.
Dawson, I. K., Russell, J., Powell, W., Steffenson, B., Thomas, W. T. B., & Waugh, R. (2015). Barley: A translational model for adaptation to climate change. *New Phytologist, 206*(3), 913–931.
Ethio-SIS (Ethiopia Soil Information System). (2016). *Fertilizer recommendation atlas of the Southern Nations, Nationalities and Peoples' Regional State, Ethiopia*. Ethio-SIS.
Hazelton, P., & Murphy, B. (2007). *Interpreting soil test results: What do all the numbers mean?* CSIRO Publishing.
Institute of Agricultural Research (IAR). (1979). *Mekelle Research Station: Progress report, April 1975–December 1976*. IAR.
Kibe, A. M., Singh, S., & Kalra, N. (2006). Water–nitrogen relationships for wheat growth and productivity in late-sown conditions. *Agricultural Water Management, 84*, 221–228.
Melkamu, H. S., Gashaw, M., & Wassie, H. (2019). Effects of different blended fertilizers on yield and yield components of food barley (*Hordeum vulgare* L.) on Nitisols at Hulla Woreda, Southern Ethiopia. *Academic Research Journal of Agricultural Science Research, 7*(1), 49–56.
Rowell, D. L. (1994). *Soil science: Methods and applications*. Longman Scientific & Technical.
SAS Institute. (2003). *SAS version 9.1.2* [Computer software]. SAS Institute Inc.
Shawl, A., Shewangizaw, B., Yassin, K. K., & Getaneh, L. (2021). Growth, yield components, and yield response of food barley (*Hordeum vulgare* L.) to the application of sulfur nutrient under balanced fertilization at North Central Highland of Ethiopia. *Journal of Crop Science and Biotechnology*, 24:461–467. https://doi.org/10.1007/s12892-021-00094-5.
Shimels, F., & Kefale, D. (2021). Response of Nitrogen Fertilizer Rate on Yield and Yield Components of Malt Barley (Hordeum vulgare L.) Varieties at Arsi Zone, Ethiopia. *World Journal of Food Science and Technology*, *5*(3), 50-54.
Sinebo, W., Gretzmacher, R., & Edelbauer, A. (2002). Environment of selection for grain yield in low fertilizer input barley. *Field Crops Research*, 74(2-3), 151-162.
Tehulie, N., & Yimer, Z. (2021). Effects of blended fertilizer rates on growth, yield and quality of malt barley (*Hordeum distichum* L.) varieties at Mekdela District, South Wollo, Ethiopia. *Research & Reviews: Journal of Botany, 10*(1), 1–5.
Tekalign, T. (1991). *Soil, plant, water, fertilizer, animal manure and compost analysis* (Working Document No. 13). International Livestock Research Center for Africa.
Tripathi, S. C., Sayre, K. D., Kaul, J. N., & Narang, R. S. (2003). Growth and morphology of spring wheat (*Triticum aestivum* L.) culms and their association with lodging: Effects of genotypes, nitrogen levels and ethephon. *Field Crops Research, 84*, 271–290.
Wassie, H., & Boke, S. (2011). Response of Irish potato (*Solanum tuberosum*) to the application of potassium at acidic soils of Chencha, Southern Ethiopia. *International Journal of Agricultural Biology, 13*, 595–598.
Woubshet, D., Selamyihun, K., & Cherukuri, V. (2017). Effect of integrated use of lime, blended fertilizer, and compost on productivity, nutrient removal and economics of barley (*Hordeum vulgare* L.) on acid soils of highlands in West Showa Zone of Ethiopia. *International Journal of Life Sciences, 5*(3), 311–322.
Yihenew, G. (2002). Selected chemical and physical characteristics of soils of Adet Research Center and its testing sites, northwestern Ethiopia. *Ethiopian Journal of Natural Resources*, 4: 199-215.

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