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Evaluation of food barley (*Hordeum vulgare L.)* varieties on yield and yield components at different rates of blended nitrogen, phosphorus, sulfur and boron fertilizer rates at Kechi, Southern Ethiopia

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Abstract

Barley is an important cereal crop in Ethiopia, accounting for nearly 25% of the total production. However, the trend of food barley production in the area has been declining for the past few years. The major production constraints for food barley production in Ethiopia, including the study area, are soil acidity and soil fertility. As a result, a field experiment was carried out during the 2019/20 cropping season at Wolaita Sodo University's Kechi testing site with the objective of evaluating the response of food barley varieties to NPSB fertiliser rates. Three food barley varieties (HB 1307, EH 1493, and local cultivar) and five NPSB fertiliser rates (0, 50, 100, 150, and 200 kg/ha) were used in the treatments. The treatments were combined in a factorial design and laid out in a randomised complete block design (RCBD) with three replications. Data for yield and yield related parameters were recorded during the specific phenological stage of the crop. The results revealed that days to heading and maturity were prolonged for all varieties as NPSB rates increased, with the longest days to heading and maturity recorded for variety BH 1307 at a NPSB rate of 200 kg/ha. At a NPSB fertiliser rate of 200 kg/ha, variety EH 1493 had the tallest plant heights and the longest spike length. The highest number of seeds per spike was observed for variety EH1493 at an NPSB rate of 150 kg/ha, whereas the highest TSW was seen for variety EH1493 at an NPSB rate of 100 kg/ha. The greatest biomass yield was obtained from variety BH 1307 at an NPSB fertiliser rate of 200 kg/ha, and the highest grain yield was observed for variety EH 1493 at an NPSB rate of 100 kg/ha. This result revealed that varieties EH 1493 and BH 1309 showed superior performance with better grain over local cultivars at NPSB fertiliser rates of 100 kg/ha. Based on the results of this study, it could be concluded that this blended NPSB application rate is superior for the production of food barley in the study area.

Keywords: Agronomic efficiency, grain yield, profitability, varieties

Introduction

Barley (Hordeum vulgare L.) is an important crop in Ethiopian cereal production and in food security (Berhanu et al., 2017). Ethiopia accounts for nearly 25% of the total production in Africa (FAO, 2021). It is the predominant cereal in high altitudes (> 2000 m a.s.l.) and Ethiopia is also recognised as a centre of diversity for barley having global significance because of its improved traits, including disease tolerance (Bekele et al., 2000). Barley, including both food and malt barley species, is cultivated in Ethiopia. Ethiopia produces mostly food barley, with its share estimated to be 90%, while malt barley has a share of 10% (Alemu et al., 2016). In Ethiopia, barley grain is primarily used for animal feed, malt, and human consumption. Traditionally, barley is used for making local recipes and drinks and other types of food. Its straw is a good source of animal feed, and it is also used for thatching roots (Yosef et al., 2013).

Balanced fertilisation is the key to sustainable crop production and the maintenance of soil health. It has both economic and environmental considerations. An imbalanced fertiliser use results in low fertiliser use efficiency, which leads to lower economic returns and a greater environmental threat (Abiye et al., 2004). Moreover, recently acquired soil inventory data revealed that the deficiencies of most nutrients, such as nitrogen (86%), phosphorus (99%), sulphur (92%), boron (65%), and zinc (53%), are widespread in Ethiopian soils and include the study area (Ethio-SIS, 2016). According toYared et al. (2020), the productivity of barley is low in the highlands of Ethiopia due to low soil fertility. Continuous application of P and N fertilisers without due consideration of other nutrients led to the depletion of other important nutrient elements such as potassium (K), magnesium (Mg), calcium (Ca), sulphur (S), and micronutrients in soils (Melkamu et al., 2019). However, information on the application of rate blended fertiliser (NPS and NPSB), especially for barley, was not determined for the study area.

Inadequate crop production and soil testing-based crop response information and knowledge for both malting and food barley, and soil fertility improvement work for barley production enhancement, do not cover all barley production systems. Moreover, the trend of food barley production in the area has been declining for the past few years. The low productivity of landraces of food barley along with the current attention of the government could be the main reason, among many others, for shifting food barley production to other high-market-value crops. The actual status of food barley production and associated production constraints have not

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been systematically studied in the area. This study, therefore, was initiated with the objective of assessing the response of food varieties to NPSB fertiliser rates.

Material and methods

Description of the experimental site

A field experiment was conducted during the 2019/2020 cropping season at the Kechi Research Center of Wolaita Sodo University. The geographical coordinates of the site are 700297' N latitude and 360 58’53’ E longitude, with an altitude of 2217 masl and a mean annual rainfall of 1320 mm. The minimum and maximum mean temperatures are 12 and 24^0C, respectively (Kechi District Agricultural Office, 2020).

Treatments and experimental design

Three food barley varieties (HB 1307, EH 1493, and local cultivar) and five NPSB fertiliser rates (0, 50, 100, 150, and 200 kg/ha) were used in the treatments. The treatments were combined in factorial and laid out in a randomised complete block design (RCBD) with three replications. The blended NPSB fertiliser has an elemental composition of 18.9% N, 37.7% P2O5, 6.95% S, and 0.1% B. The plot size was 2 x 2 m, with a total gross area of 224.54 m2. An experimental field was ploughed, pulverized, and levelled in order to get a smooth seed bed. Planting was carried out following the onset of rainfall and planting time in the area. Seeds were drilled in rows at a row spacing of 25 cm with a seed rate of 150 kg/ha. At planting, the rated blended NPSB fertiliser was applied to the plots. Urea as a source of N was applied in splits, taking into account the N amount in blended NPSB to meet the recommendation of 100 kg/ha for barley production. Crop management practises such as cultivation, weeding, etc. were carried out as desired during the crop-growing period.

Soil analysis

Soil samples were taken from the entire experimental field to a depth of 0–20 cm using a soil augur. The samples were air-dried and ground to pass a 2 mm sieve and thoroughly mixed to get one composite sample. The representative soil sample was analysed for organic carbon, total nitrogen, soil pH, available phosphorus, cation exchange capacity (CEC), and textural analysis using standard laboratory procedures at the Wolaita Sodo Soil Testing Laboratory. Organic carbon content was determined by the volumetric method (Walkley and Black, 1934). The total nitrogen was calculated using the Micro-Kjeldhal digestion method (Jackson, 2007). The pH of the soil was determined by using a 1:2.5 (weight/volume) ratio of soil samples to water using a glass electrode attached to a digital pH meter. Particle size distribution was done by the hydrometer method (2008). The cation exchange capacity (CEC) was measured after saturating the soil with 1N ammonium acetate (NH4OAc) and displacing it with 1N NaOAc (Chapman, 1965). Available phosphorus FAO was determined by Olsen's method using a spectrophotometer (Olsen et al., 1965) (Table 1).

Table 1. Some physical and chemical properties of soils of experimental site

Parameter	Unit	Value	Rates	Remark
Particl size distribution	%	-	-	-
• Sand	%	24	-	-
• Silt	%	10	-	-
• Clay	%	66	-	-
Textural class	-	clay	-	Bouyoucas hydrometer method
Bulk density	gcm^3	0.80	Best	EthioSIS (2016)
Soil pH	%	6	Moderately	‘’
Organic Carbon	%	0.936	Low	
Total N	%	0.1	Low	‘’
Available P	$mg\ kg^{-1}$	12.32	Low	‘’
Available B	$mg\ kg^{-1}$	0.46	Low	‘’
Available S	$mg\ kg^{-1}$	11.73	Low	‘’
CEC	$meq100g^{-1}$	24.4	Medium	‘’

Soil lab. data (2020); CEC: Cathion Exchange Capacity

Data collection and measurements

Crop parameters recorded were days to heading, days to physiological maturity, plant height, spike length, number of spikelets per spike, effective tillers, noneffective tillers, total tillers, seeds per spike, thousand seed weight, biomass yield, grain yield, harvest index, agronomic

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efficiency (AE), and economic analysis. When 50% of the plants in a plot showed signs of heading, the days to heading were recorded. When 90% of plants in a plot lost their green leaf on their panicle or head, the days to physiological maturity were recorded. Plant height was measured at physiological maturity for five randomly selected plants per plot from ground level to the tip. Spike length was measured at physiological maturity for five randomly selected plants in each plot. At physiological maturity, effective tillers and total tillers per plant were counted for five randomly selected plants per plot. Effective tillers are those with productive spikes. Seeds per spike were counted for five randomly selected plants per plot at harvesting. Thousand seed weight (TSW) was measured by counting a thousand seeds with a seed counter and weighing them using a sensitive balance after adjusting for moisture at 12.5%. The biomass yield from the net plot area was calculated by weighing the total above ground biomass at harvesting. Grain yield was calculated after adjusting for moisture content at 12.5%. The harvest index (HI) was calculated by dividing the grain yield by the total biomass yield. Agronomic efficiency (AE) is defined as the economic production obtained per unit of nutrient applied and estimated as:

$$\mathrm{AE} = \frac{Gf - Gu}{NPSBa}$$

Where:

G_f = Grain yield of the fertilized plot (kg/ha)

Gu = Grain yield unfertilized plot (kg/ha),

NPSBa = Quantity of NPSB applied (kg/ha).

Economic analysis

The mean grain yields of the treatments were used in the partial budget analysis as described by CIMMYT (1998). The field price of 1 kg of malt barley at the time of harvesting in November 2018 was taken as 13 birr based on the market price of food barley at Kechi near the experimental site. The price of NPSB that was used as a fertiliser source was 16.36 birr per kilogram, and the daily labour expense was 60 birr.The gross benefit was calculated by multiplying 10% adjusted grain yield (kg/ha) by the field price received by farmers for crop sale.The net return was calculated by subtracting total variable costs from the gross benefit; the minimum acceptable rate of return was set at 100% (CIMMYT, 1998) in order to use the marginal rate of return (MRR) as a basis for fertiliser recommendation. Thus, the marginal rate of return (MRR) calculated was the marginal net benefit (i.e., the change in net benefits) divided by the marginal cost (i.e., the change in costs), expressed as a percentage. Treatments with higher variable costs but lower net benefits than treatments with lower variable costs and higher net benefits were deemed dominant and were excluded from the partial analysis.

Statistical analysis

All the measured parameters were subjected to an analysis of variance (ANOVA) appropriate to the factorial experiment in RCBD according to the General Linear Model of SAS (Statistical Analysis System) (SAS, 2008), and interpretations were made following the procedure described by Gomez and Gomez (1984). Whenever the effects of the treatments were found to be significant, the means were compared using the Least Significant Differences (LSD) test at 5% level of significance.

Results and discussion

Days to heading and physiological maturity

Analysis of variance showed that the interaction effects of NPSB and K significantly ($P \leq 0.05$) affected days to heading (Table 2). As NPSB fertiliser rates increased from 0 to 200 kg/ha, days to heading increased for all varieties. At a NPSB rate of 200 kg/ha, the variety BH 1307 had the longest day to heading (78.66). The shortest days to heading (74.33) were recorded for varieties BH 1307 and EH 1493 from the unfertilized plot. There was a difference of 4.33 days between the longest and shortest days to heading. In general, the days to heading of varieties in response to NPSB rates were relatively narrow, indicating a closer genetic distance. The same findings were disclosed by Biruk and Demelash (2019), who found detectable differences among barley varieties in days to heading. Moreover, Rut et al. (2019) reported that increasing NPSB fertiliser rates prolonged the days to heading in wheat. Analysis of variance indicated that the main effect of NPSB rates had a significant effect on days to physiological maturity (Table 2). Days to physiological maturity as affected by the main effect of NPSB rates varied from 121.33 to 127.89. It tended to prolong with increasing NPSP rates from 0 to 200 kg/ha. The longest days to physiological maturity (127.89) were achieved with an NPSB fertiliser rate of 200 kg/ha, followed by an NPSB rate of 150 kg/ha with a mean days to physiological maturity of 126.67. The shortest days to physiological maturity (121.33) were obtained from unfertilized plots. This

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finding is consistent with Wakene et al. (2014)'s finding that increasing NPSB fertilisation delayed the days to physiological maturity in barley. However, the main effect of varieties and their interactions with NPSB fertiliser rates did not result in significant differences on days to physiological maturity (Table 2).

Plant height and spike length

The analysis of variance showed that the interaction effects of blended NPSB and varieties were significant ($P \leq 0.05$) on plant height (Table 2). The tallest plant height (108.61 cm) and longest spike length (9.00 cm) were observed at an NPSB fertiliser rate of 200 kg/ha, followed by an NPSB fertiliser rate of 150 kg/ha with a mean plant height of 100.53 cm and a spike length of 8.47 cm. The shortest plant height (69.11 cm) and spike length (8.03 cm) were obtained from unfertilized plots. In line with this, significant differences were detected due to the effect of varieties on NPSB fertiliser rate interactions on plant height and spike length (Table 1). Plant heights increased with increasing NPSB fertiliser rates for all varieties. All varieties attained higher plant heights at the highest NPSB fertiliser rate. Regarding the overall effect, the tallest plant height (110.00 cm) was observed for variety EH 1493 at an NPSB fertiliser rate of 200 kg/ha, followed by variety BH 1307 at the same NPSB rate with a mean plant height of 108.33 cm. The shortest plant height (67.00 cm) was seen for the local cultivar at NPSB in unfertilized plots. Increasing NPSB rates probably promoted the production of dry matter, which led to an increase in plant height.

In terms of spike length, varieties BH 1307 and EH 1493 demonstrated a relative tendency to increase spike length with increasing NPSB fertiliser rate, whereas the local cultivar displayed spike length inconsistency as NPSB fertiliser rate increased (Table 2). The longest spike length (9.46 cm) was recorded for variety EH 1493 at an NPSB rate of 200 kg/ha, followed by the same variety at an NPSB rate of 150 kg/ha with a mean spike length of 9.33 cm. The shortest spike length (7.33 cm) was seen for variety BH 1307 from unfertilized plots. This is an indication that varieties responded differently to varying levels of NPSB fertiliser rates. Previous research found that increasing the doses and combinations of macro- and micronutrients with nitrogen, phosphorus, sulfur, and born fertilisers can increase spike length (Bereket et al., 2014; Arif et al., 2006; Dewal and Pareek, 2004; Gupta et al., 2004). Conversely, varieties did not show significant differences in plant height and spike length (Table 2).

Table 2. Days to flowering, physiological maturity, plant height and spike length as affected by varieties and NPSB rates

Varieties	NPSB rates (kg/ha)	Days to heading	Days to maturity	Plant height (cm)	Spike length (cm)
BH 1307	0	74.33d	129.67	70.00j	7.33f
	50	74.66cd	120.00	85.00g-i	7.56ef
	100	76.33a-d	122.00	90.00fg	7.56ef
	150	77.00a-c	123.67	98.67de	7.66d-f
	200	78.66a	126.33	108.33ab	8.20b-f
EH 1493	0	74.33d	124.33	70.33j	8.30b-f
	50	75.66b-d	121.00	80.33hi	8.60a-d
	100	76.00b-d	123.67	92.67ef	9.03ab
	150	77.00a-c	123.67	100.67cd	9.13ab
	200	78.33ab	127.67	110.00a	9.46a
Local cultivar	0	75.33cd	126.00	67.00j	8.46a-d
	50	75.34cd	123.00	78.33i	8.76a-c
	100	76.00b-d	124.00	87.00f-h	8.56a-e
	150	76.66a-d	125.00	102.25b-d	8.63a-c
	200	78.33ab	129.67	107.51a-c	9.33
	LSD	2.4	NS	7.42	1.02
	BH 1307	76.20	124.33	90.40	7.70
Variety mean	EH 1493	76.26	124.07	90.80	8.90
	Local Cultivar	76.33	125.53	88.41	8.75
	LSD	NS	NS	NS	NS
	0	74.66	121.33b	69.11e	8.03b
	50	75.22	123.22ab	81.22d	8.37b
NPSB mean	100	76.11	124.11ab	89.89c	8.38b
	150	76.88	126.67ab	100.53b	8.47ab
	200	78.44	127.89a	108.61a	9.00a
	LSD	NS	5.60	4.28	0.58
	CV (%)	0.93	4.66	4.94	7.18

Means followed by the same letters within a column are not significantly different at 5% probability level, NS=not significant

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Number of effective and total tillers

The main effect of NPSB fertiliser rates had a significant effect on the number of effective and total tillers, according to the analysis of variance (Table 3). The greatest number of effective tillers (62.44) and total tillers (82.22) were recorded at an NPSB rate of 200 kg/ha, followed by an NPSB fertiliser rate of 150 kg/ha, with a mean number of effective tillers of 60.44 and total tillers of 82.22. The lowest number of effective tillers per plant (15.67) and total tillers (43.67) were achieved in unfertilized plots. Similarly, the interaction of varieties by NPSB fertiliser rates resulted in significant differences in effective and total tillers (Table 3). With respect to the overall effect, variety EH 1493 produced the highest number of effective tillers (67.33) and total tillers (89.67) at an NPSB fertiliser rate of 200 kg/ha. The local cultivar produced the fewest effective tillers (13.67), while variety BH 1307 produced the most total tillers (46.0) from unfertilized plots. Wakene et al. (2014) reported that increasing NPSB fertilisation rates corresponded to an increasing number of effective and total tillers.

Number of seeds per spike and thousand seed weight

Analysis of variance showed that the interaction effects significantly ($P<0.05$) affected the number of seeds per spike (Table 3). The greatest number of seeds per spike (46.81) was recorded for variety BH 1307, followed by variety EH 1493 with a mean number of seeds per spike of 45.44. The lowest number of seeds per spike (36.36) was seen for local cultivars (Table 3). The variation of varieties with respect to a number of seeds per spike was probably attributed to their genetic variability. According to Alam et al. (2007), the number of seeds per spike was determined by genotype. This finding is consistent with the findings of Guluma et al. (2010), who found a significant difference in the number of seeds per spike among three wheat varieties. Similarly, significant differences were detected due to the effect of varieties on NPSB fertiliser rate interactions on the number of seeds per spike (Table 3). At a NPSB rate of 150 kg/ha, the variety EH1493 had the most seeds per spike (51.53). On unfertilized plots, Local cultivars had the fewest seeds per spike (34.00). This finding indicated that the varieties reacted differently to variable rates of NPSB fertilisation with respect to the production of seeds per spike.

On the other hand, the main effect of NPSB fertiliser rates did not have a significant effect on the number of seeds per spike (Table 3). Significant differences were detected due to the main effect of NPSB fertilizer rates on Thousand seed weight (TSW) (Table 2). TSW as affected by the main effect of NPSB fertiliser rates ranged from 31.76 to 38.14 g. It increased with increasing NPSB rates up to 100 kg/ha and then declined with a further increment of the NPSB rate above that rate. The highest TSW, averaged over varieties, was recorded at an NPSB rate of 100 kg/ha, followed by an NPSB rate of 150 kg/ha with a mean TSW of 35.81 g. The lowest TSW (31.76 g) was obtained from unfertilized plots. In line with this, varieties by NPSB fertiliser rate interactions had a significant effect on TSW (Table 3). It was noticed that TSW tended to increase as NPSB increased up to 100 kg/ha for all varieties and then declined for fertiliser rates above that rate. The variety EH 1493 had the highest TSW (41.80 g) at a NPSB rate of 100 kg/ha, followed by the Local cultivar at a NPSB rate of 100 kg/ha with a mean TSW of 37.66 g. In unfertilized plots, local cultivars produced the lowest TSW (30.43 g). The results are consistent with the results of Asghari et al. (2006), who reported that increasing blended fertilisation tended to increase TSW. Similarly, Rashid (2010) found that increasing fertiliser levels significantly increased TSW of wheat compared to the control. In contrast, the main effect of varieties did not have a significant effect on TSW (Table 3).

Biomass yield

Analysis of variance showed that the interaction effects significantly ($P<0.05$) affected biomass yield (Table 3). Both improved varieties outperformed native cultivars. The highest biomass yield (19547 kg/ha), averaged over NPSB fertiliser rates, was recorded for variety EH 13, followed by variety BH 1307 with a mean biomass yield of 18320 kg/ha. The lowest biomass yield (14467 kg/ha) was obtained for the local cultivar. Similarly, NPSB fertiliser rates had a significant effect on biomass yield (Table 3). In general, biomass yield increased with increasing NPSB fertiliser rates from 0 to 200 kg/ha. The greatest biomass yield (21156 kg/ha) was recorded at an NPSB fertiliser rate of 200 kg/ha, followed by an NPSB fertiliser rate of 150 kg/ha, with a mean biomass yield of 19867 kg/ha. The lowest biomass yield (11689 kg/ha) was achieved from unfertilized plots.

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Table 3. Productive tillers, total tillers, seeds per spike and TSW as affected by varieties and NPSB rates

Varieties	NPSB rates (kg/ha)	Productive tillers per plant	Total tillers per plant	Seeds/spike	TSW (g)
BH 1307	0	17.33b	46.00cd	36.66ab	30.96b
	50	27.00ab	51.67b-d	43.93ab	34.63ab
	100	48.67ab	74.33a-d	51.00a	36.53ab
	150	53.00ab	76.00a-d	43.93ab	35.00ab
	200	51.67ab	81.33a-c	47.66ab	33.33ab
EH 1493	0	16.00b	40.33d	46.33ab	31.53ab
	50	38.67ab	44.67d	47.66ab	31.93ab
	100	65.67a	81.67a-c	48.16ab	41.80a
	150	66.00a	86.00ab	51.53a	36.53ab
	200	67.33a	89.67a	40.36ab	34.46ab
Local cultivar	0	13.67b	16.00a-d	34.00b	30.43b
	50	42.00ab	82.33ab	37.16ab	36.00ab
	100	60.67a	86.33ab	39.33ab	37.66a
	150	64.00a	87.00ab	36.13ab	37.11a
	200	67.00a	87.00ab	36.70ab	34.66ab
	LSD	14.75	15.95	16.85	10.68
Varieties mean	BH 1307	39.53	65.87	46.81a	35.25
	EH 1493	50.73	73.53	45.44a	35.18
	Local Cultivar	49.47	71.40	36.36b	34.94
	LSD	NS	NS	7.53	NS
NPSB rates mean	0	15.67b.	43.67b	39.00	31.76b
	50	42.52ab	66.56a	42.92	34.31ab
	100	52.22ab	74.67a	46.16	38.14a
	150	60.44ab	82.22a	45.20	35.81ab
	200	62.44a	84.22a	41.57	35.58ab
	LSD	12.53	20.76	NS	6.15
	CV (%)	16.29	11.97	23.46	16.86

Means followed by the same letters within a column are not significantly different at 5% probability level, NS=not significant

Moreover, this result is in agreement with the finding of Melkamu et al. (2019) that the highest biomass yield was obtained from 200 kg/ha NPSB fertilizer and the lowest from unfertilized plots. This might be due to the presence of sulphur in fertiliser elements, which enhances the formation of chlorophyll and encourages vegetative growth, and to the fact that B helps in N absorption. Salvagiotti and Miralles (2008) indicated that biomass production in wheat increased with increasing fertilisation of N and S.

Grain yield

Analysis of variance showed that the interaction effects significantly ($P<0.05$) affected grain yield (Table 4). The highest grain yield (4497 kg/ha) was achieved at a BPSB rate of 100 kg/ha, followed by a NPSB fertiliser rate of 150 kg/ha, with a mean grain yield of 4423 kg/ha. The lowest grain yield (1320 kg/ha) was seen on unfertilized plots. The lowest grain yield (2832 kg/ha) was obtained from the local cultivar. The yield variation among varieties was likely due to their inherent genetic differences. This result is in line with the findings of Aynewa et al. (2013) that malt barley genotypes for yield showed significant differences among the ten genotypes considered in the study.

Harvest index

Analysis of variance showed that the interaction effects significantly ($P \leq 0.05$) affected the harvest index (Table 4). Harvest index values as affected by the main effect of NPSB fertiliser rate varied from 0.16 to 0.24, with the highest HI value (0.24) recorded at a NPSB fertiliser rate of 100 kg/ha, followed by a NPSB fertiliser rate of 150 kg/ha with a mean HI value of 0.19. The lowest HI value (0.16) was obtained from unfertilized plots. The harvest index is a crop's physiological efficiency and ability to convert total dry matter into economic yield (Sinclair, 1998). Hence, HI reflects the proportion of assimilated distribution between economic and total biomass yield (Donald & Hamblin, 1976). Thus, HI values are closely associated with the amount of grain yield on a per-treatment basis. In contrast, the main effect of varieties and their interactions with NPSB fertiliser rates did not have a significant effect on HI (Table 4).

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Table 4. Biomass, grain yield and HI as affected by varieties NPSB rates

Varieties	NPSB rates (kg/ha)	Biomass yield (kg/ha)	Grain yield (kg/ha)	HI
BH 1307	0	11467ef	1450gh	0.13
	50	15333c-e	2200fg	0.14
	100	18800b-d	4767a-c	0.23
	150	22000ab	4687a-d	0.22
	200	24000a	3600de	0.19
EH 1493	0	13600ef	1500gh	0.15
	50	19467a-c	3853a-e	0.19
	100	20400a-c	4963a	0.31
	150	21600ab	4847ab	0.22
	200	22667ab	3120ef	0.19
Local Cultivar	0	10000f	1010h	0.10
	50	12267ef	1940gh	0.16
	100	14067d-f	3763b-e	0.27
	150	16000c-e	3737b-e	0.23
	200	20000a-c	3710c-d	0.19
	LSD	5144	1133	NS
Varieties mean	BH 1307	18320a	3341a	0.18
	EH 1493	19547a	3657a	0.19
	Local cultivar	14467b	2832b	0.19
	LSD	2300	507	NS
NPSB rates mean	0	11689c	1320d	0.16b
	50	16000b	2664c	0.18ab
	100	18511ab	4497a	0.24a
	150	19867a	4423a	0.19ab
	200	21156a	3477b	0.17ab
	LSD	2970	654	0.05
	CV (%)	17.63	20.69	32.35

Means followed by the same letters within a column are not significantly different at 5% probability level, NS=not significant

Agronomic efficiency and profitability

Data for agronomic efficiency (AE) as affected by varieties and NPSB fertilizer rates are depicted in Table 5. Agronomic efficiency is the amount of additional yield produced for each additional amount of fertilizer applied (Mengel and Kirkby, 2001). It nearly peaked at the NPSB fertiliser rate of 100 kg/ha for all varieties and then tended to decline for the NBSP fertiliser rate above that optimum rate. The highest AE value (30.82) was recorded for variety BH 1307 at an NPSB fertiliser rate of 100 kg/ha, followed by variety EH 1493 at the same NPSB fertiliser rate with a mean AE of 30.43. Local cultivars from unfertilized plots had the lowest AE (11.68). The declining trend of AE above the NPSB rate of 100 kg/ha could be attributed to NPSB supply reaching an optimal level or to the yield potential of the barley varieties.

Table 5. Profitability and agronomic efficiency of NPSB application on food barley varieties

Varieties	NPSB rates (kg/ha)	Total Revenue	Net profit	MRR (%)	AE
BH 1307	0	23490	19790	-	-
	50	35640	29826	475	14.13
	100	77220	70952	9058	30.82
	150	75924	69132	-347	18.99
	200	58320	51004	-3459	16.41
EH 1493	0	24300	20600	-	-
	50	62424	56610	1703	19.47
	100	80406	74138	3861	30.43
	150	78516	71724	-461	20.33
	200	50544	43228	-5438	16.71
Local cultivar	0	16362	12662	-	-
	50	31428	25614	613	11.68
	100	60966	54698	6406	18.60
	150	60534	53742	-182	18.60
	200	60102	52786	-182	13.26

Economic analysis revealed that the highest net benefit of 74138 birr/ha with a marginal rate of return (MRR) of 3861% was obtained from variety EH 1493 at a NPSB fertiliser rate of 100

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kg/ha, followed by variety BH 1307 with a net benefit of 70952 and an MRR of 9058%. An increase in output would always raise profit as long as the MRR is higher than the minimum rate of return, i.e., 50–100% (CIMMYT, 1998). The result showed that fertiliser has a major role in the yield of a crop. Similarly, Terman and Engelated (1996) indicated that the most profitable nutrient rate can be determined by calculating the maximum net profit or minimum cost per unit of production. Therefore, the optimum NPSB fertiliser rate in combination with an efficient variety is important to obtain maximum net profit.

Conclusions

A field experiment was conducted during the 2019/2020 cropping season at the Kechi Research Center of Wolaita Sodo University to evaluate the response of food barley varieties to NPSB fertiliser rates. Analysis of fertiliser resulted in significant differences on days to heading, physiological maturity, and emergency, and NPSB fertiliser rates had significant effects on plant height. Varieties resulted in significant differences in spike length, with the longest spike length recorded for variety EH 1493 at 200 kgha-1 NPSB rate and the shortest spike length for variety BH 1307 at 0 kgha-1 NPSB rate. The main effect of variety and NPSB fertiliser rate was significant on the total tiller but not significant on the effective tiller. Economic analysis revealed that the highest net benefit of 64104 birr ha-1 with a marginal rate of return (MRR) of 3489.3% was obtained from variety EH 1493 at a NPSB fertiliser rate of 100 kgha-1 followed by variety BH 1307 with a net benefit of 63246.58 birr ha and a MRR of 4466%. This result revealed that varieties EH 1493 and BH 1309 showed superior performance with better grain over local cultivars at NPSB fertiliser rates of 100 kgha-1. However, because the experiment was conducted in a single season for a single location, it is recommended that similar studies be conducted in different agro-climatic and soil conditions to reach a conclusion.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

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