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Research article

Maize (*Zea mays* L.) yield response to the effect of blended fertilizer and varieties under supplemental irrigation at Hadero Zuria *Kebele*, southern Ethiopia

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ABSTRACT

Maize is one of the staple cereal crops in Ethiopia. However, in southern Ethiopia, the productivity of the crop is very low as compared to the average national productivity, which is mainly attributed to poor soil fertility and the use of low yielding varieties. Hence, a field experiment was conducted at Hadero Zuria kebele, southern Ethiopia under supplemental irrigation to investigate the effects of different rates of blended Nitrogen, Phosphorus, Sulphur, and Boron (NPSB) fertilizer on the performance of maize varieties. Treatments involving three varieties of maize (30G19, BH-546, and BH-547) and six rates of NPSB fertilizer (0, 50, 75, 100, 125, and 150) kg ha^{-1} were tested in RCBD using a factorial arrangement with three replications. Data on crop Phenological, growth, yield, and yield components were collected. The results showed that the blended NPSB fertilizer rates and varieties of maize affected days to physiological maturity, leaf area, leaf area index, hundred kernels weight (HKW), dry biomass yield (DBY), and grain yield (GY). The highest mean values for HKW, DBY, and GY were obtained from the 150 kg ha^{-1} NPSB rate. Similarly, the highest values for DBY and GY were obtained from the BH-546 variety. Significant differences ($P < 0.05$) were obtained on days to tasseling, days to silking, and harvest index (HI) due to the interaction effect of NPSB rates and varieties. As the NPSB rates increased from 0 to 150 kg ha^{-1}, HKW and DBY increased consistently from 29.62 to 36.62 g and 31.41 to 43.70 t ha^{-},^{1} respectively. Grain yield showed a highly significant and positive correlation with cob length, leaf number, HI, HKW, and DBY. Also, maximized economic profitability was gained at a rate of 150 kg ha^{-1} NPSB fertilizer. Thus, from this result, the NPSB rate of 150 kg ha^{-1} with the hybrid maize variety BH-546 could be better for the study area.

1. Introduction

Maize (*Zea mays* L.) is one of the major food crops in Ethiopia leading in the volume of production and productivity (3.67 t ha^{-1}) (CSA, 2017). Yet, the national crop productivity remained low compared to the 4.7 t ha^{-1} reported from on-farm trials (IFPRI, 2010) and lower than the world average yield which is about 5.21 t ha^{-1} (FAO, 2011). Recent study conducted by Tadesse et al. (2021), also confirmed that the productivity level of maize was lower than that of national productivity level in Bench Sheko and Kaffa zones, in southern Ethiopia. Poor soil fertility is one of the bottlenecks for sustaining maize production and productivity in Ethiopia in general (Aticho et al., 2011).

The Ethiopian soil information system (EthioSIS), a project launched by the Ethiopian Government's Agricultural Transformation Agency (ATA) in 2012, is a detailed soil map providing up-to-date soil fertility data. The information's revealed that in addition to nitrogen and phosphorus, sulfur and boron deficiencies are widespread in Ethiopian soils, while some soils are also deficient in potassium, copper, manganese, and iron ((EthioSIS, 2013; 2014; 2015; Lelago et al., 2016), which all potentially grasp back crop productivity despite continued use of N and P fertilizers as per the blanket recommendation. Fertilizer recommendation for crops in the country has until recently focused on Nitrogen and Phosphorus macronutrients only, but future gains in food grain production will be more difficult and expensive considering the increasing problem of multi soil nutrient deficiencies.

After the soil fertility map was developed by Agricultural Transformation Agency (ATA) in 2016, 13 blended fertilizers containing N, P, S, B, Zn, and Cu in different mix forms have been recommended for South

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Nation Nationalities and People Regional State (SNNPR) (EthioSIS, 2016). The low productivity of the crop is attributed to many biotic and abiotic factors, mainly to poor soil fertility (CSA, 2018). Hadero Tunto Zuria *kebele* is also characterized by nutrient deficiencies, among these limiting factors nitrogen (N), phosphorus (P), sulfur (S), and boron (B) are the most limiting nutrients in the study area as described in EthioSIS (2016).

Maize is an exhaustive crop having higher potential than other cereals and absorbs large quantities of nutrients from the soil during different growth stages. Nitrogen is a vital plant nutrient and a major yield determining factor required for maize production. It is very essential for plant growth and makes up one to four percent of the dry matter of the plants (Jeet et al., 2012). Phosphorus is among the essential nutrients, which are the most important nutrients for higher yield in larger quantity and control mainly the reproductive growth of the plant (Khan et al., 2014). In crop production, sometimes S is considered to be a forgotten secondary nutrient. However, it is most essential for the activity of proteolytic enzymes and the synthesis of amino acids (Sarfaraz et al., 2014). Also, the application of micronutrients through fertilizers recovers plant growth and production. From the micronutrients, B is an important micronutrient for healthy crop growth (Saleem et al., 2016).

According to the soil map of Hadero Tunto Zuria woreda (EthioSIS, 2016), soil sample results from cultivated land of 16 *kebeles* of the woreda showed that up to 5 kebeles including the study area soils have N, P, S, and B nutrients deficiencies, which decreases crop production in some amount in the study area. In addition to this, there is limited empirical information on the effect of blended NPSB fertilizer on maize yield in association with their improved varieties in the study area. Thus there is a need to investigate the effects of blended Nitrogen, Phosphorus, Sulphur, and Boron (NPSB) fertilizer in the performance of different improved maize varieties on growth, yield, and yield components of the crop.

So far research carried out in many localities across Ethiopia in previous years also recommended different rates of P and N in accordance to crop and soil types. Also, blended fertilizer significantly increased the yield of maize crops as compared to the recommended NP fertilizers (Chimdessa, 2016). The application of deficient soil nutrients such as nitrogen, phosphorus, sulfur, and boron improves the grain and biological yield of maize crops (Shiferaw et al., 2018). However, there is limited information regarding the performance of different maize varieties at different rates of NPSB fertilizer levels in the study area as described in EthioSIS (2016). Therefore, the objectives of this study were:

- ➢ To evaluate the effects of NPSB fertilizer on growth, yield, and yield components of maize varieties.
- ➢ To suggest the feasible rate of fertilizer with ideal maize variety for the study area.

2. Materials and methods

2.1. Description of the study area

The study was conducted under supplementary irrigation at Hadero Zuria Kebele in the Kambata Tembaro zone, southern Ethiopia, on farmers' fields from October 2018 to April 2019 cropping season. Geographically, it is situated at 7° 10′00″ to 7° 13′00″ N latitude, 37° 38′00″ to 37° 41′30″ E longitude, with an elevation of 1670 meters above sea level (Figure 1). The highest mean monthly rainfall which occurred in August was recorded at 230.62 mm, whereas the lowest mean monthly rainfall amount was 16.13 mm (Figure 2). The mean monthly maximum temperature ranges from 22.4 to 28.8 °C, the highest being in March and the lowest in August. The mean monthly minimum temperature ranges from 13.3 to 15.7 °C, the lowest mean minimum temperature being in December and the highest mean minimum in March (Figure 2).

2.2. Experimental materials and agronomic practices

A high-yielding maize variety 30G19 (Shone-pioneer), BH-546, and BH-547, which adapts to the agro-ecology of the area, were used for the study. Urea and NPSB were used as sources of N, P, S, and B respectively. The recommended rate of N fertilizer (100 kg ha^{-1}) in the form of urea (46% N) was used uniformly to all plots due to the amount of N in the blended NPSB fertilizer is small as compared to the requirement of maize and blended fertilizer in the form of NPSB (18.9% N+37.7% P_2O_5+6.95% S+0.1% B) (ATA, 2016), which is one of the major recommended blended fertilizers for Ethiopian soils Viz. NPS, NPSB, NPSZn, NPSZnB, NPSFeZn and NPSFeZnB (EthioSIS, 2015). Depending on the

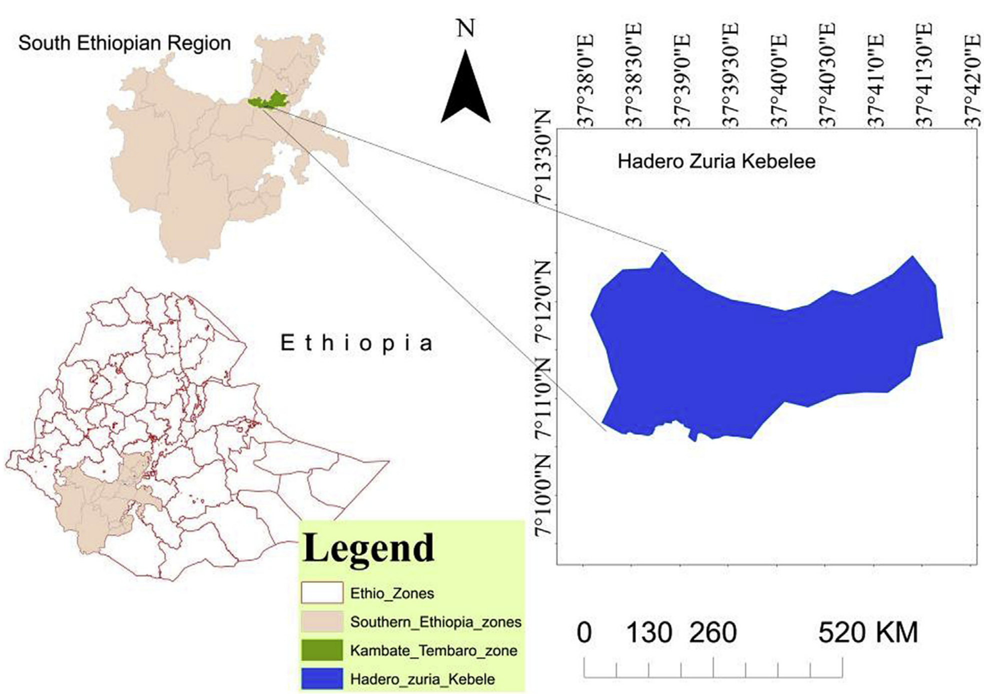

Figure 1. Map of the study area.

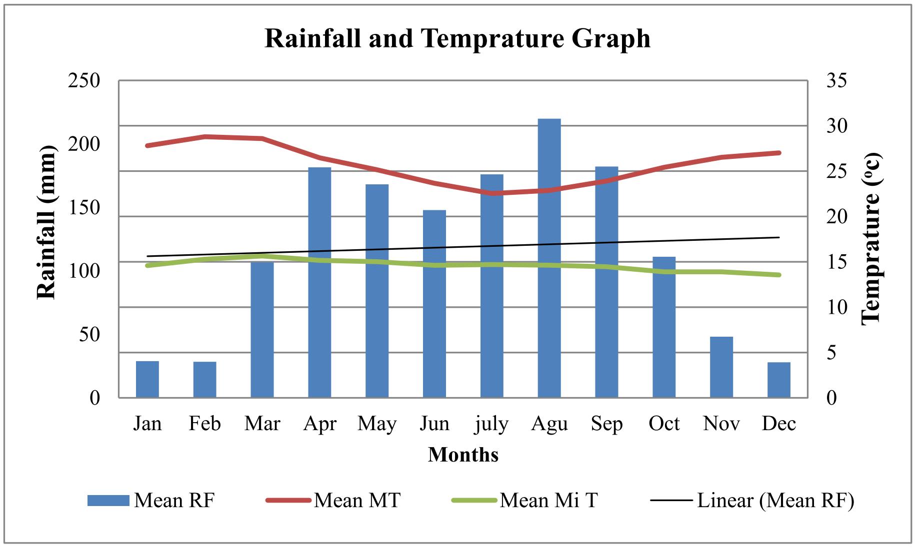

Figure 2. Mean monthly meteorological data of the study area for 10 years (2008–2017); Where, Mean RF = mean monthly rainfall; Mean MT = mean monthly maximum temperature; Mean MiT = mean monthly minimum temperature. Source: Araka Agriculture Research Center Meteorology station, southern Ethiopia.

nature of nutrients, a full dose of blended NPSB based on treatments was applied at sowing whereas nitrogen was applied in the split application (1/2 N rate at sowing and the rest was applied 45 days after sowing). The nitrogen content in blended NPSB is very low which is about 18.9 kg N out of 100 kg NPSB not enough to plant growth and development, and thus, supplement N application is very essential to satisfy crop requirements. Then, all the remaining necessary agronomic practices and crop management activities were undertaken.

2.3. Treatments and experimental design

The treatments consisted factorial combination of six blended NPSB fertilizer levels (0, 50, 75, 100, 125, and 150) kg ha^{-1} with three improved maize varieties. The experiment was laid out in Randomized Complete Block Design (RCBD) and replicated three times per treatment in factorial combination with a total of eighteen treatments. The spacing between plots and blocks was 0.50 m and 1 m, respectively. The total experimental area was therefore 646 m^2. The seeds were planted with intra and inter row spacing of 25 and 75 cm, respectively.

2.4. Data collection

Soil sampling and analysis

Soil samples were collected from the experimental field before sowing. Random soil samples were collected in a zigzag manner from 10 different points from a depth of 0–30 cm using an auger and composited to make one homogenized sample. The soil samples were air-dried, grinded, and mixed thoroughly before laboratory analysis. The air-dried soil was sieved through 2 mm mesh and soil physicochemical properties, which are relevant for this study, were analyzed. The parameters including textural analysis, soil pH, organic carbon, total N, and available P were analyzed at Sodo Soil Testing Laboratory, whereas soil available S and soil available B at JIJE Analytical Testing Service Laboratory, Addis Ababa, Ethiopia.

Soil texture was measured by Bouyoucos hydrometer method (Day, 1965). Organic matter was determined based on the oxidation of organic carbon with acid dichromate medium following the Walkley and Black method as described by Dewis and Freitas (1970). Soil pH was determined by using a glass electrode attached to a digital pH meter (Black, 1965). Total N was determined by Kjeldahl method (Munsinger and McKinneay, 1982). Available P was determined by Olsen method (Bray and Kurtz, 1945), and also soil available B was extracted by hot water and measured by Azomethine-H Colorimetric method (Bingham, 1982) and soil available S was measured with Turbidimetric-KH2PO3 Extract; they were analyzed as described by Lisle et al. (1994).

2.5. Phenological and growth parameters of maize

The number of days to tasseling was recorded by counting the number of days from sowing when 80% of plants in the net plot area develop tassels.

The number of days to Silking was recorded by counting the number of days from sowing when 80% of plants in the net plot area develop silks.

Anthesis Silking Interval was calculated as the days to 50% silking minus days to 50% anthesis in maize plants in the net plot area.

The number of days to physiological Maturity was recorded as the number of days after planting to the formation of a black layer at the point of attachment of the kernel with the cob by 75% of the maize plants in the net plot.

Plant height (cm) was measured as the vertical distance between the soil surface and the base of the tassel of 5 randomly selected plants from the net plot area at physiological maturity.

Cob length (cm) was measured from the point where the cob attached to the stem to the tip of the cob from 5 randomly selected plants in the central net plot at crop harvest.

Leaf area (cm^2) was determined by multiplying leaf length and maximum leaf width adjusted by a correction factor (i.e. Leaf Area = k (L*W)) at 50% of silking as suggested by (Francis et al., 1969).Where, k = 0.75 which is constant for all cereals, L = Leaf length, W = Leaf width.

Leaf area index (LAI) was determined by taking the ratio of the leaf area and ground area (Radford, 1967). The leaf area index was calculated using this equation:

LAI= (leaf area/ground area, m^2/m^2)

The number of a leaf was determined by counting all the leaves on each plant from 5 randomly selected plants in the net plot area at tasseling.

2.6. Yield components and yield of maize

Hundred kernels weight (g) was determined by counting 100 seeds from a bulk of shelled grains from a net plot and weighed using sensitive balance and then adjusted to 12.5% moisture level.

Total above ground dry biomass yield (kg ha^{-1}) was determined from plants harvested from 6 m^2 of each plot after sun drying for seven days to a constant weight and the result was converted to kilogram per hectare basis.

Grain yield (kg ha^{-1}): the central rows of each plot were harvested, sun dried, threshed, cleaned and weighted with in sensitive balance and the yield was adjusted to 12.5% moisture content before estimating hectare base yield.

Harvest Index (%) was recorded as the ratio of grain yield to total above ground biomass yield and multiplied by 100% at harvest in each plot (Huehn, 1993).

$$HI = \left[\frac{Grain\ yield}{TAGBY}\right] * 100$$

Where; TAGBY is total above ground biomass yield.

2.7. Statistical data analysis

Data collected on various growths, yield, and yield components were subjected to Analysis of Variance (ANOVA) by using statistical analysis system software (SAS, 9.1 versions), and mean separation was carried out using the least significant difference (LSD) test at 5% level of significance when the analysis of variance indicated the presence of significant differences. Also, correlation analysis was done to determine the relationship between plant growth parameters and yield and yield components as affected by rates of NPSB fertilizer and maize varieties using SAS, 9.1 versions.

2.8. Economic analysis

The economic feasibility of NPSB fertilizer application with hybrid varieties for maize production was analyzed following procedures described in Banziger & Diallo (2004). Mean grain yield was used in the partial budget analysis (Banziger and Diallo, 2004). Economic analysis computes income and expenses based on variable costs. From the last experimental data; the gross yield for different treatments was obtained.

Accordingly, the collected maize yield data was adjusted downward by 10% to gain the net yield of grain and stalk of maize and to adjust the yield obtained from the research field to actual farmer's practices. The field price of 1 kg of maize that farmers receive from sale for the crop was taken as 8.50 Ethiopian Birr (ETB) kg^{-1} based on the market price of maize at Hadero near the experimental site at the time of harvest. The price of NPSB and N (urea) fertilizer during planting time were 11.48 and 10 ETB kg^{-1}, respectively. Also cost of land preparation, seed, watering, weeding, chemical, harvesting, and threshing was considered in variable cost.

Then the gross benefit was calculated as average adjusted grain and stalk yield (kg ha^{-1}) multiplied by field price that farmers receive for the sale of the crop yield (8.50 and 0.50 ETB kg^{-1}, respectively). The total variable cost as the sum of all cost that was variable or specific to treatment against the control. Net benefit was calculated by subtracting the total variable cost from the gross benefit.

3. Results

3.1. Effect of NPSB fertilizer rates and maize varieties on phenological and growth parameters of maize

3.1.1. Number of days to tasseling

Statistically, a significant variation was observed on days to tasseling due to two-way interactions of NPSB rates by improved varieties. The shortest (97.67) and the longest (112.33) days to tasseling were recorded to the level of 100 kg ha^{-1} NPSB with 30G19 varieties and 0 kg ha^{-1} NPSB with BH-546 variety respectively (Table 1).

Table 1. Interaction effect of NPSB fertilizer rates and improved varieties of maize on days to tasseling.

Treatments						
Varieties	NPSB fertilizer Rates (kg ha^{-1})					
	0	50	75	100	125	150
30G19	107.33^{bdac}	98.33^{gh}	101^{gfeh}	97.67^{h}	101^{gfeh}	100^{gfh}
BH-546	112.33^{a}	107.67^{bac}	110.67^{ba}	105.33^{fdec}	103^{gfdech}	103^{gfdech}
BH-547	105^{fde}	103.67^{gfdec}	102^{gfdeh}	104.33^{fdec}	103.67^{gfdec}	106^{bdec}
$LSD_{0.05}$			4.79			
SE ±			1.67			
P-value			0.017*			
CV %			2.775			

LSD = Least Significant Difference at 5% level; SE = Standard error; CV = Coefficient of variation; Means in the column within a parameter followed by the same letter(s) are not significantly different at 5% level of significance.

3.1.2. Number of days to silking

Statistical data analysis of variance indicated that two-way interaction of variety× NPSB had a significant effect on the number of days to silking from this experiment. Accordingly, the more (121) number of days to silking was recorded at the combination of the control plots with maize variety (BH-546) while the less (108) number of days to silking was noted at the rate of 100 kg ha^{-1} NPSB application with a variety (30G19) (Table 2).

3.1.3. Anthesis silking interval

The main effect of NPSB rates and their interaction with varieties showed a non-significant variation on the anthesis silking interval. However, the main effect of maize varieties showed significant variation. The result indicated that the number of days (11.28) to ASI was required for the variety 30G19, while the least number of days (8.11) was required for the variety BH-546 (Table 3).

3.1.4. Number of days to physiological maturity

The result of experiments indicated that the effect of NPSB rates and varieties were showed a significant variation on days to physiological maturity of the crop. Accordingly, the longest (172.11) days to maturity was obtained at the rate of 0 kg ha^{-1} while the shortest (165.89) days to physiological maturity was verified at the rate of 100 kg ha^{-1}. Similarly, delayed maturity (171.94 days) was obtained for variety 30G19 whereas, the earliest days to maturity (166.05 days) were recorded from variety BH-547. However, their interaction was non-significant for physiological maturity (Table 3).

Table 2. Interaction effect of NPSB fertilizer rates and improved varieties of maize on days to silking.

Treatments						
Varieties	NPSB fertilizer Rates (kg ha^{-1})					
	0	50	75	100	125	150
30G19	117^{ba}	112.67^{bdc}	112.67^{bdc}	108^{d}	113.33^{bdc}	115.33^{bac}
BH-546	121^{a}	115.33^{bac}	116.33^{ba}	114.67^{bc}	108.67^{d}	110^{dc}
BH-547	118^{ba}	115.67^{bac}	115.67^{bac}	113.33^{bdc}	117^{ba}	116^{bac}
$LSD_{0.05}$			5.26			
SE ±			1.83			
P-value			0.028*			
CV %			2.767			

LSD = Least significance difference; SE = Standard error; CV = Coefficient of variation; Means in the column within a parameter followed by the same letter(s) are not significantly different at 5% level of significance.

Table 3. Anthesis Silking Interval (ASI), Days to physiological maturity DPM), Plant height (PH), cob length (CL), leaf area (LA), leaf area index (LAI), and number of leaves (NLP) maize as influenced by applied NPSB blended fertilizer and varieties at the study area.

Treatments	Phenological Traits		Growth Parameters				
NPSB (kg ha^{-1})	ASI	DPM	PH (cm)	CL (cm)	LA (cm^2)	LAI	NLP
0	9^b	172.11^a	181.38^b	19.08^c	4928^b	2.63^b	13.91^{ba}
50	10.89^a	170.11^{ba}	197.04^a	19.37^{bc}	5704.2^a	3.04^a	13.80^b
75	11^a	168.89^b	200.13^a	20.25^{ba}	5951.4^a	3.17^a	14^{ba}
100	10.22^{ba}	165.89^c	201.51^a	20.79^a	5635^a	3^a	14.69^a
125	10^{ba}	169^b	194.33^a	19.38^{bc}	5670^a	3.02^a	14.31^{ba}
150	10^{ba}	172^a	193.58^a	20.52^{ba}	5842.2^a	3.11^a	14.24^{ba}
$LSD_{0.05}$	1.51	2.48	11.7	1.16	437.71	0.234	0.6
Standard error SE (±)	0.53	0.86	4.07	0.4	107.69	0.081	0.24
Varieties							
30G19	11.28^a	171.94^a	218.97^a	19.42^b	5486.5^b	2.93^b	14.87^a
BH-546	8.11^b	171^a	179.8^b	21.52^a	6056^a	3.23^a	14.27^b
BH-547	11.17^a	166.05^b	185.22^b	18.75^b	5323^b	2.84^b	13.34^c
Fertilizer	ns	**	*	*	**	**	ns
Variety	**	**	**	**	**	**	**
Fertilizer*Variety	ns	Ns	ns	Ns	ns	ns	ns
$LSD_{0.05}$	1.07	1.75	8.27	0.82	309.51	0.165	0.48
SE (±)	0.37	0.61	2.88	0.28	107.69	0.058	0.17
CV (%)	15.53	1.52	6.27	6.09	8.13	8.14	5.04

LSD = Least Significant Difference at 5% level; SE = Standard error; CV = Coefficient of variation; Means in the column within a parameter followed by the same letter(s) are not significantly different at 5% level of significance; * and ** mean significant differences at 0.05 and 0.01 probability levels, respectively and ns = means non-significant differences.

3.1.5. Plant height

Regarding the plant height, there was a significant difference among treatments of the level of NPSB rates and improved maize varieties whereas; their interaction was non-significant (Table 3). The longest (201.51 cm) plant height was noted in maize plants fertilized with 100 kg ha^{-1} NPSB while the shortest (181.38 cm) plant height was obtained from the control treatment (Table 3). Correspondingly, improved varieties showed a significant variation in plant height; the tallest maize plant (218.97 cm) was attained in plots having 30G19 variety and the shortest maize plant height (179.8 cm) were seen in the BH-546 variety (Table 3).

3.1.6. Cob length

Combined analysis of variances showed that among treatments, NPSB fertilizer had a significant effect on cob length. The tallest (20.79 cm) mean cob length was obtained from plots supplied with treatment NPSB (100 kg ha^{-1}) which was significantly superior when compared with the control treatment. The shortest (19.08 cm) plant height was recorded from the treatment NPSB (0 kg ha^{-1}) (control), which was significantly shortest than other treatments. Likewise, planting of different varieties for the cob length of maize was showed highly significant variation. Hence, variety BH-546 had the longest cob length (21.52 cm) whereas; the BH-547 variety had the shortest cob length (18.75 cm). However, the interaction between NPSB fertilizer and variety was non-significant for cob length (Table 3).

3.1.7. Leaf area

Based on analysis of variances, the main effect of NPSB fertilizer and variety had shown a highly significant variation on leaf area of maize, whereas their interaction effect was non-significant. The highest (5951.4 cm^2) leaf area was recorded at the rate of NPSB 75 kg ha^{-1}, while the lowest (4,928 cm^2) leaf area was gained from the control treatment. Likewise, a larger leaf area (6056 cm^2) was noted in BH-546 while the narrower leaf area (5323 cm^2) was obtained from the BH-547 variety (Table 3).

3.1.8. Leaf area index

Leaf area index (LAI) was significantly affected by both different rates of blended NPSB fertilizer and improved maize varieties. The largest leaf area index was obtained from 150 kg ha^{-1} NPSB fertilizer rate and closely followed by all rates, except control (0 kg ha^{-1}) treatment, which showed significantly lowest leaf area index value. Similarly, the largest LAI was obtained from variety BH-546 and the rests were non-significant to each other (Table 3).

3.1.9. Number of leaves per plant

The number of leaves per plant was significantly affected by improved maize variety. The higher leaves number per plant (14.87) was recorded for variety 30G19 whereas the fewer number of leaves (13.34) was recorded for variety BH-547. However, the main effect of NPSB rates and their interaction effect of both (NPSB*variety) showed non-significant variation in all treatments on the number of leaves per plant (Table 3).

3.2. Effect of NPSB fertilizer rates and maize varieties on yield and yield components of maize

3.2.1. Hundred kernels weight (HKW)

The data given in Table 4 showed that there were highly significant ($P < 0.01$) variations due to different rates of NPSB fertilizer and varieties for HKW. Maximum HKW (36.62 g) was obtained from plots treated with NPSB at 150 kg ha^{-1}wheras, the minimum (29.62 g) HKW was obtained from the control (0 kg ha^{-1}) treatment. Likewise, maximum HKW (36.34 g) was obtained from the planting of variety 30G19, while minimum HKW (32.73 g) was recorded in variety BH-547 (Table 4).

3.2.2. Total above ground dry biomass yield (DBY)

The total aboveground dry biomass yield was high significantly ($P < 0.01$) affected by the main effects of blended NPSB fertilizer rates and varieties while their interaction did not show any significant variation. The highest DBY yield (43.70 t ha^{-1}) was attained at a rate of 150 kg ha^{-1} NPSB, while the lowest TBY (31.4 t ha^{-1}) was obtained from the

Table 4. Hundred kernels weight (HKW), total above ground dry biomass yield (DBY), and grain yield (GY) of maize as influenced by applied NPSB blended fertilizer and varieties.

Treatments	Yield and Yield Component Traits		
NPSB (kg ha^{-1})	HKW (g/100 seeds)	DBY (t ha^{-1})	GY (t ha^{-1})
0	29.62^{d}	31.41^{c}	4.46^{b}
50	32.64^{c}	36.85^{b}	6.69^{a}
75	35.12^{ba}	37.85^{b}	7.40^{a}
100	35.27^{ba}	38.25^{b}	7.20^{a}
125	34.42^{bc}	38.40^{b}	7.35^{a}
150	36.62^{a}	43.70^{a}	7.70^{a}
$LSD_{0.05}$	2.11	48.72	1.13
SE (±)	0.73	16.95	3.93
Varieties			
30G19	36.34^{a}	32.31^{c}	6.65^{a}
BH-546	32.77^{b}	43.66^{a}	7.12^{a}
BH-547	32.73^{b}	37.26^{b}	6.63^{c}
Fertilizer	**	**	**
Variety	**	**	**
Fertilizer*Variety	Ns	Ns	ns
$LSD_{0.05}$	1.49	34.45	7.98
SE (±)	0.52	11.98	2.77
CV%	6.48	13.47	17.32

LSD = Least Significant Difference at 5% level; SE = Standard error; CV = Coefficient of variation; Means in the column within a parameter followed by the same letter(s) are not significantly different at 5% level of significance; * and ** mean significant differences at 0.05 and 0.01 probability levels, respectively and ns = means non-significant differences.

control plots (Table 4). Similarly, the maximum above DBY (43.66 t ha^{-1}) was obtained from variety BH-546, whereas the minimum (32.31 t ha^{-1}) was recorded from 30G19 maize variety (Table 4).

3.2.3. *Grain yield*

The application of blended fertilizer resulted in a highly significant yield influence on the grain yield of maize. The maximum (7.70 t ha^{-1}) and the minimum (4.46 t ha^{-1}) grain yield were attained from application 150 NPSB kg ha^{-1} of blended fertilizer and control respectively. Similarly, planting of BH-546 improved variety resulted from the highest grain yield (7.12 t ha^{-1}), whereas the lowest (6.63 t ha^{-1}) was obtained from the BH-547 variety. However, the interactions between NPSB rates and varieties were showed a non-significant variation on grain yield of the maize ($P > 0.05$) (Table 4).

3.2.4. *Harvest index (%)*

The analysis of variance showed that the interaction between blended NPSB fertilizer rates and varieties was statistically significant on harvest index (HI). The highest HI (23.41%) was obtained from the combination of 30G19 variety and NPSB rate of 125 kg ha^{-1} whereas, the lowest (9.18%) was obtained from the combination of BH-547 variety and at the control plot (0 kg ha^{-1} NPSB) (Table 5).

3.3. *Association of selected growth, yield and yield components of maize*

Correlation analysis between growth parameters, grain yield, and yield components of maize was worked out and presented in Table 6. It was observed that plant height (PH) showed highly significant and revealed a good association with hundred kernel weight (r = 0.600**) and leaf number (r = 0.524**) while a weak positive association with harvest index (r = 0.438**), respectively. But it showed an insignificant and negative relationship with cobe length, leaf area, and leaf area index with (r = -0.068,-0.135, and -0.137) respectively. Similarly, cob length indicated a significant and weak positive relationship with leaf area (r = 0.401**), leaf area index (r = 0.400), leaf number (r = 0.384**) and HI (r = 0.437**), while there was a strong positive correlation with above ground dry biomass yield (r = 0.653**) and grain yield (r = 0.736**). However, cob length revealed a negative and insignificant association with plant height (r = -0.068) (Table 6).

Table 5. Interaction effect of NPSB rates and varieties of maize on harvest index at Hadero.

Treatments						
Varieties	NPSB (kg ha^{-1})					
	0	50	75	100	125	150
30G19	13.99^{egf}	19.35^{bc}	22.28^{ba}	17.52^{edc}	23.41^{a}	18.40^{c}
BH-546	14.66^{edf}	17.99^{dc}	18.13^{dc}	20.52^{bac}	17.53^{edc}	16.96^{edc}
BH-547	9.18^{h}	10.89^{hg}	12.90^{gf}	13.15^{gf}	12.39^{hgf}	12.77^{gf}
$LSD_{0.05}$		3.25				
SE ±		1.13				
P-value		0.02*				
CV %		12. 06				

LSD = Least Significant Difference at 5% level; SE = Standard error; CV = Coefficient of variation; Means in the column within a parameter followed by the same letter(s) are not significantly different at 5% level of significance.

Leaf area showed a strong positive and highly significant correlation with leaf area index (r = 0.989**); whereas it showed a weak positive and highly significant association with dry biomass yield (r = 0.487**). Similarly, the number of leaves showed a positive and significant correlation with hundred kernel weight (r = 0.620**), grain yield (r = 0.560**) and HI (r = 0.645**) but an insignificant and weak positive association with dry biomass yield (r = 0.152), leaf area (r = 0.058) and LAI (r = 0.056) (Table 6).

Hundred kernel weight also indicated a weak positive and significant association with grain yield (r = 0.480**) and harvest index (r = 0.510**) while cob length (r = 0.239), leaf area (r = 0.192), LAI (r = 0.184), and dry biomass yield (r = 0.225) indicated insignificant and positive correlation.

Grain yield showed a positive and highly significant correlation with dry biomass yield (r = 0.646**) and HI (r = 0.778** while **) however, plant height (r = 0.077), leaf area (r = 0.251), and LAI (r = 0.258) showed insignificantly and weak positive association, respectively (Table 6).

3.4. *Economic analysis of NPSB fertilizer effect on maize*

As indicated in (Table 7) below the partial economic analysis showed that the highest net benefit of 58,345.40 ETB ha^{-1} was obtained from the treatment 150 kg ha^{-1} NPSB fertilizer rate followed by 75 kg ha^{-1} with (56,691.60 ETB ha^{-1}), whereas the lowest net benefit (34,923.00 ETB ha^{-1}) was gained at 0 kg ha^{-1} NPSB or from the control treatment.

4. Discussions

This study revealed that application of the deficient soil nutrients viz. nitrogen, phosphorus, sulfur, and boron, which were low as indicated in pre-sowing soil analysis of the site, improved maize yield and yield component (Table 8). Hence, the research results showed that blended fertilizers with different rates of N, P, S, and B might have encouraged the early establishment, rapid growth, and development of crop thus; shortening the days to tasseling, silking, and maturity but the current result was divergent in this respect. The probable reason could be an application of N fertilizer except on control treatment applied at the same rate for all treatments and thus the effect of N was insignificant. The parameters like anthesis silking interval and physiological maturities were significantly affected due to different rates of blended NPSB fertilizer and varieties. Increasing the rate of NPSB fertilizer up to 100 kg

Table 6. The correlation coefficient between mean values of selected growth parameters and yield components of maize.

Variables	PH	CL	LA	LAI	NLP	HKW	DBY	GY	HI
PH	1								
CL	-.068^{ns}	1							
LA	-.135^{ns}	.401**	1						
LAI	-.137^{ns}	.400**	.989**	1					
NLP	.524**	.384**	.058^{ns}	.056^{ns}	1				
HKW	.600**	.239^{ns}	.192^{ns}	.184^{ns}	.620**	1			
DBY	-.334*	.653**	.487**	.487**	.152^{ns}	.225^{ns}	1		
GY	.077^{ns}	.736**	.251^{ns}	.258^{ns}	.560**	.480**	.646**	1	
HI	.438**	.437**	-.023^{ns}	-.014^{ns}	.645**	.510**	.041^{ns}	.778**	1

Where, PH = plant height; CL = cob length; LA = leaf area; LAI = leaf area index; NLP = number leaf per plant; HKW = hundred kernels weight; DBY = total above ground dry biomass yield; GY = grain yield; HI = harvest index. ns, * and ** = non-significant, significantly different at 5% and 1%, respectively.

Table 7. Results of the economic analysis and marginal rate of return for the effects of NPSB fertilizer rate on maize at Hadero Zuria kebele.

Treatment	AGY (Qt ha^{-1})	ASY (Qt ha^{-1})	GYR (ETB)	SYR (ETB)	TR (ETB)	TVC (ETB)	NR (TR-TVC)	MINB	MIVC (ETB ha^{-1})	Dominance	MRR %
NPSB (kg ha^{-1})											
0	40.13	16.25	34110.5	812.50	34923.0	0	34923.0				
50	60.26	16.36	51220.1	818.15	52038.3	574.00	51464.3	16541.3	574		2882
75	66.60	18.75	56615.1	937.50	57552.6	861.00	56691.6	5227.30	287		1821
100	64.80	19.16	55082.5	958.30	56040.8	1148.0	54892.8			D	
125	66.16	21.56	56238.5	1078.15	57316.7	1435.0	55881.7	988.90	287		344
150	69.34	22.50	58942.4	1125.00	60067.4	1722.0	58345.4	2463.70	287		858

Where, AGY = Adjusted Grain Yield; ASY = Adjusted Stalk Yield; GYR = Grain Yield Revenue; SYR = Stalk Yield Revenue; TVC = Total Variable Cost and TR = Total Revenue; Qt ha^{-1} = quintal per hector; NR = Net return; MINB = Marginal increase in Net benefit; MIVC = Marginal increase in variable cost; MRR = marginal rate of return; D = dominance; 8.50 ETB kg^{-1} of grain yield of maize; and 0.50 ETB kg^{-1} of stalk yield of maize; ETB = Ethiopian Birr.

Table 8. Physicochemical properties of soil in the experimental site before sowing.

Soil properties	Value	Status	Source
Particle Size Distribution	(%)		
Sand	58		
Silt	27		
Clay	15		
Textural Class	Sandy loam		
pH (H_2O)	5.8	Moderately acidic	EthioSIS team analysis, 2014
OC %	2	Low	EthioSIS team analysis, 2014
TN %	0.22	Low	EthioSIS team analysis, 2014
Av.P (mg kg^{-1})	2.6	Very low	EthioSIS team analysis, 2014
Av.SO4 (mg kg^{-1})	18.25	Low	EthioSIS team analysis, 2014
Av. B (mg kg^{-1})	0.68	Low	EthioSIS team analysis, 2014

ha^{-1} hastens early maturity and then after it showed the lengthy of physiological maturity. The earliest day of maturity was obtained from treatment received the rate of 100 kg ha^{-1} of NPSB fertilizer and the longest day for maturity was noted from no fertilized at all treatment (control). This might be due to favorable conditions of soils for the crop nutrient requirement by application of deficient soil nutrients found in the blended fertilizer and the presence of Boron, which is necessary for stimulation of roots and shoots development and tassel and silk formation for maize in that it hastens the early maturity of the crop. Some earlier studies by (Chimdessa (2016) and Bakala (2018)) have also shown that silking, tasseling, and days to maturity of maize were significantly affected by the application of blended fertilizer rates.

With regards to varieties, the earliest maturity was obtained from improved varieties of BH-547 and the opposite was obtained from the 30G19 variety. This might be due to genetic variation between varieties which finally resulted in variation to reach maturity. The results are in line with Toga and Tana (2014), who reported highly significant effects of varieties on days to physiological maturity of maize.

The application of blended NPSB fertilizer showed a variation in the parameters like plant height and cob length. This might be due to an increase in cell elongation and more vegetative growth attributed to crop requirements of the NPSB blended fertilizer for its normal physiological growth. On the other hand, the shortest plant height in unfertilized plots might have been due to the low level of those essential nutrients in the soil for crop requirements. The results were in agreement with the findings of (Chimdessa (2016) and Bakala (2018)) who found that significantly increased plant height with the application of blended fertilizer as compared to the recommended NP fertilizers and the control. Similarly, the influence of variety also showed a significant variation on plant height and cob length. The variation on those growth parameters might be due to the differences in genetic potential and plant characteristics, and also nutrient uptake potential of maize varieties. In line with this, Ahmad et al. (2003) reported that the improved maize cultivars were significantly affected the plants' height. Likewise earlier studies by Woilamo and Tana (2012), Toga and Tana (2014) and Idoko et al. (2018), confirmed that there were significant variations between varieties of maize for plant height and cob length.

The rest of plant growth parameters like leaf area, leaf area index, and the number of leaves per plant showed variation due to different rates of NPSB blended fertilizer. This might be associated with the application of NPSB fertilizer, which has a positive effect on a photosynthetic rate which in turn can hasten dry matter accumulation further contributing to the expansion of leaf and improved crop growth as well as development in maize crop. The result is in line with Chimdessa (2016), who reported that significantly increased leaf area, leaf area index, and the number of leaves per plant by the application of blended fertilizer in maize crops. Correspondingly, different maize varieties showed variation towards leaves area, leaf area index, and the number of leaves per plant. This might be due to the difference in genetic performance potential and plant morphological characteristics of maize varieties. Likewise, Abera et al.

(2017) and Idoko et al. (2018), who reported that the leaf area, leaf area index, and the number of leaves per plant of maize were significantly affected by the use of varieties.

Yield components, viz., hundred kernels weight, total above ground dry biomass yield, and grain yield of maize were highly influenced by different levels of NPSB blended fertilizer at the study area. The increase in the rates on NPSB fertilizer level increases yield components like kernels weight, total above ground dry biomass yield and grain yield of maize crop. The increase in yield components was due to supplementary application of NPSB fertilizer, which in turn attributed to low nutrient status determined by analysis of soil before planting for the experimental site (Table 8). This may be due to the greater contribution of NPSB fertilizer by producing healthy kernels i.e. well-filled kernels and bigger kernels, whereas minimum kernel weight was obtained at lower levels. Thus, the availability of these nutrients enables the plant to develop a more extensive root system to extract water and nutrients, from more depth. Moreover, it could be attributed to the beneficial effect of yield contributing characters and positive interaction of nutrients in the blended fertilizer. This implies that the application of NPSB blended fertilizer as soil fertility management practices from this demonstration confirmed that the necessity of NPSB fertilizer for the improvement of yield and yield component of maize crop and in line with this, Chimdessa (2016) who identified that application of blended fertilizer was significantly improved the weights of the kernels, total above ground dry biomass yield, and grain yield when compared with control plots. Similarly, Shiferaw et al. (2018) reported that significantly high grain yield was obtained from the plots treated with NPSB linked to the control treatments.

Likewise, planting of improved maize variety also resulted in significant variation in hundred kernels weight, total above ground dry biomass yield, and grain yield of the crop. This might be due to the inherent genetic potential of individual varieties under similar trials of fertilizer application for such differences. This is similar to earlier studies by different authors (Idoko et al. (2018); Toga and Tana (2014), and Woilamo and Tana (2012)) that showed that the 100-kernels weight, total above ground dry biomass yield, and grain yields of maize was significantly influenced by maize variety.

The harvest index (HI) of a crop is an interaction of its physiological efficiency and its ability to convert the photosynthetic material into economic yield. Interaction of variety by NPSB had a significant effect on the harvest index. However, the result for HI from this study was not consistent across the different rates of blended NPSB fertilizer and varieties. In general, HI was increased when the NPSB rate increased within different maize varieties. Higher HI implies higher partitioning of dry matter into grain might be due to the genetic potential of the varieties. A similar trend was shown by different authors (Woilamo and Tana (2012); Dawadi and Sah (2012); Kena (2015); Takele et al. (2017)) that different varieties shown variation on HI for maize crops.

The relationship between Grain yield and total above ground dry biomass yield was also positive and significant, indicating that higher biomass yield could be due to result in increased cob length and consequently increase grain yield of the crop. This might be the longer cobe length due to more absorption of photoassimilates, the most portion of assimilates remobilizes to grains, and invariably increase grain weight. However, the relationship between plant height, leaf area, and leaf area index has shown a positive and non-significant association with grain yield, and implied that their modifications have no influence on grain yield. This result is in agreement with Wu et al. (2019) who found a non-significant correlation between plant height and maize grain yield but a significant and positive correlation to cobe length, hundred kernels weight, and total above ground biomass with grain yield.

Based on the partial economic analysis, the treatment with the highest net benefit was recorded at the rate of 150 kg ha^{-1} NPSB fertilizer compared to treatments: 50, 75, and 125 kg ha^{-1} NPSB fertilizer rates. However, the marginal rate of return (MRR) at the rates of 50, 75, and 125 kg ha^{-1} NPSB fertilizer were 2882%, 1821%, and 344. This means that for each 1 ETB investment, the producer can get more than 100%. According to CIMMYT, experience and empirical evidence, for the majority of situations indicated that the minimum rate of return acceptable to farmers would be 100%. Since the minimum acceptable rate of return assumed in this experiment was 100%, all these treatments can give an acceptable marginal rate of return for the extra investment except 100 kg ha^{-1} NPSB rate, which showed net benefits less than lower variable costs termed as dominated treatment and dropped from economic analysis. As a result of this, marginal rates of return (MRR) of the five treatments were computed. Accordingly, the highest MRR% (2,882) was recorded from the application of 50 kg ha^{-1} NPSB blended fertilizer when compared to the other for this specific area to get more profit.

5. Conclusion

Optimization of nutrient inputs and production costs is among the best options in producing a sustainable crop production system for the subsistent smallholder producer. Therefore, the use of blended fertilizer for plant nutrient management practices and selecting the most productive varieties of improved maize variety are the most strategic goals for subsistence farmers like the current study area. The research result showed that the rate of 150 kg ha^{-1} NPSB rate gave the maximum number of hundred kernels weight per 100 seed, total above ground dry biomass yield, and grain yield of maize. Likewise, the maximum number of hundred kernels weight per 100 seed was obtained from maize variety of 30G19 whereas higher total aboveground biomass yield and grain yield were obtained from a variety of BH-546. Correlation analysis indicated significant associations of growth parameters and yield components with the grain yield of maize. The partial budget analysis also confirmed that the highest net benefit (58,345.40 ETB) with a marginal rate of return (858%) was obtained from the application of 150 kg ha^{-1} rate NPSB fertilizer. Based on this result, it can be concluded that the application of blended NPSB fertilizer at the rate of 150 kg ha^{-1} and improved maize variety BH-546 could improve the yield and the income of maize growing farmers for the study area and similar agro-ecological zones.

Declarations

Author contribution statement

Detebo Orebo: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Dereje Shanka; Mulugeta Hadaro: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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