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*Research Article*

# Effect of Blended Nitrogen, Phosphorus, Sulfur, Boron, and Potassium Fertilizer Rates on Growth and Yield of Maize (*Zea mays* L.) at Sodo Zuriya District, Southern Ethiopia

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There are various challenges that limit crop productivity in developing countries like Ethiopia. Lack of accessible plant nutrients in proper quantity as well as form to plants is an important determinant of reducing agricultural productivity. In this regard, a trial was conducted at Shela Borkoshe on the land owned by the farmer in Sodo Zuriya District, Wolaita Zone, Southern Ethiopia over the planting seasons of 2019 to 2020 with the aim of identifying the appropriate rates of blended nitrogen, phosphorus, sulfur, boron (NPSB), and potassium (K) fertilizer in maize production. The treatments, which were assessed using a factorial randomized complete block design with three replications, comprised of four rates of blended NPSB (0, 50, 100, and 150 kilograms/hectare) and four rates of K (0, 30, 60, and 90 kilograms/hectare $K_2O$). Agronomic traits leaf area, LAI, ear length, seeds per row, seeds per ear, TSW, biomass as well as grain produce have been significantly varied due to NPSB by K fertilizer rates interactions. The highest leaf area ($9886.20 \pm 343.95\ cm^2$), LAI ($7.78 \pm 0.26$), ear length ($32.58 \pm 1.46$ cm), TSW ($160.67 \pm 4.85$ g), biomass ($14941 \pm 200.92$ kilograms/ha), and grain output ($7544 \pm 119.49$ kilograms/ha) have been attained by combining 150 kilograms/ha NPSB and 90 kilograms/ha K fertilizer rate. Following this, maximum quantity of seeds per row ($44.88 \pm 1.67$) and seeds per ear ($705.87 \pm 25.61$) have been attained from combination of 150 kilograms/ha NPSB and 60 kilograms/ha K fertilizer rates. Economic analysis revealed that maximum net profit (1491 Dollar/ha) and marginal rate of return (MRR) 1196.67% have been achieved from combining 150 kilograms/ha NPSB and 60 kilograms/ha K fertilizer rates. This investigation revealed that the combination of the NPSB fertilizer level of 150 kilograms/ha and 60 kilograms/ha K fertilizer showed superior performance with higher grain yield and economic return over other treatments. Therefore, a combined application of 150 kilograms/ha NPSB with 60 kilograms/ha K fertilizer rates could be recommended for maize production in the study area and similar agro-ecologies.

## 1. Introduction

Due to its excellent adaptability and production, maize (*Zea mays* L., $2n = 2x = 20$) ranks third among all cereal crops in terms of importance worldwide [1, 2]. Although maize is grown all over the world in a variety of environments, it produces best in conditions of moderate temperature and ample moisture. Maize is greatly prominent cereal crop grown in Ethiopia, which has the highest yearly production compared to the productivity of any cereal crop (apart from tef, *Eragrostis tef* (Zucc.) Trotter) [3]. With respect to area coverage, maize ranks second to tef (*Eragrostis tef*), yet it tops the list for productivity and overall production among all cereals. Of Ethiopia's total 14 million hectares set aside for crop cultivation, maize is the primary food crop cultivated on more than two million hectares (15%). Ethiopia consumes 1,858 kilocalories per day on average; among these four main cereals, maize, "*teff*," wheat, and sorghum contribute above sixty percent, while maize and wheat each contributing twenty percent [3]. In the nation, maize is primarily grown for human use by 9.3 million smallholder farmers. These farmers rely heavily on it as a source of revenue [4]. Being a means of obtaining food as well as financial earnings, maize has remained a significant cereal crop in the southern region [5].

Ethiopia's crop production faces serious bottlenecks as a result of the periodic decline in soil fertility brought on by both natural and man-made factors [6]. One of the solutions to these problems is to use the ideal K fertilization in combination with the ideal blend of blended fertilizers, such as NPSB. Blended fertilizer is important for balancing macro and micronutrients in crop nutrition and increasing crop yields. Because of their adaptability, simple economics, and enhanced environmental protection, blended fertilizers are therefore beneficial [7]. As a result, potassium (K) exerts a strong osmotic pull on water, drawing it into plant roots and assisting in the synthesis of protein and chlorophyll. Potassium decreases lodging in maize and generates strong and rigid straw. Potassium controls how quickly leaf stomata open, which in turn controls how quickly gases are exchanged and transpired [8]. It is a necessary nutrient that has an impact on the majority of biochemical and physiological processes which influence plant development as well as metabolism [9]. A shortage of potassium in the soil can reduce yields [10]. Optimization of nutrient combinations is crucial because it allows for precise matching of these to local soil characteristics and plant requirements, preventing surplus nutrients from potentially entering the environment [11]. Conversely, with intensive agriculture, deficiencies in secondary macronutrients as well as micronutrients can develop provided that these nutrients fail to be timely supplemented [12–14]. Additionally, the Ethiopian Agricultural Transformation Agency (ATA) is starting to use a variety of blended fertilizer mixes for the nation's various agro-ecologies to increase crop yield. However, there are restrictions on the optimum rate of fertilization for maize production in diverse agro-ecologies in Ethiopia. This shows that the lack or shortage of optimum rates of nutrients in the area would limit the region's output, which would help to explain why farmers in the Sodo Zuriya district are reporting lower yields [15]. In order to establish appropriate levels of blended nitrogen, phosphorus, sulfur, boron (NPSB), and K for the growing of maize; therefore, this investigation has been carried out.

## 2. Methodology

*2.1. Experimental Area.* During 2019 to 2020 cropping seasons, a field trial was conducted on farmers' field of Shela Borkoshe Peasant Association, Sodo Zuriya District, Wolaita Zone, Southern Ethiopia. The site, which is 1857 meters above sea level, is roughly situated at 6°50′22″N latitude and 37°49′19″E longitude. The experimental area experiences 1483.1 mm of annual rainfall with a bimodal trend, characterized by a rainfall period lasting between March and September. Annual average temperature ranges between 12.9 and 24.6°C (Table 1). Before initiation of investigation, composite specimen of soil has been gathered throughout the experimental site and tested for some physico-chemical properties. When tested, it was discovered that the particle size distribution matched sand, silt, and clay with proportions of 30%, 18%, and 52%, respectively, that implied that its texture was clay with pH of 6.70 (Table 2).

*2.2. Treatments and Experimental Design.* Treatments comprised of four rates of blended NPSB (0, 50, 100, and 150 kilograms/hectare) as well as four rates of K (0, 30, 60, and 90 kilograms/hectare $K_2O$) fertilizers which have been combined in a factorial randomized complete block design involving triplicate. Variety of maize BH 546, which is well suited to altitude ranges of 1000 to 2000 meters above sea level and introduced in 2013 by Agricultural Research Center of Bako, was employed as a trial plant. Every plot had dimensions of 3.75 m wide and 3 m long with total gross plot area of 11.25 $m^2$. To prepare a smooth seedbed for planting, testing site was plowed, ground down, as well as flattened. The plants were thinned following germination to preserve required crop population per plot after two seeds per hill were manually sowed. Seventy-five and fifteen cm, respectively, were employed as the inter- and intra row spacing. Blended NPSB fertilizer with elemental composition of 18.9% N, 37.7% $P_2O_5$, 6.95% S, and 0.1% B and muriate of potash (KCl) with 60% $K_2O$ were combined and applied at planting as rated per plots. With the exception of plots not fertilized with NPSB fertilizer, suggested quantity of urea, the untreatment component, was used at the dosage of 100 kilograms/ha evenly to every plot in split (1/2 at planting, the remaining second 1/2 close to blossoming) taking into account the N content of NPSB. Everything related to crop management, including cultivation and weeding, was done as desired. During the growth season of the crops, diseases and insect damage were observed visually.

*2.3. Collection of Data.* Number of days required for physiological maturity, number of days required for anthesis, number of days required for silking, anthesis silking interval (ASI), height of plant, area of leaves, leaf area index (LAI), length of ear, diameter of ear, rows per ear, seeds per row, seeds per ear, thousand seed weight (TSW), biomass yield, yield of grain, and harvest index (HI) were all recorded for data analysis. Observations, parameter measurements, and harvesting operation processes in the field are shown from Figures 1–4. The total number of days between sowing until the day fifty percent of a plot's plants started pollen shading was used for determining days to anthesis. Total number of days just after sowing until fifty percent of the plot's plants extrude silks have been used to record days to silking, while the gap between the numbers of days to silking and anthesis was used to determine anthesis silking interval (ASI) and calculated as

$$ASI = DS - DA, \tag{1}$$

where ASI = anthesis silking interval, DS = days to silking, and DA = days to anthesis.

The number of days between planting and the day when fifty percent of the crops in the plot form a black layer on the sample grains was used to calculate the days to physiological maturity. Five arbitrarily picked plants from each plot have been measured from the ground to the tip at physiological maturity for determining plant height. By measuring three leaves from the upper, middle, as well as lower portions of each plant, the leaf area (LA) of five arbitrarily chosen plants

Table 1: Annual rainfall and minimum and maximum temperature data for Shela Borkoshe experimental station during 2019 to 2020 cropping seasons.

| Duration | Climatic parameter | Months | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | J | F | M | A | M | J | J | A | S | O | N | D | Total |
| 2019-2020 | Rainfall (mm) | 2.0 | 21.6 | 39.9 | 216.8 | 129.8 | 338.2 | 230.9 | 101.2 | 181.3 | 131.8 | 82.6 | 7.0 | 1483.1 |
| | | Temperature (°C) | | | | | | | | | | | | Mean |
| 2019-2020 | Min temp. | 15.6 | 14.7 | 13.8 | 13.6 | 12.9 | 12.4 | 11.6 | 11.4 | 11.7 | 12.1 | 12.8 | 13.1 | 12.9 |
| 2019-2020 | Max temp | 25.6 | 24.9 | 24.8 | 24.7 | 25.6 | 23.8 | 23.7 | 24.0 | 23.5 | 24.8 | 24.9 | 24.6 | 24.6 |

Table 2: Some physicochemical characteristics of soils of testing field during 2019 to 2020 cropping seasons before sowing the crop.

| Soil properties | Unit | Value | Rates |
|---|---|---|---|
| Soil separates | % | — | — |
| Sand | % | 30 | — |
| Silt | % | 18 | — |
| Clay | % | 52 | — |
| Textural class | — | Clay | — |
| Soil pH | % | 6.70 | Neutral |
| OC | % | 0.74 | Very low |
| TN | % | 0.07 | Very low |
| Available phosphorous | ppm | 5.71 | Low |
| Available sulphur | ppm | 11.73 | Medium |
| Available boron | ppm | 0.25 | Low |
| Available potassium | ppm | 140.25 | Low |
| Cation exchange capacity | meq100 $g^{-1}$ | 19.67 | Medium |

per plot at physiological maturity was computed using the formula [9] as

$$\text{LA} = W \times L \times K, \quad (2)$$

where $W$ = leaf width, $L$ = leaf length, and $K$ = correction factor.

The ratio of total leaf area to the ground area was used to determine the leaf area index (LAI) [10] and computed as follows:

$$\text{LAI} = \frac{W \times L \times K \times NL}{\text{Ground area}}, \quad (3)$$

where LAI = leaf area index, $W$ = leaf width, $L$ = leaf length, $K$ = correction factor, and NL = number of leaves per plant.

Five arbitrarily picked ears per plot have been measured from base to tip to determine the length of the ear and the ear diameter was identified by measuring at middle using a digital caliper during harvesting. At harvest, five randomly chosen ears in each plot were counted for their number of rows to determine the total quantity of rows per ear. Via listing the total quantity of seeds per row in 5 arbitrarily picked ears from each plot following harvesting, the total quantity of seeds in each row has been calculated. For five arbitrarily picked ears in each plot, the total quantity of rows by the total quantity of seeds per ear has been multiplied to get the total quantity of seeds in each ear. TSW has been calculated through utilizing a seed counter to count 1,000 seeds and a sensitive balance to weigh them after setting the moisture content at 12.5% during harvest. By weighing the entire above-ground portion of the 6.75 $m^2$ net plot during harvest from the center row with exclusion of the boundary rows, the biomass yield was calculated. After correcting the moisture content to 12.5%, the grain produce has been manually gathered from a net plot size of 6.75 $m^2$ (excluding boundary rows) and converted to kilograms/hectare. In order to find out the harvest index (HI), grain yield was divided by total biomass as follows:

$$\text{HI} = \frac{\text{Grain yield}}{\text{Biomass yield}}. \quad (4)$$

Using the partial budget analysis, the financial benefit of fertilizer consumption in maize production was evaluated. The whole benefit was determined as the ten percent corrected grain yield multiplied by the actual cost that growers earn from the selling of their harvest and converted to US dollars using the current exchange rate. Partial budget analysis [17] has been performed through employing the average grain outputs of the treatments, and for every combination of sorted treatments, the marginal rate of return in % has been determined by the following way:

$$\text{MRR (\%)} = \frac{\text{Change in NB}}{\text{Change in TVC}} \times 100, \quad (5)$$

where MRR = marginal rate of return, NB = net benefit, and TVC = total variable cost.

Based on general linear model (GLM) of GenStat sixteenth edition, the taken variables have been subjected to analysis of variance fit to the factorial experiment in RCBD [18], and interpretations were performed in accordance with the standard operating procedure [19]. In cases wherever the influences of the treatments have been subsequently considered to be significant, the means were contrasted employing the least significant differences (LSD) test using a 5% level of significance. With regard to the relationship between NPSB and K fertilizer levels and grain yield, linear regression was conducted using the following regression equation:

$$Y = \alpha + \beta 1X1 + \beta 2X2, \quad (6)$$

where $Y$ = dependent variable (grain yield), $\alpha$ = intercept, $\beta 1X1$ = regression coefficient for first independent variable $X1$ (NPSB rates), and $\beta 2X2$ = regression coefficient for first independent variable $X2$ (K rates).

With the help of the following correlation equation, a correlation analysis has been performed to ascertain the link within two agronomic traits:

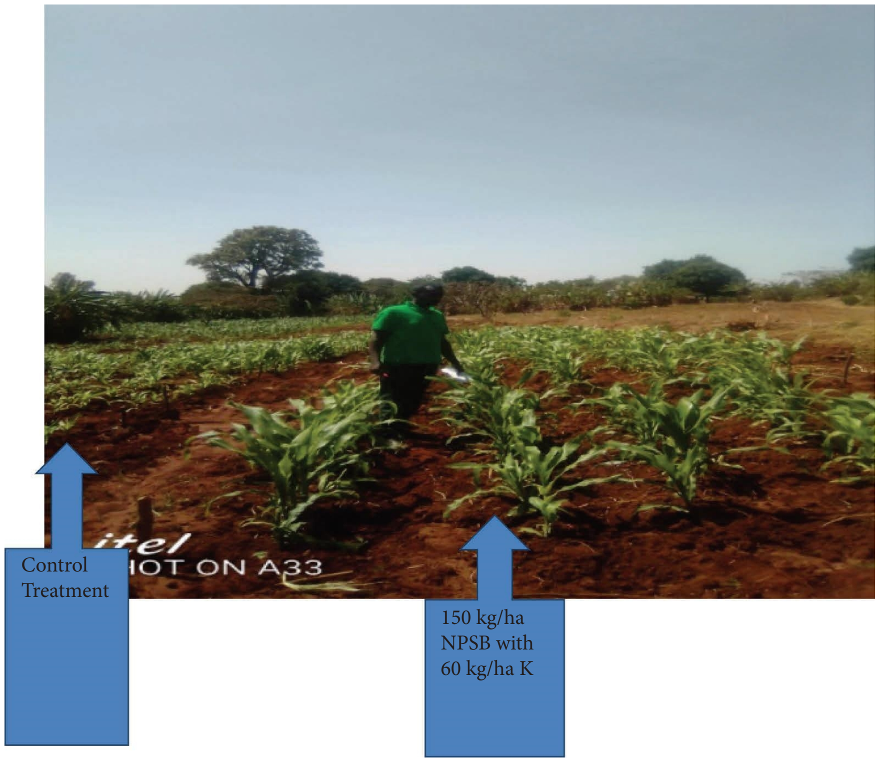


Figure 1: Field observation during early establishment period of the crop.

Figure 2: Field evaluation at reproductive growth stage of the crop.

$$r = \frac{\sum xy}{\sqrt{(\sum x2)(\sum y2)}}, \quad (7)$$

where $r$ = correlation coefficient and $xy$ = pair of parameters.

## 3. Results and Discussion

*3.1. Days to Anthesis and Silking.* Data assessment (Table 3) implied that there were considerable variations in the days to anthesis and silking owing to the substantial influence of

Figure 3: Data collection in the field.

NPSB fertilizer dosages. With the elevation of NPSB fertilizer levels from 0 to 150 kilograms/hectare, both parameters tended to shorten. The longest days to anthesis (85.67 ± 0.63 d) and silking (90.00 ± 0.77 d) appeared in the unfertilized plots, which were preceded by NPSB fertilizer dosage of 50 kg/ha with mean days to anthesis of 83.58 ± 0.63 and silking of 86.33 ± 0.77. With a dosage of 150 kilograms/hectare of NPSB fertilizer, the shortest days to anthesis (77.50 ± 0.63 d) and silking (79.75 ± 0.77 d) were observed (Table 3). Shortening tendency of the days to anthesis and silking with increasing blended NPSB fertilizer rates probably suggests that nutrient availability hastened plant growth and development leading to earlier anthesis and silking. Fageria et al. [13] reported that balanced fertilization has positive impact on crop earliness. The findings by Brady and Weil [20] showing balanced fertilization of N, P, and S improved plant physiological activities such as photosynthesis, flowering, seed formation, as well as maturity, which are also consistent with this result. The main influence of K fertilizer levels also significantly affected the total quantity of days until anthesis as well as the total quantity of days till silking. The unfertilized plots resulted in the longest days to anthesis (84.42 ± 0.63 d) and silking (86.42 ± 0.77 d) preceded by K fertilizer level of 30 kg/ha K having average days

Figure 4: Harvesting the crop from the field for data collection.

until anthesis of 82.42 ± 0.63 and silking of 85.17 ± 0.77, respectively. The shortest days to anthesis (80.42 ± 0.63 d) and silking (83.00 ± 0.77 d) were occurred at K fertilization level of 90 kg/ha (Table 3). This is probably an indication that proper amount of K fertilization expected to stimulate growth and development of plants for early maturation. In line with it, Marschner [21] reported that adequate supply of K stimulated early growth and silking in maize. The days to anthesis and silking, however, were not significantly impacted through interactions of NPSB and K fertilizer applications (Table 3).

*3.2. Anthesis Silking Interval.* Significant difference was observed as result of the primary influence of NPSB fertilizer levels on ASI. Anthesis-silking interval (ASI) as governed through principal influence of NPSB fertilizer doses ranged from 3.50 ± 0.52 to 11.92 ± 0.52. The longest ASI (11.92 ± 0.52 d) was recorded from unfertilized plots whereas the shortest ASI (3.50 ± 0.52 d) was observed at NPSB fertilizer dosage of 150 kg/ha (Table 3). Likewise, a significant difference was identified as a result of the principal influence of K fertilizer levels on ASI. The gap between ASI was narrowed as potassium fertilizer dosages was elevating from 0 to 90 kilograms/ha. Extended ASI of 8.00 ± 0.52 days was attained from the unfertilized plots followed by ASI of 7.58 ± 0.52 days that was achieved from the application of 30 kg/ha K fertilizer. Potassium fertilizer dosage of 90 kilograms/ha resulted in the fastest ASI of 6.25 ± 0.52 days. The proportional growth of the male (tassel) and female (ear) inflorescences because of the presence of K nutrient in soils for crop uptake could be the cause of the reduction of ASI under increased levels of K fertilization. Nevertheless, interactions between NPSB and K fertilizer rates did not considerably alter ASI (Table 3).

*3.3. Days to Physiological Maturity.* Major impact of NPSB fertilizer rates on days to physiological maturity was noted as a notable variation. As a result of NPSB fertilizer rates, the ranges of days to physiological maturity ranged from 152.00 ± 0.52 to 157.00 ± 0.52 days. The extended period of time till physiological maturity (157.00 ± 0.52 d) had been achieved from the unfertilized plots, whereas the shortest days to physiological maturity (152.00 ± 0.52 d) had been achieved from the plots that received 150 kg/ha NPSB fertilizer rate application (Table 3). Early phenological development in cereal crops hastened with adequate fertilization of nitrogen and phosphorus [22]. Comparatively, there was no discernible influence of K fertilizer levels or its interactions with NPSB fertilizer rates on the total quantity of days required for physiological ripeness (Table 3).

*3.4. Plant Height.* The predominant impact of NPSB fertilizer rates appeared noticeable on the height of the plant. It was consistently improved as NPSB fertilizer doses were raised from 0 to 150 kg/ha. The tallest crop measured occurred at the NPSB fertilizer dosage of 150 kg/ha (186.89 ± 3.55 cm), and it was proceeded by a plant measured at the NPSB fertilizer dosage of 100 kilograms/hectare (177.62 ± 3.55 cm). The minimum plant height (144.17 ± 3.55 cm) was obtained from the unfertilized plots (Table 4). Availability of the essential nutrients in the soils improved plant uptakes and promoted vegetative growth and led taller plant heights. Thus, the enhanced vegetative development seen in this investigation could be linked to the soil's properly supplied nutrients. The use of blended fertilizer considerably improved plant height in the maize plant when contrasted with the crop where no fertilizer was applied [23]. However, if any nutrient component is present in the soil in quantities less than its given threshold or is not correctly matched with other nutrient components, the progress of crops will be slowed down [24]. Hence, there were noticeable changes in plant height as a result of the predominant influence of K fertilizer levels (Table 4). Plant height varied from 163.33 ± 3.55 to 174.92 ± 3.55 cm as a result of the predominant influence of K fertilizer rates, with the tallest plant height (174.91 ± 3.55 cm) being noted at the 90 kg/ha level of K fertilization. The shortest plant height (163.33 ± 3.55 cm) has been measured from 0 dosage of K application (Table 4). The low plant height from plots

Table 3: Effect of blended NPSB and K fertilizer rates on days to anthesis, silking, ASI, and maturity of maize at Shela Borkoshe during 2019 to 2020 cropping seasons.

| NPSB rates (kg/ha) | K rates (kg/ha) | Days to anthesis (d) | Days to silking (d) | ASI | Days to physiological maturity (d) |
|---|---|---|---|---|---|
| 0 | 0 | 87.00 | 91.33 | 13.00 | 156.00 |
| | 30 | 85.33 | 89.66 | 13.00 | 156.00 |
| | 60 | 85.67 | 90.00 | 13.00 | 156.00 |
| | 90 | 84.67 | 89.00 | 11.00 | 156.00 |
| 50 | 0 | 84.67 | 87.67 | 10.67 | 154.67 |
| | 30 | 84.67 | 86.67 | 9.67 | 154.33 |
| | 60 | 83.33 | 86.00 | 8.67 | 154.00 |
| | 90 | 82.33 | 85.00 | 7.33 | 154.00 |
| 100 | 0 | 82.00 | 84.33 | 7.00 | 154.00 |
| | 30 | 82.33 | 83.33 | 5.67 | 154.00 |
| | 60 | 81.00 | 83.00 | 5.00 | 154.00 |
| | 90 | 80.00 | 82.33 | 4.33 | 154.00 |
| 150 | 0 | 80.00 | 82.33 | 4.00 | 154.00 |
| | 30 | 79.00 | 81.00 | 3.67 | 153.00 |
| | 60 | 76.33 | 80.00 | 3.67 | 152.67 |
| | 90 | 74.67 | 75.67 | 3.33 | 152.33 |
| | LSD (0.05) | NS | NS | NS | NS |
| NPSB rates mean | 0 | 85.67a | 90.00a | 11.92a | 157.00a |
| | 50 | 83.58b | 86.33b | 8.17b | 154.25b |
| | 100 | 81.08c | 83.25c | 4.75c | 154.08b |
| | 150 | 77.50d | 79.75d | 3.50d | 152.00c |
| | LSD (0.05) | 1.01 | 0.52 | 0.49 | 0.46 |
| K rates mean | 0 | 84.42a | 86.42a | 8.00a | 154.67 |
| | 30 | 82.42b | 85.17b | 7.58a | 154.33 |
| | 60 | 81.58c | 84.75b | 6.50b | 154.17 |
| | 90 | 80.42d | 83.00c | 6.25b | 154.17 |
| | LSD (0.05) | 1.01 | 0.52 | 0.49 | NS |
| | SE± | 0.63 | 0.77 | 0.52 | 0.52 |
| | CV (%) | 2.04 | 0.74 | 8.35 | 1.01 |

Values followed by the same letter (s) within a column are not significantly different at 5% probability level. NS: not significant, d: days, kg/ha: kilograms/hectare, and SE: standard error.

without fertilization could be caused by the lower leaf area expansion, which might have resulted in a less solar interception and, as a result, reduced effectiveness in the conversion of solar energy [25].

*3.5. Leaf Area and Leaf Area Index.* Noticeable variations have been identified as a result of NPSB by K fertilizer levels combinations on leaf area and LAI. When NPSB fertilizer doses were elevated from 0 to 150 kilograms/ha, leaf area as well as LAI tended to rise with all K values. The maximum leaf area (9886.20 ± 343.95 $cm^2$) and LAI value (7.78 ± 0.26) were produced by combining 150 kilograms/ha NPSB and 90 kilograms/ha K fertilizer rates, which were followed by combining 150 kilograms/ha NPSB and 60 kilograms/ha K fertilizer rates, which produced a mean leaf area of 8210.4 ± 343.95 $cm^2$ and LAI value of 6.33 ± 0.26. The lowest leaf area (3727.7 ± 343.95 $cm^2$) and LAI value (2.30 ± 0.26) have been resulted from 0 rates of application (Table 4). Amount of leaf area as well as how it is spread across the land is among the main issues in light capture, that influence photosynthesis, transpiration, as well as the buildup of dry matter. Thus, blended NPSB and K fertilizer combinations have affected significantly the leaf area and LAI where the higher leaf area and LAI values were observed with increasing dosage of both fertilizers. Increasing dosage of NPSB and K fertilizer proportionally increased with rising NPSB as well as potassium fertilizer rates indicating that at higher NPSB and K fertilizer rates had a greater leaf area and LAI values. This could be due to the high dosage of blended fertilizer and higher K fertilization levels that possibly have resulted in more crop growth than the lower ones.

*3.6. Ear Length.* Substantial changes on ear length were achieved as a result of interactions of NPSB with K fertilizer rates. With raising NPSB and K fertilizer rates, length of ear increased. The longest ear length (32.58 ± 1.46 cm) resulted from the combined application of 150 kilograms/hectare NPSB with 90 kilograms/ha K fertilizer rates followed by the application of 150 kilograms/hectare NPSB and 60 kilograms/hectare K fertilizer rates with an average length of ear, 31.47 ± 1.46 cm. The unfertilized plots had the smallest recorded ear length (14.68 ± 1.46 cm) (Table 5). An increase in ear length with increasing dosages of NPSB as well as K fertilizer rates could be attributed to a proportion of

Table 4: Effect of blended NPSB and K fertilizer rates on plant height, leaf area, and LAI of maize at Shela Borkoshe during 2019 to 2020 cropping seasons.

| NPSB rates (kg/ha) | K rates (kg/ha) | Plant height (cm) | Leaf area ($cm^2$) | LAI |
|---|---|---|---|---|
| 0 | 0 | 132.20 | 3727.7i | 2.30i |
| | 30 | 135.21 | 4595.7h | 3.08h |
| | 60 | 153.40 | 4784.8h | 3.27gh |
| | 90 | 155.80 | 5202.0fgh | 3.65f–h |
| 50 | 0 | 163.60 | 5071.1gh | 3.72fg |
| | 30 | 165.43 | 5599.1e–g | 4.09d–f |
| | 60 | 168.87 | 5675.6d–g | 4.04d–f |
| | 90 | 171.73 | 5712.5d–g | 401ef |
| 100 | 0 | 175.47 | 5851.9def | 4.19d–f |
| | 30 | 175.80 | 6077.9de | 4.40de |
| | 60 | 179.60 | 6284.7c–e | 4.59c–e |
| | 90 | 179.60 | 6319.2cd | 4.60cd |
| 150 | 0 | 182.07 | 6182.1de | 4.50de |
| | 30 | 185.87 | 6964.70c | 5.18c |
| | 60 | 187.13 | 8210.4b | 6.33b |
| | 90 | 192.50 | 9886.2a | 7.78a |
| | LSD (0.05) | NS | 702.4 | 0.59 |
| NPSB rates mean | 0 | 144.17d | 4577.8d | 3.08d |
| | 50 | 167.41c | 5514.6c | 3.97c |
| | 100 | 177.62b | 6133.4b | 4.45b |
| | 150 | 186.89a | 7810.9a | 5.95a |
| | LSD (0.05) | 3.62 | 351.2 | 0.29 |
| K rates mean | 0 | 163.33b | 5208.2d | 3.68d |
| | 30 | 165.59b | 5837.7c | 4.19c |
| | 60 | 172.25a | 6238.9b | 4.56b |
| | 90 | 174.91a | 6751.9a | 5.01a |
| | LSD (0.05) | 3.62 | 351.2 | 0.29 |
| | SE± | 3.55 | 343.95 | 0.26 |
| | CV (%) | 2.57 | 7.01 | 6.58 |

Values followed by the same letter (s) within a column are not significantly different at 5% probability level. NS: not significant, kg/ha: kilograms/hectare, and SE: standard error.

photosynthates that were transported to the growing ear after fertilization which might have accounted for a positive influence on the proliferation of the ear. This assessment clearly indicated that ear length was longer at high rates of NPSB and K fertilization and tended to decline with decreasing rates of NPSB and K fertilizers.

*3.7. Ear Diameter and Rows per Ear.* Ear diameter as well as the total quantity of rows for each ear had been considerably influenced by the principal impact of NPSB fertilizer levels. As the levels of NPSB fertilizer were increasing from 0 to 150 kg/ha, both parameters were also increasing. The NPSB fertilizer doses of 150 kg/ha provided the thickest ear diameter ($6.72 \pm 0.26$ cm) and the largest number of rows per ear ($14.83 \pm 0.45$), proceeded by the NPSB fertilizer level of 100 kilograms/ha, which provided an average ear diameter about $5.24 \pm 0.26$ cm and the number of rows per ear of $13.93 \pm 0.45$. The thinnest ear diameter ($5.02 \pm 0.26$ cm) and the smallest number of rows per ear ($12.47 \pm 0.45$) had been obtained from unfertilized plots (Table 5). The proportion of proliferation is frequently influenced by the accessibility of nutrients for taking by crops, and this relationship is related to the optimal rate of a nutrient in a demand. The balanced nutrition in dry matter buildup and integrating to the ear has probably encouraged improvement of ear diameter as well as the total quantity of rows per ear as a result of increasing NPSB fertilizer rates. Likewise, considerable variations had been perceived as the result of the primary influence of potassium fertilizer dosages on ear diameter and the total quantity of rows per ear. When potassium fertilizer doses increased from 0 to 90 kilograms/hectare, ear diameter and the total quantity of rows for each ear showed a tendency of increasing. The thickest ear diameter ($5.93 \pm 0.26$ cm) and the largest number of rows per ear ($14.13 \pm 0.45$) had been achieved from K fertilizer rate of 90 kilograms/hectare. The thinnest ear diameter ($5.32 \pm 0.26$ cm) and smallest number of rows per ear of $13.27 \pm 0.45$ were recorded from unfertilized plots (Table 5). Increasing K fertilizer dosage positively influence ear diameter mainly as the result of enhanced K nutrient availability for development of ear as evidenced by the increased ear diameter with increasing K fertilization. Conversely, the ear diameter was not considerably affected by the interactions of NPSB and K fertilizer doses (Table 5).

*3.8. Seeds per Row and Ear.* Considerable variations in the total quantity of seeds per row as well as ear were identified due to the result of interaction between NPSB and K

Table 5: Effect of blended NPSB and K fertilizer rates on length of ear, ear diameter, rows per ear, seeds per row, seeds per ear, and TSW of maize at Shela Borkoshe during 2019 to 2020 cropping seasons.

| NPSB rates (kg/ha) | K rates (kg/ha) | Ear length (cm) | Ear diameter (cm) | Rows per ear | Seeds per row | Seeds per ear | TSW (g) |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 14.68J | 4.90 | 12.26 | 17.40i | 214.13i | 33.03 j |
| | 30 | 17.80I | 4.92 | 12.13 | 22.07h | 264.93hi | 35.90ij |
| | 60 | 21.23h | 5.10 | 12.53 | 25.40gh | 318.13g | 45.80i |
| | 90 | 21.50h | 5.16 | 12.93 | 25.53g | 332.13fg | 61.04h |
| 50 | 0 | 25.17g | 5.16 | 12.40 | 25.40gh | 314.93gh | 76.74g |
| | 30 | 25.80fg | 5.16 | 13.73 | 26.07g | 361.47fg | 88.24f |
| | 60 | 26.20ef | 5.16 | 13.87 | 26.53g | 364.53g | 97.82ef |
| | 90 | 26.77e | 5.16 | 13.47 | 28.33fg | 381.20ef | 101.23e |
| 100 | 0 | 27.00e | 5.16 | 14.00 | 30.07f | 420.40de | 104.41e |
| | 30 | 28.90d | 5.16 | 13.60 | 31.07ef | 420.93de | 104.41e |
| | 60 | 30.10c | 5.30 | 13.60 | 33.67de | 462.27d | 132.99c |
| | 90 | 30.60bc | 5.32 | 14.40 | 36.73cd | 528.67c | 140.64bc |
| 150 | 0 | 30.80bc | 6.05 | 14.40 | 38.47bc | 554.00bc | 145.30b |
| | 30 | 31.00bc | 6.05 | 14.67 | 38.80bc | 568.00bc | 145.38b |
| | 60 | 31.47b | 6.71 | 14.53 | 44.86a | 597.20b | 150.17b |
| | 90 | 32.58a | 8.08 | 15.73 | 44.88a | 705.87a | 160.67a |
| | LSD (0.05) | 0.94 | NS | NS | 3.40 | 52.30 | 9.91 |
| NPSB rates mean | 0 | 18.80d | 5.02d | 12.47d | 22.60d | 282.83d | 40.69d |
| | 50 | 25.98c | 5.16c | 13.37c | 26.58c | 355.53c | 90.11c |
| | 100 | 29.15b | 5.24b | 13.93b | 32.88b | 458.07b | 123.80b |
| | 150 | 31.46a | 6.72a | 14.83a | 40.80a | 606.27a | 136.9a |
| | LSD (0.05) | 0.47 | 0.11 | 0.47 | 1.70 | 26.15 | 4.36 |
| K rates mean | 0 | 24.41d | 5.32c | 13.27b | 27.83d | 282.83d | 84.95c |
| | 30 | 25.88c | 5.38c | 13.53b | 29.62c | 355.53c | 95.14b |
| | 60 | 27.25b | 5.57b | 13.67ab | 31.58b | 458.07b | 106.09a |
| | 90 | 27.86a | 5.93a | 14.13a | 33.83a | 606.27a | 105.39a |
| | LSD (0.05) | 0.47 | 0.11 | 0.47 | 1.70 | 26.15 | 4.36 |
| | SE± | 1.46 | 0.26 | 0.46 | 1.67 | 25.61 | 4.83 |
| | CV (%) | 2.14 | 1.27 | 4.14 | 6.64 | 7.37 | 11.47 |

Values followed by the same letter (s) within a column are not significantly different at 5% probability level. NS: not significant, kg/ha: kilograms/hectare, and SE: standard error.

fertilizer levels. Total quantity of seeds for each row as well as ear enhanced with improving NPSB fertilizer levels at whole levels of K fertilizer rates and the reverse. The maximum quantity of seeds per row (44.88 ± 1.67) and seeds per ear (705.87 ± 25.61) were preceded from the combined application of 150 kilograms/hectare NPSB with 90 kilograms/hectare K fertilizer rates. From plots without applied fertilizer, the fewest seeds per row (17.40 ± 1.67) and seeds per ear (214.13 ± 25.61) had been achieved (Table 5). Variable combinations of NPSB and K fertilizer rates led to variations in the total quantity of seeds per row as well as ear, which might have been caused by the variations in ear size as a result of assimilate buildup.

*3.9. Thousand Seed Weight.* Data analysis revealed that there were significant differences on TSW as a result of the interactions between NPSB and K fertilizer rates. For all K levels, it was observed that TSW tended to rise when NPSB fertilizer doses elevated from zero to maximum and vice versa. Application of levels 150 kilograms/ha NPSB and 90 kilograms/ha K in combination has achieved the highest TSW (160.67 ± 4.85 g). The least TSW (33.0 ± 4.85 g) was registered from the plots with no fertilizer (Table 5). Lower TSW was produced when NPSB fertilization was excluded from all K fertilizer rates, demonstrating how crucial NPSB inclusion is for proper grain filling and development.

*3.10. Biomass Yield.* Data analysis showed that there were considerable variations in biomass yield as a result of the interactions between NPSB and K fertilizer levels. In general, the range of biomass yield as influenced by NPSB and K fertilizer interactions was 5548 ± 200.92 to 14941 ± 200.92 kg/ha. Biomass yield exhibited the tendency of increasing with increasing NPSB fertilizer rates for levels of K fertilizer rates. The maximum biomass yield (14941 ± 200.92 kg/ha) was produced using 150 kilograms/ha of NPSB with 90 kilogram/ha K fertilizer rates in combination. This was followed by 150 kilograms/ha NPSB with 60 kilograms/ha K fertilizer rates of application, which produced an average biomass yield of 14567 ± 200.92 kg/ha. But, statistically, there were no significant differences between the two treatments. From the control plots, the least quantity of biomass (5548 ± 200.92 kg/ha) was produced (Table 6). By applying blended fertilizers, as opposed to unfertilized plots, biomass yield was maximized and increased, according to several authors [17, 26]. Furthermore, Mekuannet and Kiya [27] revealed that different rates of

Table 6: Effect of blended NPSB and K fertilizer rates on biomass, grain yield, and HI of maize at Shela Borkoshe during 2019 to 2020 cropping seasons.

| NPSB rates (kg/ha) | K rates (kg/ha) | Biomass yield (kg/ha) | Grain yield (kg/ha) | HI |
|---|---|---|---|---|
| 0 | 0 | 5548e | 788k | 0.14 |
| | 30 | 5549e | 958jk | 0.17 |
| | 60 | 7684de | 1058j | 0.14 |
| | 90 | 8750c–e | 1138ij | 0.13 |
| 50 | 0 | 8751c–e | 1374i | 0.16 |
| | 30 | 9925b–d | 2507h | 0.25 |
| | 60 | 10202b–d | 2854g | 0.28 |
| | 90 | 10394b–d | 3063g | 0.29 |
| 100 | 0 | 10992a–d | 3460f | 0.31 |
| | 30 | 11376a–d | 3947e | 0.35 |
| | 60 | 11691a–d | 5347d | 0.46 |
| | 90 | 12433a–c | 5570cd | 0.45 |
| 150 | 0 | 12860ab | 5692bc | 0.44 |
| | 30 | 13564ab | 5863b | 0.43 |
| | 60 | 14567a | 7411a | 0.51 |
| | 90 | 14941a | 7544a | 0.50 |
| | LSD (0.05) | 4103 | 244 | NS |
| NPSB rates mean | 0 | 6883c | 986d | 0.14d |
| | 50 | 9818b | 2449c | 0.25c |
| | 100 | 11623b | 4581b | 0.39b |
| | 150 | 13983a | 6627a | 0.47a |
| | LSD (0.05) | 2051 | 122 | 0.02 |
| K rates mean | 0 | 9538b | 2828d | 0.30c |
| | 30 | 10104ab | 3319c | 0.33b |
| | 60 | 11036ab | 4167b | 0.38a |
| | 90 | 11630a | 4329a | 0.37a |
| | LSD (0.05) | 2051 | 122 | 0.02 |
| | SE± | 200.91 | 119.49 | 0.08 |
| | CV (%) | 23.27 | 14.09 | 14.87 |

Values followed by the same letter (s) within a column are not significantly different at 5% probability level. NS: not significant, kg/ha: kilograms/hectare, and SE: standard error.

blended NPS fertilizer had varying effects on the responses of different maize varieties, with the maximum biomass output being observed with 150 kg/ha dose of NPS fertilizer application.

*3.11. Grain Yield.* The outcomes of the data analysis demonstrated that the interactions between the NPSB and potassium fertilizer levels took a considerably varied influence on grain performance (Table 6). The grain yield ranged from 788 ± 119.49 to 7544 ± 119.49 kg/ha as impacted by the interactions of NPSB as well as K fertilizer doses. With the propensity to increase as NPSB fertilizer rates increased for all levels of K fertilizer, all fertilized plots produced higher total grain yield than their respective unfertilized plots. Hence, grain yield showed progressive increment with increasing NPSB and K fertilizer rates in the combinations. With the exception of the combined application of 50 kilograms/ha NPSB fertilizer level with 90 kilograms/ha K level, the grain yield was below 3000 kg/ha (30 qt/ha) at lower dosages of NPSB fertilizer (0 and 50 kilograms/ha NPSB) with K levels. These treatment combinations indicated that the applied nutrients did not satisfy the crop's need for normal growth, development as well as seed formation processes as evidenced with relatively low grain yield ranged from 788 ± 119.49 to 2854 ± 119.49 kg/ha. With the combination of 100 kg/ha NPSB fertilizer rate with all K fertilizer rates, grain yield advanced from 3460 kg/ha (nearly 35 qt/ha) to 5570 kg/ha (nearly 56 qt/ha) which was better than the previous range of treatment combinations. Likewise, when 150 kg/ha NPSB fertilizer rate was applied in combination with all K fertilizer levels, the grain yield increased from 5692 (nearly 57 qt/ha) to 7544 kg/ha (nearly 75 qt/ha) with a negligible increment from K rates from 0 to 30 and 60 to 90 kg/ha. However, grain yield increment was prominent from 30 to 60 kg/ha K fertilizer rates applied in combination with NPSB fertilizer at the dosage of 150 kilograms/ha for obscure unexplainable reasons. With respect to the overall effect, it was discovered that combining NPSB fertilizer at 150 kilograms/ha rate with 90 kilograms/ha K led to the maximum grain output (7544 ± 119.49 kg/ha), which had been preceded by combining the same NPSB rate with 60 kg/ha of K, which resulted in an average grain output of 7411 ± 119.49 kg/ha. On unfertilized plots, the least amount of grain (788 ± 119.49 kg/ha) was produced (Table 6). Applying blended fertilizer improved maize grain yields relative to unfertilized circumstances [17, 18]. In contrast to the control, the application of blended fertilizers

Table 7: Correlation among agronomic traits of maize.

| | DA | DS | ASI | DPM | PH | LA | LAI | EL | ED | TSW | BY | GY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DA | 1.00 | 0.98* | 0.91* | 0.91* | −0.88* | −0.96* | 0.01NS | −0.87* | −0.88* | −0.93* | −0.94* | −0.97* |
| DS | | 1.00 | 0.95* | 0.94* | −0.93* | −0.95* | −0.01NS | −0.92* | −0.83* | −0.95* | −0.96* | −0.97* |
| ASI | | | 1.00 | 0.91* | −0.94* | −0.84* | −0.04NS | −0.95* | −0.65* | −0.98* | −0.96* | −0.96* |
| DPM | | | | 1.00 | −0.92* | −0.89* | −0.08NS | −0.91* | −0.74* | −0.92* | −0.94* | −0.91* |
| PH | | | | | 1.00 | 0.84* | 0.05NS | 0.98* | 0.66* | 0.96* | 0.98* | 0.89* |
| LA | | | | | | 1.00 | −0.04NS | 0.82* | 0.93* | 0.85* | 0.89* | 0.89* |
| LAI | | | | | | | 1.00 | 0.03NS | −0.11NS | 0.01NS | 0.98* | −0.06NS |
| EL | | | | | | | | 1.00 | 0.63* | 0.97* | 0.97* | 0.89 |
| ED | | | | | | | | | 1.00 | 0.71* | 0.75* | 0.79 |
| TSW | | | | | | | | | | 1.00 | 0.98* | 0.96* |
| BY | | | | | | | | | | | 1.00 | 0.95* |
| GY | | | | | | | | | | | | 1.00 |

Da: days to anthesis, DS: days to silking, ASI: anthesis-silking interval, DPM: dyas to physiological maturity, PH: plant height, LA: leaf area, LAI: leaf area index, EL: ear length, ED: ear diameter, TSW: thousand seed weight, BY: biomass yield, and GY: grain yield.

Table 8: Effect of blended NPSB and K fertilizer rates on profitability of maize production at Shela Borkoshe during 2019 to 2020 cropping seasons.

| NPSB rates (kg/ha) | K rates (kg/ha) | Total revenue | Net profit | MRR (%) |
|---|---|---|---|---|
| 0 | 0 | 164 | 40 | — |
| | 30 | 224 | 37 | −7.89 |
| | 60 | 248 | 57 | 666.67 |
| | 90 | 266 | 73 | 533.33 |
| 50 | 0 | 321 | 171 | — |
| | 30 | 587 | 380 | 366.67 |
| | 60 | 668 | 458 | 260.00 |
| | 90 | 717 | 504 | 153.33 |
| 100 | 0 | 810 | 659 | — |
| | 30 | 924 | 700 | 55.41 |
| | 60 | 1251 | 1025 | 1083.33 |
| | 90 | 1303 | 1074 | 1633.33 |
| 150 | 0 | 1332 | 1182 | — |
| | 30 | 1372 | 1132 | −54.95 |
| | 60 | 1734 | 1491 | 1196.67 |
| | 90 | 1765 | 1519 | 933.33 |

kg/ha: kilograms/hectare and MRR: marginal rate of return.

containing the necessary amounts of nitrogen as well as phosphorous enhanced tef yield [28]. In line with this, Mulugeta et al. [29] found that using blended fertilizers increased the yields of straw, grain, and dry matter in bread wheat compared to unfertilized plots. The results of the linear regression test which was performed in regard to NPSB and potassium fertilizer dosages with the grain harvest as equation $Y = -0.18 + 38.12X1$ (NPSB rates) $+ 17.83X2$ (K rates) with $R^2 = 0.97$ were greatly significant ($P < 0.01$) indicating that grain output of investigated crop was greatly reliant on and responsive to NPSB and potassium fertilizer levels.

*3.12. Harvest Index.* There was a statistically considerable variation in the harvest index (HI) as a result of the major effect of NPSB fertilizer levels. The maximum HI value ($0.47 \pm 0.08$) has been resulted from NPSB fertilizer dosage of 150 kilograms/ha, and it was preceded by an average HI value $0.39 \pm 0.08$ at NPSB fertilizer level 100 kg/ha. The minimum harvest index ($0.14 \pm 0.08$) was occurred at 0 rate of application (Table 6). HI values were maximized when the dosage of blended fertilizer increased [2, 22]. Similarly, HI values were considerably affected by the primary impact of K fertilizer levels. Potassium fertilizer application at the level of 60 kilograms/ha gave the maximum HI value ($0.38 \pm 0.08$), which had been preceded by 90 kilograms/ha K dosage of application, which yielded a mean HI value of $0.37 \pm 0.08$. The plots without fertilization resulted in the lowest HI value ($0.30 \pm 0.08$). Nevertheless, interactions between NPSB and K fertilizer rates had no substantial influence on harvest index values (Table 6).

*3.13. Correlation of Agronomic Traits with Grain Yield.* The correlation among agronomic characters with grain yield and other related traits is shown in Table 7. In general, the correlation coefficient ($r$) results ranged from −0.97 to 0.98. In this particular case, the discussion was centered on the association between traits and grain yield in relation to an agronomic point of view. Days to anthesis, days to silking, ASI as well as days to physiological maturity are some of traits which were significantly negatively ($P \leq 0.05$) associated with grain harvest. Laouali [30] also noted a strong inverse relationship between grain harvest and days to anthesis, days to silking, and anthesis-silking interval.

In contrast, the grain produce was strongly positively associated ($P$ 0.05) with characteristics including plant height, leaf area, length of ear, diameter of ear, total quantity of rows in each ear, total quantity of seeds in each row, total quantity of seeds in each ear, TSW, biomass yield, and HI. These features, which exhibited a strong positive link with grain yield, could be the main emphasis for predicting yield. This suggests that plant height probably contributed to yield increase by enabling a plant to bear more number of ears per plant. Similarly, other traits also probably contributed to the grain yield enabling the plant to bear more number of seeds per ear. Iftikhar et al. [31] as well as Kalimullah et al. [32] found related findings suggesting a substantial and beneficial connection between TSW and grain yield.

*3.14. Economic Analysis.* It was carried out to determine whether the treatments (fertilizer rates) could be affordably implemented. The data for economic evaluation with respect to blended NPSB and K fertilizer application are presented in Table 8. According to the analysis, applying 150 kilograms/hectare blended NPSB with 60 kilograms/hectare K fertilizer rates gave a supreme net profit of 1491 Dollars/ha with a marginal rate of return (MRR) 1196.67%. Hence, it seems that the most cost-effective choice for producing maize is to use application of 150 kilograms/hectare NPSB with 60 kilograms/hectare K.

## 4. Conclusion

Blended NPSB, K fertilizer levels, and their interactions had varying effects on phenological, growth, yield components, and yield. Economic analysis disclosed that applying 150 kilograms/hectare-blended NPSB with 60 kilograms/hectare K fertilizer levels provided the maximum net profit 1491 Dollars/ha with marginal rate of return (MRR) 1196.67%. According to this study, using 150 kilograms/hectare-blended NPSB with 60 kilograms/hectare K fertilizer rates performed better than other treatments and increased grain yield. Therefore, the experimental area and other related agro-ecologies could use applying 150 kilograms/hectare-blended NPSB with 60 kilograms/hectare K fertilizer rates for the production of maize.

## Data Availability

The data used to support the findings of this study will be provided by the corresponding author upon request.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

## Authors' Contributions

The authors of this study gathered, processed, analyzed, and prepared the final manuscript for publication.

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