Response of Bread Wheat (Triticum aestivum L.) to Potassium (K) and Blended NPS Fertilizer Rates in the Nitisols of Southern Ethiopia

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Wheat is the most important cereal crop ranking 4th in total grain production and area coverage in Ethiopia. However, its productivity is low compared to the yield obtained under the research station. Multinutrient deficiency, low/no chemical fertilizer usage, and poor management practices are among the major constraints. Thus, response of bread wheat to NPS and K fertilizer rates was evaluated in the nitisols at Kokate, Wolaita Sodo, Southern Ethiopia, in 2016. Four rates of KCl (0-0-60) (0, 25, 50, and 75 kg·ha⁻¹) and five blended NPS (19N-38P₂O₅-7S) rates (0, 50, 100, 150, and 200 kg·ha⁻¹) were investigated using randomized complete block design with factorial arrangement involving three replications. Soil physical and chemical properties, crop phenology, growth parameters, yield components, and yield data were collected. Analysis of variance showed that crop phenology, productive tillers, and straw yield were significantly affected by KCl and NPS fertilizer rates; however, most of growth parameters, yield components, grain yield, and agronomic efficiency were influenced by the interaction effects of KCl and NPS fertilizers. Combined application of 50 kg·ha⁻¹ KCl and 150 kg·ha⁻¹ NPS resulted in highest growth, yield component, grain yield, agronomic efficiency, and economic return, whereas the lowest measured values were recorded from unfertilized plots. The maximum grain yield (4.34 t·ha⁻¹) that was recorded from 50 kg·ha⁻¹ KCl and 150 kg·ha⁻¹ NPS was 8.86-fold higher than the minimum yield (0.44 t·ha⁻¹) from the control. It is concluded that 50 kg·ha⁻¹ KCl and 150 kg·ha⁻¹ NPS are suggested for better agronomic and economic performance of wheat. As NPS was tested in the blended form, the individual and interaction effects of nutrients under investigation are suggested as future research areas. Additional investigation over season and location is also recommended.

1. Introduction

Ethiopia is the second-largest wheat producer in sub-Saharan Africa, after South Africa [1]. Wheat in Ethiopia has become one of the most important cereal crops ranking 4th in total grain production (4.53 × 10⁶ t) and area (1.69 × 10⁶ ha) next to teff (Eragrostis teff), maize (Zea mays L.), and sorghum (Sorghum bicolor L. Moench) [2]. The average productivity of wheat at the national level, South Nation, Nationalities, and People Regional State (SNNPRS), and Wolaita zone of SNNPRS is 2.67, 2.58, and 1.45 ton·ha⁻¹, respectively [2]. However, potential yield of wheat goes beyond 5 t·ha⁻¹ that rises questionable yield gap between farmers’ and attainable yield of the crop [3–5].

The depletion of soil nutrients, low level of chemical fertilizer usage, and poor management practices are among the major constraints for improving wheat yield in Ethiopia [6, 7]. Based on the national soil database of Ethiopia [8], continuous wheat cultivation has resulted in the depletion of macronutrients and also the micronutrients such as zinc (Zn), boron (B), and copper (Cu) in the major crop-producing areas of the country. The survey result on soils of SNNPRS showed the limitation of nitrogen (N), phosphorous (P), potassium (K), sulfur (S), Zn, B, and iron (Fe) [8]. All these recall the need to address the problem through balanced fertilization.

Balanced fertilization not only guarantees optimal crop production, better food quality, and benefits for the growers but also provides the best solution for minimizing the risk of nutrient losses to the environment [9]. Fertilization, particularly of the macronutrients such as N, P, K, and S, is a
major input in wheat production affecting yield and quality [10, 11]. Various research studies so far conducted in Ethiopia showed different amounts of fertilizer rates for wheat cultivation. For instance, the study made by Esayas [9] indicated that 100 kg of NPS (19-38-0-7S) and 125 kg ha$^{-1}$ urea (46-0-0) top-dressed resulted in maximum yield (2.91 t ha$^{-1}$) of wheat in the Adaa district of Eastern Shewa Zone, Ethiopia. Additionally, research conducted in the Dawro zone of southern Ethiopia showed that application of 69 kg ha$^{-1}$ N and 30 kg ha$^{-1}$ P resulted in the highest grain yield of bread wheat (4.02 t ha$^{-1}$) [12]. Furthermore, in the Hawzen district of Tigray Region, Northern Ethiopia, application of P with N at a rate of 46 kg ha$^{-1}$ gave grain yield (3.81 t ha$^{-1}$) [13]. The study in Wolaita area by Laekemariam et al. [14, 15] demonstrated that 46% of essential nutrients sourced from soil (i.e., N, P, K, S, B, and Cu) were identified as principal growth-limiting factors. Meanwhile, research findings have shown that the K limitation in Wolaita area was potentially related to magnesium-induced deficiency [15, 16]. However, application of mineral K has not been practiced in this area. Yet, to our knowledge, in Wolaita area, the performances of wheat under the application of N, P, K, and S fertilizers have not been studied. Thus, it is hypothesized that wheat grown under multinutrient-deficient soils of Wolaita can respond and result in better yield through the application of N, P, K, and S. Therefore, this study was initiated with the following objectives: (i) to investigate the growth and yield response of bread wheat to K and blended NPS fertilizer rates on the study area, (ii) to examine the nutrient use efficiency of wheat, and (iii) to evaluate the economic feasibility of the fertilizers for bread wheat production.

2. Materials and Methods

2.1. Description of the Study Area. This experiment was conducted at Kokate-Marachere (06° 53′ 34.8″N latitude and 37° 48′ 42, 4°E longitude), Sodo Zuria district, Wolaita Zone, Southern Ethiopia. The mean altitude of the area is 2000 meters above sea level (m.a.s.l). The experimental area has a bimodal rainfall with the lowest and highest rainfall of 1000 mm and 1500 mm, respectively. The ten-year average annual rainfall was 1250 mm, and the rainy season extends from March to September. The mean annual minimum and maximum temperature is 19.5 and 24.2°C, respectively [17].

Major annual crops growing in the area include haricot bean (Phaseolus vulgaris L.), wheat (Triticum aestivum L.), maize (Zea mays L.), barley (Hordeum vulgare), sweet potato (Ipomoea batatas), and teff (Eragrostis tef). The vegetation is dominated by eucalyptus trees (Eucalyptus camaldulensis), as homestead and farm forest. The area is characterized by nitisol and gentle slope (4–8%) where farmers practiced livestock-crop production farming system.

2.2. Experimental Nutrient Sources and Materials. Potassium and NPS fertilizers were used for the study. The source of K was KCl (0-0-60), while the source of NPS was blended NPS (18% N-38% P$_2$O$_5$-7% S). Bread wheat variety Danda’a which was developed and released by Kulumsa Agricultural Research Centre in 2010 was used as the test crop. It is a high-yielding white-seeded variety adapted to a wide range of altitudes of 2000 to 2600 m a.s.l (mid to highland areas) and rainfall of greater than 600 mm. Days to heading, days to physiological maturity, and plant height of the variety are 56–80, 110–145, and 90–113 cm, respectively. The variety is able to produce a grain yield of 2500–5000 kg ha$^{-1}$ at farmers’ fields and is also resistant to leaf rust [18].

2.3. Treatments and the Experimental Design. The treatment consisted of five rates of blended NPS (0, 50, 100, 150, and 200 kg ha$^{-1}$) and four rates of K (0, 25, 50, and 75 kg ha$^{-1}$). The treatments were combined in factorial arrangement and laid out in randomized complete block design (RCBD) with three replications. The total and net plot size was 4 m$^2$ (2 m × 2 m) and 3.2 m$^2$ (1.6 m × 2 m), respectively. The spacing between blocks and plots was 1.0 and 0.5 m, respectively.

2.4. Experimental Procedures and Management. The land was cleared and ploughed thrice with oxen, while diskimg and harrowing were done manually. After leveling, the layout was prepared against soil fertility grading and slope. Sowing was done at a seed rate of 125 kg ha$^{-1}$ during the mid of July in 2016 with a recommended spacing of 25 cm between rows. The total number of rows per plot was eight and harvesting rows was six, while two rows at the border of each side of the plot were ignored. The NPS and KCl fertilizers were applied as per the proposed treatment levels at sowing time by drilling, while urea (46-0-0) fertilizer at a rate of 100 kg ha$^{-1}$ was applied with top dress during the tillering stage for all plots. All other necessary agronomic management practices were carried out properly throughout the cropping season.

2.5. Data Collection and Measurements

2.5.1. Soil Data. Before sowing, ten subsamples to form one kg of the composite sample from the experimental site were collected in a zigzag pattern at the depth of 0–20 cm to represent the plough layer. The samples were air-dried, ground using a pestle and a mortar, and allowed to pass through a 2 mm and 0.5 mm sieve. The sample was analyzed for soil particle size distribution, soil pH, organic carbon (OC), total N, available P, available K, available S, and cation exchange capacity (CEC) using standard laboratory procedures. Soil particle size was analyzed by the Bouyoucos hydrometer method [19]. Soil pH was measured in water at a soil-to-water ratio of 1:2.5 [20]. Organic carbon content was determined by the volumetric method [21]. Total N was analyzed by the micro-Kjeldahl digestion method with sulfuric acid [22]. Available P was determined by Olsen's method using a spectrophotometer [23]. Exchangeable K was determined with the ammonium acetate extract method using flame photometry [24]. Available S was measured...
using the turbidity method [25]. Cation exchange capacity (CEC) was measured after saturating the soil with 1 N ammonium acetate (NH₄OAc) and displacing it with 1 N NaOAc [26].

2.5.2. Crop Data Collection and Procedures. Data on crop phenology such as days to 50% heading and days to physiological maturity were collected. Wheat crop growth-indicating parameters such as plant height, leaf area, and yield and yield components such as the number of tillers per plant, number of productive tillers per plant, number of grains per spike, and thousand-grain weight (g) were collected. In addition, straw yield (t·ha⁻¹), grain yield (t·ha⁻¹), above-ground dry biomass (t·ha⁻¹), and harvest index (%) were recorded. Furthermore, agronomic efficiency (AE) (kg·kg⁻¹) was computed. Details of each parameter are given as follows.

Days to 50% heading were determined by counting the number of days taken from the date of sowing to 50% heading. Days to physiological maturity were recorded when 90% of all plants per plot lost chlorophyll and turned yellow. This was determined on visual basis. Plant height was determined from the base to the tip of the spike (awns excluded) of 10 randomly pretagged plants from the net plot area at physiological maturity. Leaf area of flag leaves (cm) was measured from 5 randomly pretagged plants from the net plot areas. It was calculated as length x maximum width x 0.68. Number of tillers per plant was determined from 10 randomly pretagged plants per plot at heading. Number of productive tillers was determined at maturity by counting all spikes producing seeds of 10 plants/plot. Number of grains per spike was the mean number of grains per spike computed as an average of 10 randomly taken spikes from the central unit area, threshed, and grains were counted using an electronic seed counter.

Above-ground dry biomass (t·ha⁻¹) was measured from plants harvested from the net plot area after sun drying for 4 days and converted into tons per hectare. Straw yield (t·ha⁻¹) was obtained as the difference of the total above-ground plant biomass and grain yield of plants in the net plot area and converted into ton per hectare. Thousand-grain weight (g) was determined based on the weight of 1000 grains sampled from the grain yield of each treatment by using an electronic seed counter and weighed with an electronic balance. Grain yield (ton·ha⁻¹) was taken by harvesting and threshing the seed yield from the net plot area, adjusted to 12.5% moisture content and was obtained as the difference of the total above-ground plant biomass and grain yield of plants in the net plot area and converted into ton per hectare. Thousand-grain weight (g) was determined based on the weight of 1000 grains sampled from the grain yield of each treatment by using an electronic seed counter and weighed with an electronic balance. Grain yield (ton·ha⁻¹) was taken by harvesting and threshing the seed yield from the net plot area, adjusted to 12.5% moisture content and expressed in ton per hectare using the following formula [27]:

\[
\text{grain yield} = \text{actual yield} \times \frac{100 - M}{100 - D}
\]  

(1)

where M is the measured moisture content in grain and D is the designated moisture content.

Harvest index (%): harvest index (HI) was computed as the ratio of dry seed yield and above-ground dry biomass yield using the following formula [28]:

\[
\text{HI} \times 100 = \frac{\text{grain yield}}{\text{biomass}}
\]  

(2)

Agronomic efficiency (AE) (kg·kg⁻¹) refers to the economic production obtained per unit of nutrient applied, and it was estimated using the formula indicated in Baligar et al. [29]:

\[
\text{AE}(\text{kg/kg}) = \frac{\text{Gu} - \text{Gf}}{\text{quantity of nutrient applied (kg)}}
\]  

(3)

where \( \text{Gf} \) = grain yield of the fertilized plants (kg) and \( \text{Gu} \) = grain yield of the unfertilized plants (kg).

2.6. Statistical Analysis. Data were subjected to analysis of variance (ANOVA) following the standard procedure using the SAS GLM procedure [30]. Mean separation was done using least significant difference (LSD) at 5% of the probability level whenever significant differences among treatment means were detected.

2.7. Partial Budget Analysis. Economic analysis was performed to investigate the economic feasibility of the treatments based on the procedure given by CIMMYT [31]. Partial budget and marginal analyses were used. The average grain yield was adjusted to 10% downwards to reflect the difference between the experimental yield and the yield of farmers expected from the same treatment. The average fertilizer prices of NPS (15.52 birr·kg⁻¹) and potassium (12.17 birr·kg⁻¹) during the study period were used for analysis. The average open market price was 10 birr·kg⁻¹ of wheat grain. Net revenue (NR) = total revenue (TR) − total variable cost (TVC), and the final line of the partial budget is the net benefits. It was calculated by subtracting the total costs that vary from the gross field benefits for each treatment. Marginal rate of return (MRR%) = ΔNR/ΔTVC * 100, which is the marginal net benefit (i.e., the change in net benefits) divided by the marginal cost (i.e., the change in costs). A treatment was considered worth to farmers when its minimum acceptable rate of return (MAR) is 100%, which is suggested to be realistic. This enables to make farmer recommendations from marginal analysis.

3. Results and Discussion

3.1. Physicochemical Properties of the Experimental Site. The soil analysis result of selected physical and chemical properties of the experimental site is presented in Table 1. The experimental soil was clay in texture. Soil pH was 5.86 and was rated as moderately acidic soil (5.6–6.5) [32]. The OC content was 2.2% which was low (2–4%) [33]. The site had a TN content of 0.16% which was categorized under the low level (0.1–0.2%) [33]. The available P content was 12.39 mg·kg⁻¹ soil which was rated under medium [34]. Available K was 0.96 cmol·kg⁻¹ which was under the high category (0.6–1.2 cmol(+·kg⁻¹) [24]. However, in the study area, evidence of Mg-induced K deficiency under soils having higher exchangeable K was reported by Laekemariam et al. [15, 16].

The available S content was 5.03 mg·kg⁻¹ and rated under the low category (≤ 10 mg·kg⁻¹) [23]. The CEC content was 25.1 cmol (+·kg⁻¹) of soil which was rated under the medium (25–40 cmol·kg⁻¹) category [30]. Overall, the inadequate amount of OC, TN, and S (Table 1) and potential of Mg-
induced K deficiency \cite{15, 16} were ascribed due to inadequate soil fertility management practices.

### 3.2. Crop Phenology

#### 3.2.1. Days to 50% Heading

Days to 50% heading were significantly \((P < 0.05)\) affected by NPS and K fertilizers, but not their interaction (Tables 2 and 3). Increasing levels of the NPS fertilizer shortened days to 50% heading from 74.6 days (150 kg ha\(^{-1}\) NPS) to 59.5 days (unfertilized plot). This might be attributed to the promotion of early vegetative growth and development as a result of availability of N, P, and S nutrients for uptake that in turn enhanced days to heading. The findings on N and S \cite{35} and P \cite{36} showed that adequate supply of N, P, and S enhances many aspects of plant physiology such as photosynthesis.

Days to 50% heading varied from 62.5 to 68.5 where the minimum and maximum days were recorded from 50 kg ha\(^{-1}\) KCl and unfertilized plots, respectively (Table 2). However, rates between 25 and 75 kg ha\(^{-1}\) KCl had a similar effect on days to 50% heading. It was clear from the data that days to 50% heading on wheat were shortened with increasing levels of KCl (Table 2). The shortened days to flowering due to KCl, averaged over NPS rate, probably ascribed the beneficial effects of K nutrition to enhance early canopy growth and heading. In agreement with this result, the role of K in plant physiological processes and stimulation of early growth was reported by Marschner and Lakudzala \cite{37, 38}. Liebersbach et al. \cite{39} also reported that K plays an important role in many physiological processes such as photosynthesis, assimilate transport, and enzyme activation. Such roles of K may enhance plants' growth and make them come early for changing of their phenology. The response of wheat plants to K application under high soil exchangeable K (Table 1) could reflect the presence of Mg-induced K deficiency \cite{15, 16, 40}.

#### 3.2.2. Physiological Maturity

Data regarding days to physiological maturity on wheat showed that blended NPS fertilizer application significantly affected \((P < 0.05)\) days to reach physiological maturity. However, KCl fertilizer and its interaction with NPS did not influence days to maturity (Table 3). Days to maturity were decreased with increasing rates of the NPS fertilizer. Maturity time varied from 113.42 to 134.25 days where the shortest and longest days were recorded from 150 kg ha\(^{-1}\) NPS and unfertilized plots, respectively (Table 2). The early maturity of wheat at higher

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### Table 1: Selected soil physicochemical properties of the experimental site.

| Parameter                     | Value | Rating       | Reference                  |
|-------------------------------|-------|--------------|----------------------------|
| Physical                      |       |              |                            |
| Soil particle size distribution|       |              |                            |
| Sand                          | 23.75 |             | Hazelton and Murphy \cite{32}|
| Silt                          | 30.07 |             |                            |
| Clay                          | 46.18 |             |                            |
| Texture class                 | Clay  |              |                            |
| Chemical                      |       |              |                            |
| pH (1 : 2.5 soil-to-water ratio) | 5.86  | Moderately acidic | Hazelton and Murphy \cite{32}|
| Organic carbon                | 2.2   | Low          | Landon \cite{33}           |
| Total nitrogen (%)            | 0.16  | Low          | Landon \cite{33}           |
| CEC (cmol(+)·kg\(^{-1}\))     | 25.11 | Medium       | Landon \cite{33}           |
| Available phosphorous(mg·kg\(^{-1}\)) | 12.39 | Medium       | Cottenie \cite{34}         |
| Available K (cmol(+)·kg\(^{-1}\)) | 0.96  | High         | FAO \cite{24}              |
| Available sulfur (mg·kg\(^{-1}\)) | 5.03  | Low          | Allen and Pilbeam \cite{25}|

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### Table 2: Days to 50% heading and physiological maturity of wheat as affected by NPS and K fertilizer rates.

| Fertilizer (kg·ha\(^{-1}\)) | Days to 50% heading | Physiological maturity |
|------------------------------|----------------------|------------------------|
| NPS                          |                      |                        |
| 0                            | 74.6\(^{a}\)         | 134.25\(^{a}\)         |
| 50                           | 65.0\(^{b}\)         | 133.75\(^{b}\)         |
| 100                          | 60.5\(^{c}\)         | 129.58\(^{b}\)         |
| 150                          | 59.5\(^{c}\)         | 113.42\(^{c}\)         |
| 200                          | 63.7\(^{b}\)         | 117.58\(^{c}\)         |
| LSD (0.05)                   | 2.22                 | 2.74                   |
| KCl                          |                      |                        |
| 0                            | 68.5\(^{a}\)         | 126.3                  |
| 25                           | 64.2\(^{b}\)         | 126.6                  |
| 50                           | 62.5\(^{b}\)         | 125.1                  |
| 75                           | 63.4\(^{b}\)         | 124.9                  |
| LSD (0.05)                   | 1.98                 | NS                     |
| CV (%)                       | 4.15                 | 2.64                   |

LSD (0.05): least significant difference at the 5% level; CV: coefficient of variation; NS: nonsignificant. Means in the column followed by the same letters are not significantly different at the 5% level of significance.

### Table 3: Mean squares of ANOVA for days to heading, days to physiological maturity, leaf area, and plant height of wheat.

| Source of Variance | DF | DH (days) | LA (cm\(^{2}\)) | DPM (days) | PH (cm) |
|--------------------|----|-----------|-----------------|------------|---------|
| REP                | 2  | 3.217     | 25.235          | 16.22      | 5.417   |
| NPS                | 3  | 433.4\(^{a}\) | 134.3\(^{a}\)  | 1109.3\(^{c}\) | 63.3\(^{a}\) |
| K                  | 4  | 105.8\(^{b}\) | 124.2\(^{b}\)  | 10.5\(^{NS}\) | 839.3\(^{b}\) |
| NPS * K            | 12 | 4.2\(^{NS}\) | 20.4\(^{a}\)    | 7.3\(^{NS}\) | 5.3\(^{b}\) |
| Error              | 38 | 7.199     | 7.035           | 11.0       | 2.5     |

NS and *: nonsignificant and significant at 5%; DF: degree of freedom; DH: days to 50% heading; DPM: days to 90% physiological maturity; LA: leaf area; PH: plant height.
NPS doses might be due to the combined effects of N, P, and S which might have hastened the physiological maturity of the plant. Particularly, P has a prominent role in reducing days to physiological maturity by controlling some key enzymes involved in hastening crop maturity [37]. Amanullah et al. [41] also indicated early phenological development on maize plants with NPK fertilizer application. Increasing N supply enhanced growth and consequently increased the demand and absorption of other nutrients (e.g., P and S) [42]. The dominant role of N in promoting crop vegetative growth and the positive interaction of N at increased supply with P and S [42] might be the reason for the delay in days to 50% heading and physiological maturity beyond 150 kg/ha NPS.

3.3. Crop Growth

3.3.1. Plant Height (cm). Plant height revealed significant \((P < 0.05)\) differences among rates of NPS and K and their interaction (Tables 3–5). Maximum plant height (115 cm) was attained from the combined effect of 150 and 50 kg·ha\(^{-1}\) of NPS and KCl, respectively, whereas the minimum plant height (90 cm) from the unfertilized plot followed by 0 kg·ha\(^{-1}\) NPS with 25 kg·ha\(^{-1}\) (Table 4). Plant height attained from combined effect of 150 and 50 kg·ha\(^{-1}\) of NPS and KCl, respectively, was 25 cm higher than plants from the unfertilized plot. However, plant height of wheat under the combined effect of 50 kg·ha\(^{-1}\) of NPS with 0 kg·ha\(^{-1}\) of KCl, 0 kg·ha\(^{-1}\) of NPS with 50 kg·ha\(^{-1}\) of KCl, and 0 kg·ha\(^{-1}\) of NPS with 75 kg·ha\(^{-1}\) of KCl was statistically similar. Likewise, statistically, the same effects were observed from the combination of other treatments (Table 4). Furthermore, it was noted that a successive increase of NPS and KCl fertilizers attributed to the gradual increase in the plant height of wheat (Table 4). This could indicate the synergistic effects of NPS and K nutrients in increasing growth which in turn gradually increased the height of wheat plants. These results are in agreement with Ayub et al. [42] and Maqsood et al. [43] who reported that the plant height increased linearly with each successive increase in NPK. Besides, fertilization studies on N [12, 44] and S [45] exhibited considerable increase in the plant height of wheat in response to each increment of nutrients.

3.3.2. Leaf Area. Leaf area was significantly \((P < 0.05)\) influenced by the interaction effects of blended NPS and KCl application rates (Tables 3–5). It was generally observed that leaf area was found to decline with the reduced rates of NPS and K fertilizers (Table 4). Maximum leaf area (25.27 cm\(^2\)) was attained at the rate of 150 kg·ha\(^{-1}\) NPS and 50 kg·ha\(^{-1}\) KCl while the minimum leaf area (4.39 cm\(^2\)) from treatment where no fertilizer was applied. Leaf area was increased successively as rates of NPS and KCl increased from 0 to 150 kg·ha\(^{-1}\) and 0 to 50 kg·ha\(^{-1}\), respectively (Table 4). This suggests the beneficial effects of N, P, K, and S nutrients towards increment of leaf size of wheat plants. Different scholars also explained the positive role of N, P, K, and S for improving crop leaf area. For instance, Järvan et al. [45] and Ara et al. [46] reported that N enhanced leaf area and interception of photosynthetically active radiation. Jiang et al. [47] indicated that the maximum leaf area was due to increased P applications. Moreover, Tisdale et al. [48] also described that K application enhanced the photosynthetic capacity and productive life of flag leaves. Furthermore, the role of S in increasing the leaf area was reported [49]. Therefore, the application of N, P, K, and S alone or in combination could improve the growth and development of wheat and consequently contribute to the higher leaf area of wheat. Yet, successive increase of K and NPS fertilizers from 50 to 75 kg/ha and 150 to 200 kg/ha, respectively, reduced the performance of most growth parameters likely implying that the nutrients had reached the saturation level, and beyond that, their antagonistic effects started to appear.

3.4. Yield and Yield Components

3.4.1. Total Number of Tillers per Plant. The total number of tillers per plant revealed significant \((P < 0.005)\) differences among main and interaction effects of NPS and KCl fertilizers (Tables 5 and 6). Application of fertilizers at 150 kg·ha\(^{-1}\) NPS and 50 kg·ha\(^{-1}\) KCl resulted in the highest number of total tillers per plant (6.6), and the minimum number of total tillers per plant (1.33) was observed from unfertilized plots (Table 7). The total number of tillers from the combined effect of 150 and 50 kg·ha\(^{-1}\) of NPS and KCl, respectively was 5-fold higher than that of the unfertilized plot. The number of tillers per plant has a vital position in controlling yield of wheat. It is clear that the more the number of tillers is, the better will be the stand of the crop, which ultimately increases the yield. This result agrees with Malghani et al. [50] and Laghari et al. [51] who reported that a progressive increase in NPK levels to optimum levels enhanced the number of tillers per plant. Moreover, Liakas et al. [52] indicated that the application of P and K favored tillering of wheat. Therefore, the combined effects of NPS and K nutrients might have positive effects on the tiller formation of wheat.

3.4.2. Productive Tillers per Plant. The analysis of variance showed that NPS and KCl fertilizers significantly \((P < 0.05)\) affected productive tillers per plant, while their interaction effect was nonsignificant (Table 7). It showed an increasing trend with the increasing level of NPS (Table 8). Productive tillers per plant varied from 4.56 to 1.9 which were recorded from 150 kg·ha\(^{-1}\) NPS and unfertilized plot, respectively (Table 8). However, tillers at 100 and 200 kg·ha\(^{-1}\) of NPS were statistically at par. In general, application of NPS at different rates had a direct effect on the tiller number per plant in the study field. This result is in agreement with that of Laghari et al. [51] who observed that increasing N application increased the number of productive tillers per unit area. In addition, fertilization studies on N and P [12, 53, 54] exhibited a considerable increase in productive tillers per plant of wheat in response to each increment of nutrients.
3.4.4. Thousand-Grain Weight. The data regarding thousand-grain weights are presented in Tables 5 and 6. Thousand-grain weights revealed significant \((P < 0.05)\) differences under varying levels of NPS and KCl and their interaction. Application of 150 kg ha\(^{-1}\) NPS with KCl at 50 kg ha\(^{-1}\) showed the highest grain weight (56.3 g), while minimum number of grain weight (27.33 g) was recorded from unfertilized plot (Table 7). Thousand-grain weights were increased by 32 and 18\% when the application of NPS and KCl increased from 0 to 150 kg ha\(^{-1}\) and 0 to 50 kg ha\(^{-1}\), respectively (Table 4). This result might be due to the synergistic effect of NPS and K nutrients that enhanced the thousand-grain weight of the crop. Previous studies on N [56], P [57], K [58], and NPKSzn [59] demonstrated that the addition of these nutrients alone or together improved photosynthetic activity, enhanced sink transport to the grain, and resulted in heavier grains. Moreover, the significant effect of P and K application on the yield component of wheat was reported [60]. Furthermore, fertilization of S for enhancing the uptake of N, P, and K and the synergistic effect of these elements towards increased productivity were also reported [11].

3.4.5. Above-Ground Biomass. The total above-ground biomass of the crop was significantly \((P < 0.05)\) affected by rates of NPS and KCl and their interaction (Tables 5 and 9). Higher dry biomass yield (9.5 t ha\(^{-1}\)) was obtained from the combination of 150 kg ha\(^{-1}\) NPS and 50 kg ha\(^{-1}\) KCl followed by 150 kg ha\(^{-1}\) NPS and 75 kg ha\(^{-1}\) KCl (Table 9), while unfertilized plots recorded the lowest biomass (1.13 t ha\(^{-1}\)). Total above-ground biomass showed an increment of 279 and 179\% as the rate of NPS and KCl application increased from 0 to 150 kg ha\(^{-1}\) and 0 to 50 kg ha\(^{-1}\), respectively (Table 7). In this study, the above-ground biomass has shown an increasing trend with an increasing amount of fertilizer rates (Table 7). The higher dry biomass at 150 kg ha\(^{-1}\) NPS and 50 kg ha\(^{-1}\) KCl could be attributed to the highest plant height, leaf area, number of productive tillers, and number of grains per spike. Similarly, the combined use of NPK resulted in the highest biological yield of wheat [61].

3.4.6. Grain Yield. Grain yield was significantly \((P < 0.05)\) influenced due to main and interaction effects of NPS and KCl fertilizer rates (Tables 5 and 9). The maximum grain yield (4.33 t ha\(^{-1}\)) was recorded from the combined application of 150 kg ha\(^{-1}\) NPS and 50 kg ha\(^{-1}\) KCl followed by 150 kg ha\(^{-1}\) NPS and 75 kg ha\(^{-1}\) KCl (3.44 t ha\(^{-1}\)) (Table 7). On the contrary, the least grain yield (0.44 t ha\(^{-1}\)) was recorded from unfertilized treatments. In general, the yield obtained from 150 kg ha\(^{-1}\) NPS and 50 kg ha\(^{-1}\) KCl was 8.84-fold higher than the yield obtained from unfertilized treatments. The grain yield advantages due to NPS and KCl fertilization could be attributed to synergistic effects of applied nutrients that enhanced the growth and yield of wheat. The result was in agreement with that of Doberman and Fairhurst [11] who reported that the combined effects of N, P, K, and S increased crop productivity. Asghar et al. [62] also concluded that an increase in NPK application resulted in increased grain yield of maize and other cereal crops. Brhane et al. [59] recommended 60 kg K\(_2\)O and blended
Table 5: Growth, yield component, yield, and agronomic efficiency of wheat as affected by NPS and K fertilizer rates at Sodo Zuria, Wolaita Zone, Southern Ethiopia, during 2016.

| Source variance | DF | TNPP | PT | NGPS | TGW |
|-----------------|----|------|----|------|-----|
| REP             | 2  | 1.163| 0.1132| 26.6 | 5.217 |
| NPS             | 3  | 7.434*| 1.1293*| 314.55*| 243.017*|
| K               | 4  | 7.827*| 11.808*| 629.358*| 243.017*|
| NPS * K         | 12 | 0.878*| 0.0825NS| 11.092*| 38.472*|
| Error           | 38 | 0.34545| 0.0414| 5.354 | 11.006 |

LSD: least significant difference at the 5% level; means in the column followed by the same letters are not significantly different at the 5% level.

3.4.7. Straw Yield. Straw yield of wheat was significantly affected (P < 0.05) by the main and interaction effects of NPS and KCl fertilizer rates (Tables 5 and 9). The highest straw yield (5.13 t·ha⁻¹) was recorded from 150 kg·ha⁻¹ NPS and 50 kg·ha⁻¹ KCl which showed an increment of 7 t·ha⁻¹ as compared to the lowest straw yield (0.641 t·ha⁻¹) recorded from unfertilized plots (Table 10). Previous studies on N and P [66], P [67], and S [68] reported that the addition of these nutrients could improve the grain and straw yield.

3.4.8. Harvest Index. Analysis of variance indicated that the harvest index (HI) did not respond significantly (P < 0.05) to the rates of the NPS fertilizer and its interaction with KCl (Table 9). However, K fertilizer had a significant effect on HI (Table 9). The maximum and minimum HI was recorded at 50 and 0 kg·ha⁻¹ KCl, respectively (Table 8), while K applications between 25 and 75 kg·ha⁻¹ KCl were statistically at par.

Table 6: Mean squares of ANOVA for the number of tillers per plant, number of productive tillers per plant, grain per spike, and 1000-grain weight of wheat.

| Source variance | DF | TNPP | PT | NGPS | TGW | AE |
|-----------------|----|------|----|------|-----|----|
| NPS             | 3  | 7.434*| 1.1293*| 314.55*| 243.017*| 9.94 |
| K               | 4  | 7.827*| 11.808*| 629.358*| 243.017*| 10.45 |
| NPS * K         | 12 | 0.878*| 0.0825NS| 11.092*| 38.472*| 10.13 |
| Error           | 38 | 0.34545| 0.0414| 5.354 | 11.006 | 1.573 |

NS and *: nonsignificant and significant at 5%. NTPP: number of tillers per plant; PTNP: number of productive tillers per plant; NGPS: number of grains per spike; AGBM: above-ground biomass; GY: grain yield; SY: straw yield; AE: agronomic efficiency.

NPKSZ as economically feasible rate for wheat-growing farmers in vertisol of Tigray Region, Ethiopia. Additionally, scholars working on individual nutrients such as N [63], P [64], K [58], and S [45, 65] have shown an increase in grain yield of wheat due to applied N, P, K, and S nutrients, respectively. Therefore, the grain yield advantage in the present study reflects the level of N, P, K, and S in the study area and the beneficial effects of blended NPS and K fertilizers in achieving high yields.

3.4.9. Agronomic Efficiency. Agronomic efficiency of wheat exhibited significant (P < 0.05) changes due to NPS and KCl and their interaction effects (Tables 5 and 9). The highest agronomic efficiency (19.5 kg·kg⁻¹) was recorded at the rate of 150 kg·ha⁻¹ NPS and 50 kg·ha⁻¹ KCl. However, the least agronomic efficiency (2.0 kg·kg⁻¹) was recorded from plots which received 25 kg·ha⁻¹ NPS and 50 kg·ha⁻¹ KCl above which the efficiency was reduced. This might indicate that the application of balanced nutrient containing NPS and K up to the optimum level has a positive contribution towards increasing the crop efficiency of nutrient uptake and conversion to the grain yield. Above the optimum level, decline of the efficiency at the highest level of nutrient application might be attributed to reduced uptake rate per unit of applied nutrients. According to Croswell and Godwin [69], high agronomic efficiency would be obtained if the yield increment per unit nutrient applied is high. Fageria and Baligar [70] also stated that high agronomic efficiency is obtained if the yield increment per unit nutrient applied is high because of reduced losses and increased uptake.
3.5. Partial Budget Analysis. The result showed that highest net benefit (36,033.4 birr·ha⁻¹) was obtained from 150 kg·ha⁻¹ NPS and 50 kg·ha⁻¹ KCl, whereas the least net benefit (3920 birr·ha⁻¹) was obtained from the unfertilized treatment (Table 11). The net return was about 8.9-fold higher than that of the control. Accordingly, the result showed that the highest MRR (i.e., 4252.6%) was obtained from the application of 150 kg·ha⁻¹ NPS and 50 kg·ha⁻¹ KCl; and it was followed by MRR (i.e., 2234.8%) recorded from 100 kg·ha⁻¹ NPS and 50 kg·ha⁻¹ KCl (Table 7). Therefore, the

| NPS (kg·ha⁻¹) | KCl (kg·ha⁻¹) | 0  | 25  | 50  | 75  |
|---------------|---------------|----|-----|-----|-----|
| TTNPP         |               |    |     |     |     |
| 0             |               | 1.33<sup>i</sup> | 2.50<sup>b</sup> | 3.00<sup>ab</sup> | 2.66<sup>ab</sup> |
| 50            |               | 3.20<sup>defgh</sup> | 3.16<sup>degh</sup> | 4.23<sup>c</sup> | 3.36<sup>degh</sup> |
| 100           |               | 3.30<sup>cdefgh</sup> | 3.50<sup>cdef</sup> | 5.26<sup>b</sup> | 3.23<sup>cdefgh</sup> |
| 150           |               | 3.70<sup>cdef</sup> | 3.87<sup>cdef</sup> | 6.60<sup>a</sup> | 3.90<sup>cdef</sup> |
| 200           |               | 3.40<sup>cdefgh</sup> | 4.10<sup>cde</sup> | 4.20<sup>d</sup> | 3.93<sup>cdef</sup> |
| LSD (0.05)    |               | 0.97 |     |     |     |
| CV (%)        |               | 16.2 |     |     |     |
| NGPS (g)      |               |    |     |     |     |
| 0             |               | 16.3<sup>j</sup> | 22.0<sup>b</sup> | 28.3<sup>bc</sup> | 24.0<sup>k</sup> |
| 50            |               | 27.7<sup>ij</sup> | 31.7<sup>ghi</sup> | 36.3<sup>de</sup> | 31.0<sup>ghi</sup> |
| 100           |               | 31.7<sup>ghi</sup> | 37.7<sup>cde</sup> | 45.7<sup>b</sup> | 36.0<sup>de</sup> |
| 150           |               | 36.0<sup>de</sup> | 40.7<sup>c</sup> | 50.7<sup>a</sup> | 39.0<sup>de</sup> |
| 200           |               | 32.7<sup>cdefg</sup> | 35.3<sup>cdef</sup> | 39.0<sup>d</sup> | 37.3<sup>c</sup> |
| LSD (0.05)    |               | 3.82 |     |     |     |
| CV (%)        |               | 6.82 |     |     |     |
| TKW (g)       |               |    |     |     |     |
| 0             |               | 27.333<sup>f</sup> | 37.3<sup>cde</sup> | 39.66<sup>def</sup> | 35.67<sup>f</sup> |
| 50            |               | 42.33<sup>cdef</sup> | 43.3<sup>cdef</sup> | 41.67<sup>de</sup> | 44.3<sup>cde</sup> |
| 100           |               | 43.3<sup>cde</sup> | 44.00<sup>cde</sup> | 56.33<sup>a</sup> | 42.00<sup>cde</sup> |
| 150           |               | 42.00<sup>cde</sup> | 44.3<sup>cde</sup> | 44.00<sup>cde</sup> | 43.3<sup>cde</sup> |
| 200           |               | 44.67<sup>cdef</sup> | 44.00<sup>cde</sup> | 43.3<sup>cde</sup> | 35.3<sup>cde</sup> |
| LSD (0.05)    |               | 5.48 |     |     |     |
| CV (%)        |               | 7.76 |     |     |     |
| AGBM (t·ha⁻¹) |               |    |     |     |     |
| 0             |               | 1.13<sup>f</sup> | 1.27<sup>f</sup> | 2.80<sup>f</sup> | 2.73<sup>f</sup> |
| 50            |               | 2.57<sup>f</sup> | 3.10<sup>f</sup> | 4.53<sup>f</sup> | 4.67<sup>ef</sup> |
| 100           |               | 5.80<sup>efd</sup> | 6.67<sup>c</sup> | 9.57<sup>f</sup> | 8.10<sup>b</sup> |
| 150           |               | 6.60<sup>c</sup> | 6.80<sup>c</sup> | 7.53<sup>b</sup> | 6.80<sup>c</sup> |
| 200           |               | 6.62 |     |     |     |
| LSD (0.05)    |               | 0.62 |     |     |     |
| CV (%)        |               | 7.28 |     |     |     |
| GY (t·ha⁻¹)   |               |    |     |     |     |
| 0             |               | 0.44<sup>f</sup> | 0.49<sup>f</sup> | 1.19<sup>f</sup> | 1.12<sup>f</sup> |
| 50            |               | 1.02<sup>i</sup> | 1.24<sup>f</sup> | 1.88<sup>f</sup> | 1.99<sup>gh</sup> |
| 100           |               | 1.99<sup>ghi</sup> | 2.23<sup>f</sup> | 2.98<sup>de</sup> | 2.87<sup>de</sup> |
| 150           |               | 2.29<sup>ghi</sup> | 2.89<sup>d</sup> | 4.34<sup>a</sup> | 3.44<sup>b</sup> |
| 200           |               | 2.49<sup>ghi</sup> | 2.72<sup>cde</sup> | 3.25<sup>bc</sup> | 2.86<sup>d</sup> |
| LSD (0.05)    |               | 0.33 |     |     |     |
| CV (%)        |               | 9.01 |     |     |     |

LSD: least significant difference at the 5% level; CV: coefficient of variation; means in columns followed by the same letters are not significantly different at the 5% level of significance; TTNPP: total number of tillers per plant; TKW: thousand-grain weights; NGPS: number of grains per spike; AGBM: above-ground biomass; GY: grain yield.
Table 8: Productive tillers per plant of wheat as affected by NPS and K fertilizer rates at Sodo Zuria, Wolaita Zone, Southern Ethiopia, during 2016.

| Fertilizer (kg·ha⁻¹) | Productive tillers | Harvest index (%) |
|----------------------|--------------------|-------------------|
|                      | No.                | No.               |
| NPS                  |                    |                   |
| 0                    | 1.91d              | 40.25             |
| 50                   | 2.87c              | 41.00             |
| 100                  | 3.53b              | 42.58             |
| 150                  | 4.57a              | 42.75             |
| 200                  | 3.69b              | 40.75             |
| LSD (0.05)           | 0.17               | NS                |
| KCl                  |                    |                   |
| 0                    | 3.01d              | 39.40b            |
| 25                   | 3.18c              | 41.13a            |
| 50                   | 3.64a              | 43.27a            |
| 75                   | 3.42b              | 42.07a            |
| LSD (0.05)           | 0.15               | 3.59              |
| CV (%)               | 6.14               | 7.42              |

LSD (0.05): least significant difference at the 5% level; CV: coefficient of variation; NS: nonsignificant. Means in the column followed by the same letters are not significantly different at the 5% level of significance.

Table 9: Mean squares of ANOVA for grain yield, straw yield, and above-ground dry biomass of wheat.

| Source variance | DF | AGDBM | GY | SY | HI | AE |
|----------------|----|-------|----|----|----|----|
| REP            | 2  | 2.0162| 0.3077| 2.2167| 2.2167| 9.589|
| NPS            | 3  | 64.457| 11.934| 15.3167<sup>NS</sup>| 15.3167<sup>NS</sup>| 92.027<sup>*</sup>|
| K              | 4  | 14.578| 3.663 | 39.9111<sup>*</sup>| 39.9111<sup>*</sup>| 162.74<sup>*</sup>|
| NPS * K        | 12 | 0.8799| 0.1929| 3.9944<sup>NS</sup>| 3.9944<sup>NS</sup>| 23.37<sup>*</sup>|
| Error          | 38 | 0.1442| 0.0388| 9.4623  | 9.4623  | 3.622  |

NS and *: nonsignificant and significant at 5%. SY: straw yield; GY: grain yield; AGDBM: above-ground dry biomass; HI: harvest index; AE: agronomic efficiency.

Table 10: The interaction effect of NPS and K on straw yield (SY) (t/ha) and agronomic efficiency (AE) of bread wheat at Sodo Zuria, Wolaita Zone, Southern Ethiopia, during 2016.

| Fertilizer (kg·ha⁻¹) | KCl (kg·ha⁻¹) |
|----------------------|---------------|
| SY (t·ha⁻¹)          |               |
| NPS                  | 0  | 25 | 50 | 75 |
| 0                    | 0.64<sup>b</sup>| 0.74<sup>k</sup>| 1.04<sup>b</sup>| 1.04<sup>b</sup>| 0.70<sup>g</sup>| 0.70<sup>g</sup>|
| 50                   | 1.56<sup>i</sup>| 1.86<sup>hi</sup>| 2.35<sup>eh</sup>| 2.35<sup>eh</sup>| 2.45<sup>gh</sup>| 2.45<sup>gh</sup>|
| 100                  | 2.98<sup>def</sup>| 2.82<sup>efg</sup>| 3.28<sup>de</sup>| 3.28<sup>de</sup>| 3.3<sup>de</sup>| 3.3<sup>de</sup>|
| 150                  | 3.43<sup>cd</sup>| 4.03<sup>b</sup>| 5.13<sup>a</sup>| 5.13<sup>a</sup>| 3.8<sup>bc</sup>| 3.8<sup>bc</sup>|
| 200                  | 4.10<sup>b</sup>| 3.77<sup>bc</sup>| 3.85<sup>bc</sup>| 3.85<sup>bc</sup>| 3.71<sup>bc</sup>| 3.71<sup>bc</sup>|
| LSD (0.05)           | 0.59          |            |       |    |
| CV (%)               | 12.9          |            |       |    |

| AE (kg·kg⁻¹)         |               |
|----------------------|---------------|
| NPS                  | 0  | 25 | 50 | 75 |
| 0                    | —  | 2.00<sup>b</sup>| 15.00<sup>bc</sup>| 15.00<sup>bc</sup>| 9.02<sup>g</sup>| 9.02<sup>g</sup>|
| 50                   | 11.53<sup>defg</sup>| 10.68<sup>fg</sup>| 14.40<sup>bcd</sup>| 14.40<sup>bcd</sup>| 12.4<sup>def</sup>| 12.4<sup>def</sup>|
| 100                  | 15.50<sup>bc</sup>| 15.413<sup>bc</sup>| 16.96<sup>eb</sup>| 16.96<sup>eb</sup>| 13.90<sup>bde</sup>| 13.90<sup>bde</sup>|
| 150                  | 12.37<sup>def</sup>| 14.01<sup>bcde</sup>| 19.48<sup>a</sup>| 19.48<sup>a</sup>| 13.94<sup>bde</sup>| 13.94<sup>bde</sup>|
| 200                  | 10.28<sup>fg</sup>| 10.16<sup>fg</sup>| 11.25<sup>fg</sup>| 11.25<sup>fg</sup>| 8.81<sup>g</sup>| 8.81<sup>g</sup>|
| LSD (0.05)           | 3.15          |            |       |    |
| CV (%)               | 16.05         |            |       |    |

LSD: least significant difference at the 5% level; CV: coefficient of variation; means in columns followed by the same letters are not significantly different at the 5% level of significance; SY: straw yield; AE: agronomic efficiency.
Table 11: Partial budget analysis for NPS fertilizer rate and K fertilizer application.

| NPS and KCl rate (kg ha\(^{-1}\)) | GY (t ha\(^{-1}\)) | ADY (t ha\(^{-1}\)) | Net benefits (birr ha\(^{-1}\)) | Total variable cost (birr) | Marginal net benefit (birr) | Marginal variable cost (birr) | MRR (%) |
|------------------------------------|-------------------|-------------------|-------------------------------|--------------------------|--------------------------|--------------------------|--------|
| 0, 0                               | 0.43              | 0.392             | 3920                          | —                        | —                        | —                        | —      |
| 0, 25                              | 0.48              | 0.437             | 4370                          | 304.28                   | 450                      | 304.28                   | 17.19  |
| 0, 50                              | 1.19              | 1.067             | 10670                         | 608.57                   | 6300                     | 304.28                   | 207.05 |
| 0, 75                              | 1.12              | 1.0019            | 10019                         | 912.8                    | 651                      | 304.28                   | 213.9  |
| 50, 0                              | 2.01              | 0.9119            | 9119                          | 776                      | —                       | —                        | —      |
| 50, 25                             | 1.23              | 1.1097            | 11097                         | 1080.28                  | 1978                     | 304.28                   | 650    |
| 50, 50                             | 1.88              | 1.689             | 16890                         | 1384.57                  | 5793                     | 304.28                   | 1903.8 |
| 50, 75                             | 1.99              | 1.791             | 17910                         | 1688.85                  | 1020                     | 304.28                   | 335.2  |
| 100, 0                             | 1.99              | 1.791             | 17910                         | 1552                     | —                       | —                        | —      |
| 100, 25                            | 2.23              | 2.004             | 20040                         | 1856.28                  | 2130                     | 304.28                   | 700    |
| 100, 50                            | 2.98              | 2.684             | 26840                         | 2160.57                  | 6800                     | 304.28                   | 2234.8 |
| 100, 75                            | 2.87              | 2.583             | 25830                         | 2464.85                  | —1010                    | 304.28                   | 331.9  |
| 150, 0                             | 2.29              | 2.0603            | 20603                         | 2328                     | —                       | —                        | —      |
| 150, 25                            | 2.89              | 2.603             | 26030                         | 2632.28                  | 5427                     | 304.28                   | 1783.5 |
| 150, 50                            | 4.33              | 3.897             | 38970                         | 2932.38                  | 12940                    | 304.28                   | 4252.6 |
| 150, 75                            | 3.44              | 3.09              | 30900                         | 3240.85                  | —8000                    | 304.28                   | 2652.1 |
| 200, 0                             | 2.49              | 2.639             | 22430                         | 3104                     | —                       | —                        | —      |
| 200, 25                            | 2.72              | 2.448             | 24480                         | 3408.28                  | 2050                     | 304.28                   | 673.7  |
| 200, 50                            | 3.25              | 2.925             | 29250                         | 3712.57                  | 4770                     | 304.28                   | 1567.6 |
| 200, 75                            | 2.86              | 2.574             | 25740                         | 4016.85                  | —3510                    | 304.28                   | 1153.5 |

GY: grain yield; ADY: adjusted grain yield; MRR: marginal rate of return.

application of 150 kg ha\(^{-1}\) NPS and 50 kg ha\(^{-1}\) KCL followed by 100 kg ha\(^{-1}\) NPS and 50 kg ha\(^{-1}\) KCL was economically profitable.

4. Conclusion

Based on the results obtained on the effects of different fertilizing rates in bread wheat, the following conclusions may be drawn. The multinutrient deficiencies in the study area could be addressed through balanced nutrition of NPKS. Consequently, fertilization of wheat with 150 kg ha\(^{-1}\) NPS and 50 kg ha\(^{-1}\) KCL produced the highest grain yield, economic return, and agronomic efficiency. Regardless of higher soil exchangeable K in the present study, the response of wheat to the K fertilizer justified the presence of K inadequacy probably from the competition of other cations such as Mg. Moreover, individual effects of N, P, and S should be further investigated on the wheat crop as they were applied in the blended form.

Data Availability

The data presented in this manuscript are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors’ Contributions

Tigist Tesfaye collected, analyzed, and interpreted the data. Fanuel Laekemariam and Abera Habte drafted the manuscript. All authors read and approved the final manuscript.

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