Received: 28 September 2024 | Accepted: 24 February 2025

DOI: 10.1002/agg2.70084

Agrosystems, Geosciences & Environment OPEN ACCESS

ORIGINAL ARTICLE

Agrosystems

Effects of nutrient omission and landscape positions on grain sorghum production in northern Ethiopia

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Assigned to Associate Editor Dinesh Panday

Abstract

Low soil fertility, inappropriate fertilizer application, and low input use are prominent factors contributing to low agricultural productivity in Ethiopia, where soil fertility status varies significantly across the landscape. Applying the correct rate, type, timing, and placement of fertilizers is essential for maximizing agricultural benefits and ensuring sustainable productivity. Addressing these issues is critical for promoting sustainable agricultural practices and improving food security. Therefore, the objective of the experiment was to identify the major yield-limiting soil nutrients for sorghum yield in northern Ethiopia. A randomized complete block design with three replications was used at each landscape positions. The nutrients evaluated in the study were nitrogen (N), phosphorus (P), sulfur (S), zinc (Zn), boron (B), and potassium (K). The treatment applied included control, recommended NP (RNP), NPSZnB, NPKSZnB, NPZnB, NPSB, NPSZn, 150% NPKSZnB, and 50% NPKSZnB. These treatments were implemented across each landscape position. The research findings indicated that the application of 150% All + K nutrients resulted in the highest grain and biomass yields across all landscape positions. When compared with the RNP treatment, there was no significant difference in yield at all slopes. Omitting S, Zn, B, and K did not significantly affect the grain and biomass yields, suggesting that these nutrients are not yield limiting for sorghum in the study area. These findings suggest that prioritizing N- and P-containing nutrients is essential for maximizing sorghum yield, thus contributing to sustainable agricultural practices and improved food security in the region.

1 | INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is an important cereal crop, particularly in the world's semiarid tropics. Because of its drought resistance and wide range of ecological adaptations, it is the preferred crop for dry regions with unreliable rainfall (Taye, 2013). Sorghum ranks as the world's

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Abbreviations: Av.P, available phosphorus; RF, rainfall; RNP, recommended nitrogen and phosphorus; SOC, soil organic carbon; T-max, maximum temperature; T-min, minimum temperature; TN, total nitrogen.

fifth most important cereal crop, following maize (*Zea mays* L.), rice (*Oryza sativa*), wheat (*Triticum aestivum*), and barley (*Hordeum vulgare*) (FAOSTAT, 2013). It is one of Ethiopia's most staple food crops by area coverage and ranks first and fourth in cereal crops in study areas and nationally, respectively (Central Statistical Agency [CSA], 2021). It serves as a crucial food security crop in sub-Saharan Africa, supporting 300 million people who rely on it (Sirany et al., 2022).

Sorghum grain is nutritionally composed of 4.4%–21.1% protein, 2.1%–7.6% fat, 1.0%–3.4% crude fiber, 57.0%–80.6% total carbohydrates, 55.6%–75.2% starch, 1.3%–3.3% total ash, and contains 179–1360 mg of total minerals per 100 g (Ratnavathi, 2019; Taylor et al., 2006). Despite sorghum's advantage in supplying a balanced human diet (Awika, 2017; Pereira & Hawkes, 2022), its productivity in Ethiopia, including the study area of Wag himra, remains far below its potential. The average yield in the study area is 1.95 t ha^{-1}, which is lower than both the national average of 2.69 t ha^{-1} (CSA, 2021) and the estimated potential yield of the study area of 2.8 t ha^{-1} (Assefa et al., 2020). This yield gap is attributed to various constraints, including limited access to improved seed varieties, suboptimal agronomic practices, soil fertility depletion, moisture stress, weed, and pest & disease pressure (Tesfahunegn, 2012; Wortmann et al., 2006).

Declining soil fertility is a major factor limiting crop yields across many African nations, including Ethiopia (Elrys et al., 2021; Kusse et al., 2019; Louis, 2010; Tan et al., 2008). This issue contributes to high food insecurity and poverty (Ejigu et al., 2021; Martey et al., 2019). National nutrient balance assessments indicate severe nutrient depletion, with annual losses of 122 kg N ha^{-1}, 13 kg P ha^{-1}, and 82 kg K ha^{-1} twice the average depletion rate in sub-Saharan Africa (Haileslassie et al., 2005). The undulating topography of Ethiopian landscapes exacerbates nutrient loss through soil erosion (Mulatu & Grando, 2011). Cultivation on steep slopes accelerates erosion, reduces soil depth, and decreases crop productivity, particularly in mountainous regions (Hurni et al., 2010; Seifu et al., 2020). Physiographic characteristics significantly influence soil degradation, with topography playing a key role in soil loss, nutrient distribution, and water erosion (Khan et al., 2013; Kotingo, 2015; Sanogo et al., 2023; Ziadat & Taimeh, 2013). Therefore, understanding the impact of landscape position on soil properties is crucial for developing sustainable soil management strategies.

Farmers are facing multiple challenges in their agricultural systems, including limited land availability, resource scarcity (Zerssa et al., 2021), and worsening soil degradation, which hinder sustainable crop production and food security (Bhattacharyya et al., 2015). In Ethiopia, extensive fertilizer validations on blended and omission trials have been conducted by regional and national research systems. The result reveals instances of deficiencies in both macro- and micronutrients. Abebe et al. (2020), Ethiopia Soil Information System (EthioSIS) (2014), and Tegbaru (2014) documented that nitrogen (N), phosphorus (P), potassium (K), sulfur (S), zinc (Zn), and boron (B) deficiencies have been reported in the soils of Ethiopia. In contrast, research carried out by Amare et al. (2022), Alemayehu et al. (2022), and Getinet et al. (2022) indicated that the most significant reduction in yield occurred when N and P were omitted. Similarly, Teshome et al. (2023) found that the highest yield reduction resulted from the omission of N. The trials were conducted in flat terrain, which did not account for sloping areas. A crucial aspect of optimizing crop production is a thorough understanding of agricultural landscape features and their effective management based on inherent capabilities and limitations (Numata et al., 2003). However, existing recommendations often have a limited representation of the country's actual cropping systems and topographic features (Desta et al., 2022). Moreover, the identification of nutrients that limit sorghum yield, considering different landscape positions in the study area, has not yet been addressed. Furthermore, previous research on nutrient omission also generally lacks consideration of how sorghum responds to variations in landscape position. Therefore, this study aims to identify the yield-limiting plant nutrients across different landscape positions for sorghum production in the study area.

Core Ideas

- Understanding the intricate interplay of landscape and soil nutrients is essential for effective land management and sustainable crop production.
- The major yield-limiting nutrients for sorghum across different landscape positions were assessed in Sekota district of Ethiopia.
- S, Zn, B, and K were found to be non-limiting nutrients for sorghum yield in the study area.
- Optimization of N- and P-containing fertilizers is crucial for enhancing sorghum productivity.

2 | MATERIALS AND METHODS

2.1 | Description of study area

The trial was conducted during the 2022 cropping season for a single year in Melka-Genet Kebele, Sekota district of Wag-himra zone, Ethiopia (Figure 1).

The area practices a diversified farming system, combining both livestock husbandry and crop cultivation. The primary crops cultivated in the area include sorghum [*S. bicolor* (L.) Moench], pearl millet (*Pennisetum glaucum*), tef (*Eragrostic tef*), and field peas (*Pisum sativum* L.). Sorghum holds the top position as the predominant staple food crop in the study area. The study area consistently faces challenges related to

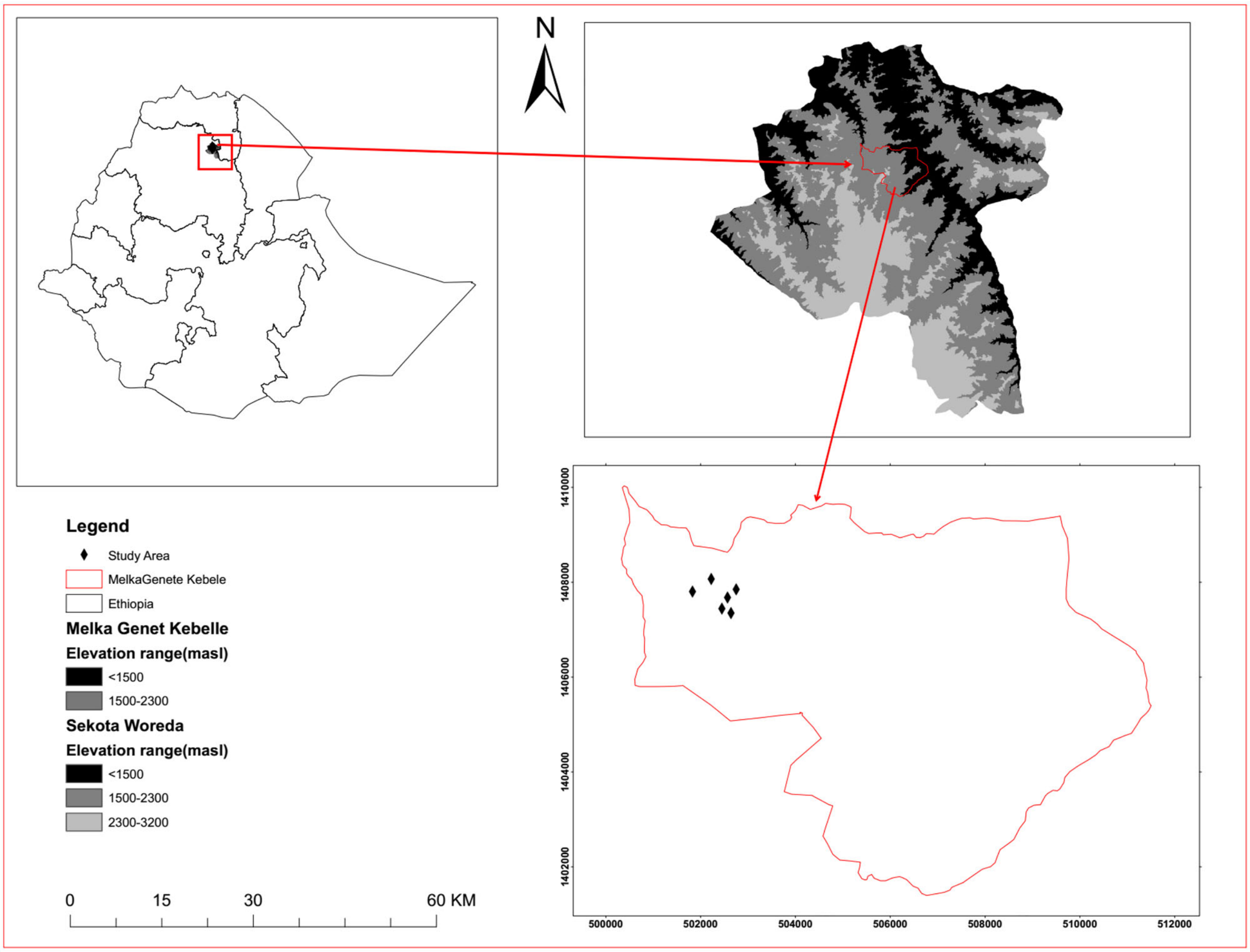


FIGURE 1 Location map of the study area.

the availability and access to sufficient amounts of nutritious food; limited farmland size; high soil erosion; and low, uneven distribution, and erratic rainfall. The critical shortage of arable land forced farmers to cultivate sloppy areas, which in turn aggravated soil erosion. Soil erosion by water in the region, particularly in the study area, is one of the major causes of low agricultural productivity (Desta et al., 2000; Girmay et al., 2020) and is responsible for food insecurity. The district exhibits a distinctive unimodal rainfall pattern, wherein the highest mean monthly rainfall typically falls during July and August (Figure 2). The mean monthly minimum temperature ranges from 12.48°C to 17.93°C, whereas the maximum temperature ranges from 26.18°C to 31.48°C.

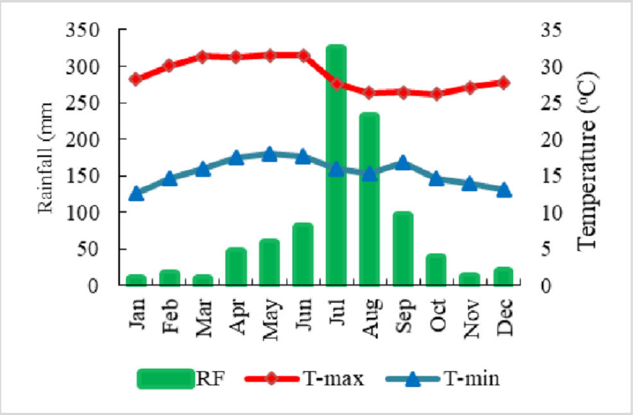


FIGURE 2 Mean monthly rainfall and temperature of Sekota district from 2018 to 2022.

2.2 | Experimental design and treatments

This on-farm experiment was conducted at six sites across three landscape positions: hillslope, midslope, and footslope (Figure 3). A hillslope is defined as having an inclination >15°, a midslope as having an inclination ranging between 5° and 15°, and a footslope as having an inclination of <5°. In each landscape position, all treatments were applied and replicated three times to observe the response of sorghum to each nutrient along the slope. A randomized complete

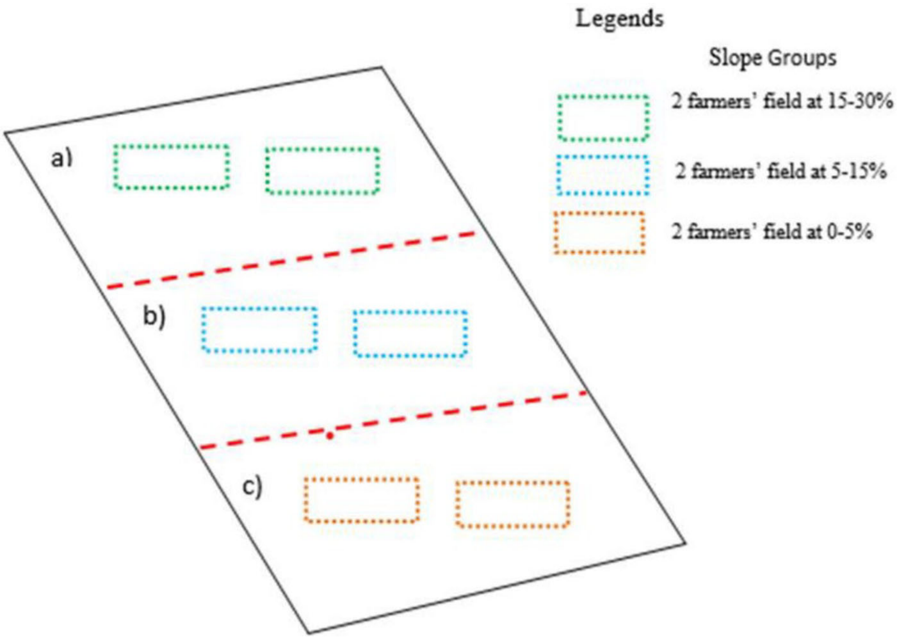


FIGURE 3 The schematic layout of farmers' fields is depicted as (a) hillslope, (b) midslope, and (c) footslope of landscape position.

TABLE 1 Treatment setup.

	Applied nutrient, kg ha^{-1}					
Treatment	N	P_2O_5	S	Zn	B	K_2O
1	75	38	7.4	0.75	0.25	0
2	75	38	7.4	0.75	0.25	60
3	75	38	0	0.75	0.25	0
4	75	38	7.4	0	0.25	0
5	75	38	7.4	0.75	0	0
6	37.5	19	3.7	0.375	0.125	30
7	112.5	57	11.1	1.125	0.375	90
8	75	38	0	0	0	0
9	0	0	0	0	0	0

block design with three replications was implemented across hillslope, midslope, and footslope positions. The experiment comprised nine treatments, including a control (Table 1). The land was thoroughly prepared using the traditional oxen plowing method and leveled before layout preparation and planting. Seeds were drilled in rows at a depth of 3–4 cm and thinned 21 days after sowing to achieve the desired plant population. Sowing was done from the first week of July, 2022. Agronomic practices such as weeding and cultivation were done uniformly for all treatments as needed. Melkam sorghum variety was used as a testing crop and plot size was 3 m × 4.5 m. The spacing between plants, rows, blocks, and plots was set at 0.15, 0.75, 1, and 0.5 m, respectively. The source of nutrients was urea for nitrogen, TSP for phosphorus, KCl for potassium, $MgSO_4$ for sulfur, Zn-EDTA (granular) for zinc, and borax (granular) for boron.

2.3 | Treatment description

Treatment description is as follows:

1. All (NPSZnB) − K = application of all nutrients except potassium (K) to observe its effect on sorghum yield.
2. All + K = Application of all nutrients, including potassium, to observe the effect of potassium on yield.
3. All − S = Application of all nutrients except sulfur to observe its effect on sorghum yield.
4. All − Zn = Application of all nutrients except zinc to observe its effect on sorghum yield.
5. All − B = Application of all nutrients except boron to observe its effect on sorghum yield.
6. 50% (All + K) = Application of all nutrients reduced by 50% to observe its effect on yield.

7. 150% (All + K) = Application of all nutrients increased by 150% to observe its effect on yield.
8. RNP = Application of the recommended nitrogen and phosphorus rates to observe their effect on yield.
9. Control (no fertilizer) = No fertilizer application.

2.4 | Data collection and statistical analysis

2.4.1 | Data collection

The data collected included aboveground biomass and grain yield. The aboveground biomass was weighed from the net plot, dried to a constant weight, and converted to kilograms per hectare. The grain yield harvested from each plot in the farmers' fields was weighed in kilograms. The yields were adjusted to 12.5% standard moisture content and then converted to kilograms per hectare.

2.4.2 | Soil sampling and analysis

Ten subsamples of soil were collected from the experimental sites at a depth of 0—20 cm using a 120-cm Edelman auger before planting. The composite soil was sieved using the necessary sieve sizes (0.5 and 2 mm), air dried, and then ground in a pestle and mortar. Total nitrogen (TN), soil organic carbon (SOC), available phosphorus (av.P), extractable B, and extractable Zn were analyzed in the produced soil sample. The combustion method was employed for measuring TN and SOC, whereas the Mehlich 3 method was used to test for av.P, extractable B, and extractable Zn (Mehlich, 1984).

2.4.3 | Data analysis

Grain and biomass yields were analyzed using analysis of variance (ANOVA) with the PROC GLM procedures in SAS software version 9.0 (SAS, 2008). Graphical presentations were created using Microsoft Excel. Means separation were compared using the least significant difference test at a 5% probability level. The statistical model was given as:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \epsilon_{ijk}$$

where Y_{ijk} is yield for the kth replicate in the ith landscape position and jth treatment, μ is overall mean, α_i is effect of the ith landscape position, β_j is effect of the jth treatment, $(\alpha\beta)_{ij}$ is interaction effect, and ϵ_{ijk} is random error.

Yield penalty refer to any decrease in yield observed when comparing the new fertilizers to the existing recommended fertilizer. It was calculated by subtracting the different source (newly introduced) nutrients from the existing recommended nutrients (Equation 1).

$$\text{YP} = \text{NIN} - \text{ERN} \tag{1}$$

where YP is yield penalty, NIN is newly introduced nutrients, and ERN is existing recommended nutrients.

3 | RESULTS AND DISCUSSION

3.1 | Soils of experimental area

There is significant variability in soil parameters among different farms. The pH of the surface soil ranged from 7.25 to 8.29 across the hill- to footslope positions. The TN content in the surface soil ranged from 0.06% to 0.12% across all slopes. Available phosphorus content at a depth of 0–20 cm ranged from 3.12 to 7.51 across all landscapes. Organic carbon content in surface soils ranged from 0.45% to 1.10% at all measured slopes. Extractable zinc levels at a depth of 0–20 cm varied from 0.44 to 0.74 ppm. Similarly, extractable boron concentrations ranged from 0.44 to 1.26 ppm in the surface soil (Table 2).

Soil parameters varied significantly among different farms across the hill- to footslope positions. The surface soil pH ranged from 7.25 to 8.29, indicating slight to moderate alkalinity. TN content in the surface soil varied between 0.06% and 0.12% across all slopes. Available phosphorus at a depth of 0–20 cm ranged from 3.12 to 7.51 mg kg^{-1} across the landscape. SOC content in surface soils ranged from 0.45% to 1.10%, reflecting differences in SOC accumulation. Extractable zinc levels at a depth of 0–20 cm ranged from 0.44 to 0.74 ppm, whereas extractable boron concentrations varied between 0.44 and 1.26 ppm in the surface soil (Table 2).

The soil's pH ranged from neutral to moderately alkaline (Jones, 2003), suggesting that fertilizer treatments could optimize the yield of sorghum. Hence, alkalinity might not be considered a yield-limiting factor. The SOC levels at the study sites were found to be very low to moderate, emphasizing the need for interventions to boost SOC. Increasing SOC is crucial for enhancing crop yields and improving fertilizer efficiency, as the critical threshold is 2% (Hazelton & Murphy, 2016). The current SOC levels indicate that achieving satisfactory sorghum yields is unlikely without the use of mineral fertilizers. The TN content of the experimental site in the measured depths was below 0.12, which falls within the "poor" category. The critical values for soil TN are considered to be above 0.2%, and this amount of soil nitrogen is recognized as limiting the productivity of sorghum (Landon, 2014). In addition to the application of inorganic fertilizer, it is crucial to implement other soil management practices that aim to enhance the TN content in the soil. The av.P (ppm) in the experimental sites was observed

TABLE 2 Selected soil parameters of the experimental sites before planting.

	Hillslope		Midslope		Footslope	
Parameters	**Farm 1**	**Farm 2**	**Farm 1**	**Farm 2**	**Farm 1**	**Farm 2**
Soil depth (cm)	0–20	0–20	0–20	0–20	0–20	0–20
pH (1:2.5; soil:water)	7.45	7.85	7.25	8.17	7.65	8.29
TN (%)	0.12	0.07	0.09	0.06	0.10	0.08
Av.P (ppm)	3.55	5.62	5.70	5.62	3.12	7.51
SOC (%)	1.00	0.48	1.08	0.45	1.10	0.55
Extractable Zn (ppm)	0.74	0.58	0.51	0.72	0.44	0.73
Extractable B (ppm)	0.47	0.60	0.44	1.26	0.50	0.60

Abbreviations: Av.P, available phosphorus; SOC, soil organic carbon; TN, total nitrogen.

TABLE 3 Analysis of variance (ANOVA) for treatment and landscape position effects on sorghum biomass and grain yield.

		Biomass yield			Grain yield		
Source of variation	***df***	**Mean square**	***F*-value**	***p* value**	**Mean square**	***F*-value**	***p* value**
Nutrients	8	7,519,882	4.83	0.0006	1,058,333	5.51	0.0002
Landscape	2	73,670,000	47.32	0.0001	6,572,083	34.22	0.0000
Nutrients × landscape	16	2,308,456	1.48	0.1671	138,668	0.72	0.7520
Error	32	1,556,769			192,032		

low to medium category at all slopes (Landon, 2014). The extractable Zn content at the experimental site was within the range classified as low to medium levels for sorghum crops (Cakmak, 2008). The extractable B content of the experimental sites was in the medium range and optimal for sorghum production.

3.2 | ANOVA for nutrients and landscape position effects on sorghum yield

The ANOVA results indicated that the application of different sources of fertilizer significantly affected the biomass and grain yield of sorghum. Additionally, landscape position also had a significant impact on these parameters. However, the interaction between different sources of fertilizer and landscape position did not significantly affect either parameter (Table 3).

3.3 | Effect of applied nutrients on grain yield of sorghum

Based on the ANOVA results, the grain yield was significantly influenced by the application of different source of fertilizer across all slopes, and the obtained yields varied considerably from site to site and among landscape positions. The highest grain yield was observed in the following order: footslope, midslope, and hillslope (Figure 4a–c). The relative increase in yield was observed with the application of all nutrients at 150% (All + K) across all landscape positions, but it was not statistically significant within the applied nutrients (Figure 4). This suggests that the application of K, S, Zn, and B fertilizers did not have a significant effect on sorghum yield when compared with the applied RNP fertilizer alone at all slopes. The highest yield was achieved with the 150% All + K treatment across all landscape positions. Compared to the control treatment, this treatment resulted in yield increases of 55.67% at the footslope (Figure 4a), 55.92% at the midslope (Figure 4b), and 46.25% at the hillslope (Figure 4c). When compared to the RNP treatment, the 150% All + K application increased yields by 10.83% at the footslope, 8.98% at the midslope, and 7.49% at the hillslope. In contrast, the RNP treatment alone resulted in yield increases of 50.31% at the footslope, 51.57% at the midslope, and 41.89% at the hillslope compared to the control. Despite these increases, the differences were not statistically significant. This indicates that the inherent soil fertility status of the study area is highly variable and requires optimization based on the actual limiting nutrients. Across all slopes, the yield obtained from applying RNP fertilizer was not statistically different from that of all other fertilizer treatments, including 150% All + K. This implies that the application of RNP is more crucial than the application of additional nutrients.

This result is aligned with the findings of Teshome et al. (2023) and Desta et al. (2022), who reported that the omission of nitrogen and phosphorus significantly reduced sorghum yield. Similar effects from the omission of these nutrients have

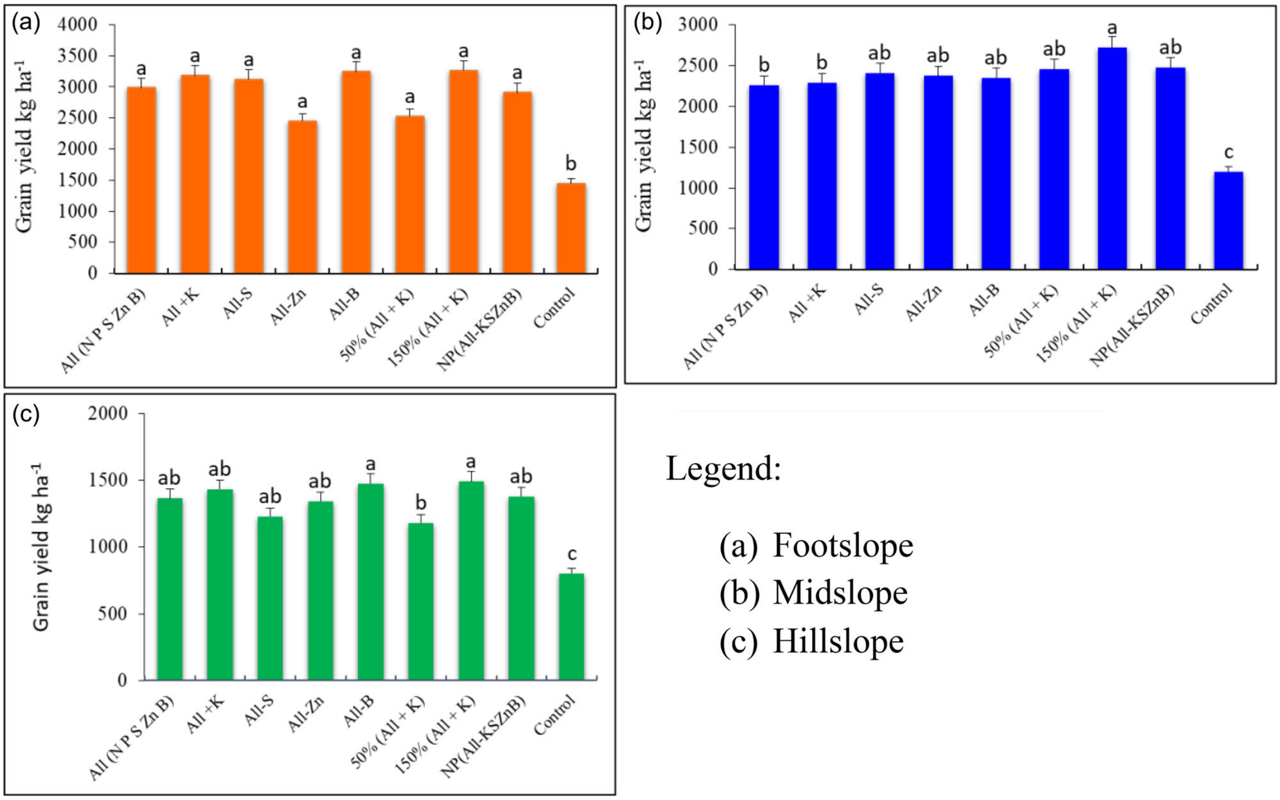


FIGURE 4 Effects of applied nutrients on sorghum yield. Means that share the same letter in a graph are not significantly different from each other at the 5% significance level.

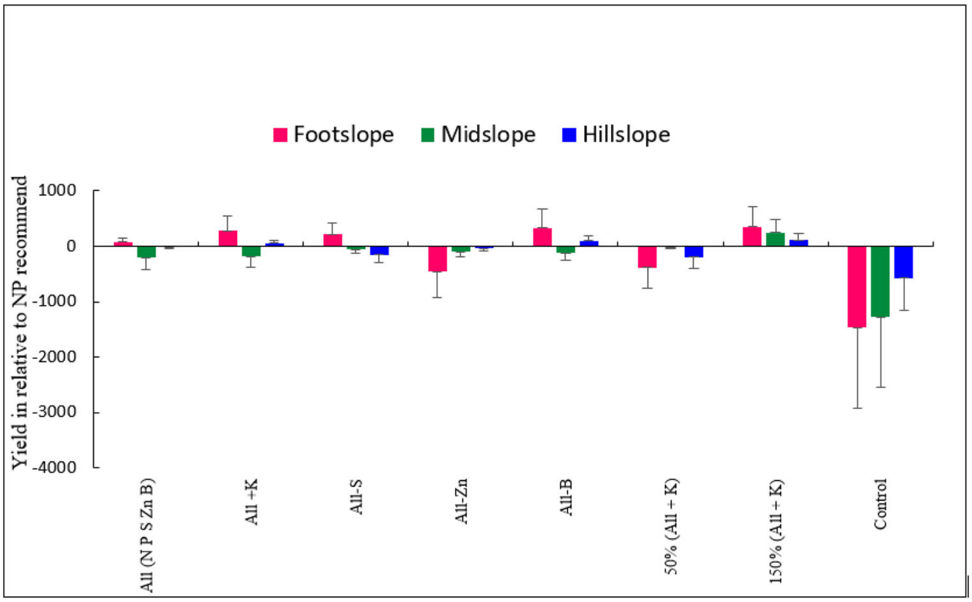
also been observed in other cereals, as reported by Amare et al. (2022), Getinet et al. (2022), Kumar et al. (2019), and Alemayehu et al. (2022). However, this result contrasts with the findings of Obsa et al. (2024) and Ekka et al. (2021), who reported that the application of N, P, S, Zn, and B nutrients enhances crop yield. Similarly, Kihara et al. (2022) reported that application on micronutrients in specific case is important to optimize plant densities and yield.

3.4 | Effects of applied nutrients in relative to RNP on yield across landscape positions

The grain yield penalties compared to the RNP-applied treatment ranged from 73.5 to −1462.6 kg ha^{-1} at the footslope and from −15.8 to −578.2 kg ha^{-1} at the hillslope (Figure 5). At the midslope, the penalties varied from −19.5 to −1276.3 kg ha^{-1} (Figure 5). The highest yield penalties of −1462.6, −1276.6, and −578.2 kg ha^{-1} were observed with the control treatment at the footslope, midslope, and hillslope, respectively. Similar findings were reported by Getahun et al. (2022), where the highest yield penalty was observed in the control treatment. At the footslope, the greatest yield penalties of −1462.6, −458.8, and −382.2 kg ha^{-1} were recorded with the control, All − Zn, and 50% (All + K) treatments, respectively. At the midslope, all treatments except 150% (All + K) showed yield reductions compared to the recommended RNP fertilizer. Similarly, at the hillslope, yield reductions were observed with all treatments except 150% (All + K), All − B, and All + K. The maximum yield penalty was observed in the control treatment across all slopes, which indicates that the soil nutrient status at the study site is very low (Table 2). Comparing the yields with the applied RNP fertilizer, the results were similar, and the increase was not significant. Hence, grain yield due to the application of RNP fertilizer was comparable with all nutrients applied. This indicates that RNP nutrient optimization is very important to achieve the maximum yield of sorghum and to reduce cost and environmental pollution. This finding is aligned with other studies (Amare et al., 2022; Teshome et al., 2023; Alemayehu et al., 2022; Desta et al., 2023; Getinet et al., 2022; Getinet et al., 2024; Getahun et al., 2022; and Sebnie et al., 2024) that highlight nitrogen and phosphorus as crucial nutrients for crop yield.

3.5 | Effects of landscape position on yield of sorghum

The highest grain yields (2789.5 and 8366.68 kg ha^{-1}; 2282.2 and 5940.18 kg ha^{-1}) were achieved at the foot- and midslopes, respectively (Figure 6). The highest and lowest grain



Note:

►◄ Negative bar indicates the yield grain from different source of nutrient less than the yield grain from RNP.

►◄ Positive bar indicates the yield grain from different source of nutrient greater than the yield grain from RNP.

FIGURE 5 Yield penalty of applied nutrients over the applied RNP across landscape position.

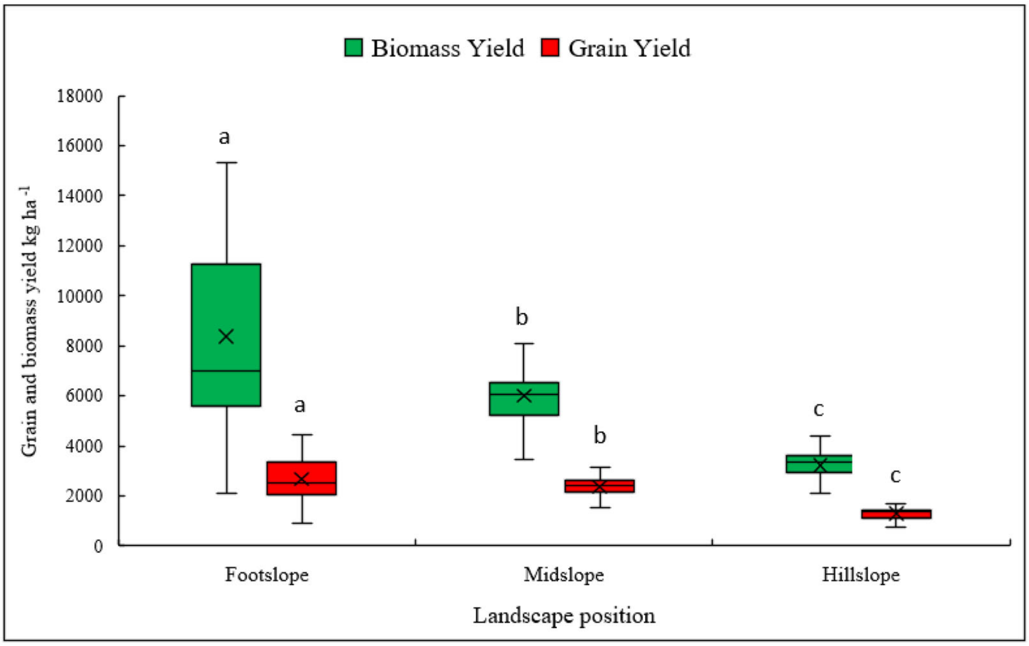


FIGURE 6 Effects of landscape position on sorghum yield. Means that share the same letter in a graph are not significantly different from each other at the 5% significance level.

and biomass yields were registered on the foot- and hillslopes, respectively. Grain and biomass yield reductions of 1489.78 and 507.27 kg ha^{-1} and 5019 and 2425.88 kg ha^{-1} were observed at the mid- and hillslopes, respectively, as compared with the footslope. Yield reduction at mid- and hillslopes may be attributed to nutrient removal caused by soil erosion. Higher slopes may contribute to soil erosion, leading to the loss of nutrients (Kateb et al., 2013; Wang

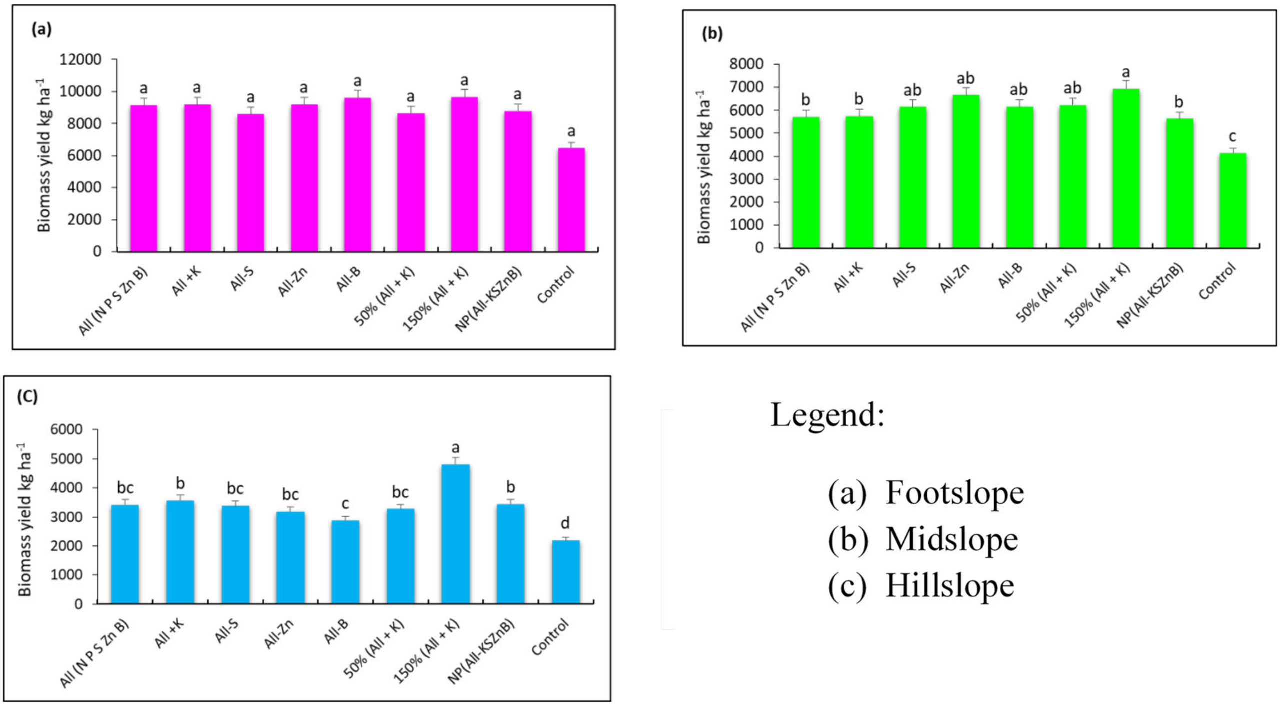


FIGURE 7 Effects of applied nutrient on biomass yield. Means that share the same letter in a graph are not significantly different from each other at the 5% significance level.

et al., 2019) and reduced water retention, ultimately negatively impacting sorghum yield. Generally, the productivity of sorghum is significantly influenced by the landscape position, with notable differences in grain yields across the foot-, mid-, and hillslopes. A similar finding was reported by Amede et al. (2022), who stated that landscape position significantly affects wheat yield. Similarly, Belew et al. (2023) reported that the maximum yield was obtained at the footslope compared to the hillslope. The lower yield on hillslopes might be attributed to the reduced fertility status of these areas, which is often affected by soil erosion. Girmay et al. (2020) confirmed that maximum soil loss due to erosion was observed in high-slope areas of the Agewmariam watershed. Additionally, Haileslassie et al. (2007) highlighted that soil fertility depletion on smallholder farms is a critical issue in Ethiopia.

3.6 | Effects of applied nutrients on the biomass yield of sorghum

The highest biomass yield was recorded from 150% (All + K) treatment (Figure 7). The lowest was obtained from the control treatment at mid- and hillslopes (Figure 7b,c). At the footslope, the application of fertilizer did not significantly affect the biomass yield of sorghum, whereas at mid- and hillslopes, it affects the biomass yield of sorghum. Except for 150% All + K and control, there was no significant difference between the applied treatments at midslope (Figure 7b). The biomass yield reduction observed at mid- and hillslopes is attributed to soil erosion and nutrient loss, emphasizing the need for effective landscape management practices to optimize sorghum production in such environments. The current result was similar to the finding of Teshome et al. (2023).

4 | CONCLUSION AND RECOMMENDATION

The result of this study confirms that the omission of S, K, B, and Zn did not have a positive effect on the yield of sorghum. A higher or significant yield penalty was not observed by omitting the nutrients S, K, B, and Zn at all slopes. The implication is that the omission of these nutrients did not result in a substantial reduction in sorghum yield. Hence, nitrogen and phosphorus are the most yield-limiting plant nutrients. Therefore, attention should be given to nitrogen and phosphorus containing nutrients to achieve the maximum yield of sorghum. Further research should be done on the RNP rate determination by considering landscape position.

AUTHOR CONTRIBUTIONS

Workat Sebnie: Conceptualization; data curation; formal analysis; investigation; software; supervision; visualization; writing—original draft. **Ewunetie Melak**: Conceptualization; data curation; formal analysis; investigation; writing—

review and editing. **Tilahun Esubalew**: Conceptualization; data curation; investigation. **Tesfaye Feyisa**: Conceptualization; methodology; supervision. **Hailu Kendie**: Supervision; visualization; writing—review and editing. **Getachew Agegnehu**: Conceptualization; funding acquisition; methodology; supervision. **Gizaw Desta**: Conceptualization; funding acquisition; methodology; supervision.

ACKNOWLEDGMENTS

The authors express their deep gratitude and appreciation toward the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Amhara Agricultural Research Institute (ARARI), and Sekota Dryland Agricultural Research Center (SDARC) for the unwavering dedication and commitment demonstrated throughout the project's execution, contributing significantly to its successful implementation and timely completion.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the finding of this study are available from the corresponding author upon the reasonable request.

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How to cite this article: Sebnie, W., Melak, E., Esubalew, T., Feyisa, T., Kendie, H., Agegnehu, G., & Desta, G. (2025). Effects of nutrient omission and landscape positions on grain sorghum production in northern Ethiopia. *Agrosystems, Geosciences & Environment*, *8*, e70084. https://doi.org/10.1002/agg2.70084