



Research Article

Effect of Blended NPS Fertilizer Rates on Growth, Yield and Quality of Potato Varieties at Mulo District, Oromia, Ethiopia

Alemu Hailu Deme^{1,*} , Biratu Abeshu Erandufa²

¹Department of Horticulture, Wallaga University, Shambu, Ethiopia

²Department of Plant Science, Wallaga University, Shambu, Ethiopia

Abstract

Potato production in Ethiopia is constrained by poor soil fertility and limited use of balanced fertilizers. This study evaluated the effects of varying rates of blended NPS (Nitrogen, Phosphorus, Sulfur) fertilizer on the growth, yield, and tuber quality of five potato varieties-Belete, Gudanie, Milki, Gera, and CIP 396004.337 (Dagem)-in Mulo District, Oromia. A factorial randomized complete block design with three replications was used to test four NPS rates (0, 100, 200, and 300 kg ha⁻¹). Increasing NPS rates significantly improved aboveground biomass, with Belete reaching 6.5 t ha⁻¹ at 300 kg ha⁻¹. Total and marketable tuber yields also increased, with Belete achieving the highest marketable yield of 30 t ha⁻¹. Higher fertilizer rates enhanced average tuber weight, tubers per plant, and dry matter content, benefiting processing quality. Unmarketable tuber yield declined, while tuber firmness improved, particularly in Belete and Milki, enhancing storage potential. Reducing sugar content decreased with increasing NPS, producing lighter chips suitable for processing. Sprout length was reduced at higher NPS levels, indicating improved tuber dormancy. Among the varieties, Belete consistently outperformed the others, followed by Milki and Gera, while Gudanie and CIP (Dagem) showed moderate performance. These findings highlight the importance of integrating improved potato varieties with optimal NPS fertilization to enhance yield, tuber quality, and farmer income, contributing to sustainable potato production and food security in the region.

Keywords

Potato Production, NPS Fertilizer, Potato Varieties, Tuber Yield, Tuber Quality

1. Introduction

Potato (*Solanum tuberosum* L.) is an important food and cash crop in Ethiopia, contributing to food security, income generation, and poverty reduction [1]. It is rich in essential nutrients, including calcium, potassium, vitamin C, and balanced amino acids, and serves as a raw material for industrial products such as French

fries, chips, starch, alcohol, and animal feed [2]. Ethiopia's favorable agro-climatic conditions allow year-round potato cultivation during the main rainy season (June–October), the Belg season (February–May), and under irrigation (December–April) [3].

Despite an increase in cultivated area from 40,000 hectares in

*Correspondence: Alemu Hailu Deme (alemu2023@gmail.com)

Received: 12 July 2025; Accepted: 30 January 2026; Published: 24 February 2026



Copyright: © The Author(s), 2026. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

1996 to over 160,000 hectares by 2006, average productivity remains low (12.9 t ha⁻¹) compared to the global average (21.5 t ha⁻¹) [4]. This yield gap is mainly due to poor soil fertility, limited use of balanced fertilizers, lack of site-specific fertilizer recommendations, disease pressure, and restricted access to improved varieties. Potato plants have shallow root systems and high nutrient demands, particularly for nitrogen, phosphorus, and sulfur. Traditionally, fertilizer use in Ethiopia has focused on nitrogen and phosphorus, neglecting other essential nutrients like sulfur. To address these deficiencies, the Ethiopian Ministry of Agriculture introduced blended NPS fertilizer (19% N, 38% P₂O₅, 7% S). However, optimal NPS fertilizer rates for different potato varieties and production areas, especially emerging areas like Mulo District, remain unclear.

This study aims to evaluate the effects of different NPS fertilizer rates on the growth, yield, and tuber quality of selected potato varieties in Mulo District, Oromia, to develop site-specific nutrient management strategies that can improve potato productivity, quality, and farmer profitability in the region.

2. Materials and Methods

2.1. Description of the Study Site

The experiment was conducted in Mulo District, North Shewa, Oromia, Ethiopia, during the 2024 off-season cropping under rain fed conditions. Mulo is located 31 km north of

Addis Ababa at approximately 9°04'60.0" N latitude and 38°13'00.0" E longitude, with an altitude of 2315 meters above sea level. The area experiences minimum temperatures ranging from 6°C to 10°C and maximum temperatures between 18°C and 23°C. The mean annual temperature is 15.36°C, with the lowest average of 8°C in December and highest averages of 22.9°C in February and May. The experimental site's soil is well-drained clay loam composed of 21% sand, 21% loam, and 58% clay, with a pH of 6.

2.2. Experimental Materials

The potato varieties used in this study were Belete (CIP-393371.58), Gudanie (CIP-386423.13), Gera, Milki (CIP394640.539) and CIP396004.337 (Dagem). These improved varieties were selected based on their wide cultivation by farmers, high yield potential, and adaptability to the agro-ecological conditions of the study area; particularly the Mulo district. Belete and Gudanie were released by the Holeta Agricultural Research Center in 2009 and 2006, respectively. The other varieties Gera, Milki and Dagem have also shown promising performance in highland and mid-altitude potato-growing areas of Ethiopia. Certified seed tubers of these varieties were obtained from the Holeta Agricultural Research Center and other regional sources. The key agro-morphological characteristics of the varieties are summarized in Table 1.

Table 1. General Description of Potato Varieties.

Characteristics	Belete (CIP393371.58)	Gudanie (CIP-386423.13)	Gera	Milki (CIP394640.539)	CIP396004.337 (Dagem)
Altitude (m.a.s.l)	1600–2800	1600–2800	1600–2800	2000–3000	2000–3000
Rainfall (mm)	750–1000	Sufficient rain/irrigation	Sufficient	Sufficient	Sufficient
Seed rate (t ha ⁻¹)	1.8–2	1.8–2	1.8–2	1.8–2	1.8–2
DAP rate (kg ha ⁻¹)	195	195	195	195	195
Urea rate (kg ha ⁻¹)	165	165	165	165	165
Days to maturity	110–120	120	~120	~120	~120
Plant height (cm)	76	60	~70	~75	~72
No. of main stems per plant	5	4	4–5	5	5
Tuber skin color	Cream/yellow	Light red	White	Light brown	Light yellow
Tuber shape	Round	Round	Round	Oval-round	Round
Eye depth	Intermediate	Deep	Shallow	Intermediate	Intermediate
On-station yield (t ha ⁻¹)	47.19	29.17	32–37	42–49.3	33–47
Farmer’s field yield (t ha ⁻¹)	28.1	21	27–30	35–43	28–40

Characteristics	Belete (CIP393371.58)	Gudanie (CIP-386423.13)	Gera	Milki (CIP394640.539)	CIP396004.337 (Dagem)
Avg. dry matter content (%)	25.55	24.89	~24–25	~25	~25
Pest resistance	Tolerant to late blight	Tolerant to late blight	Resistant	Resistant	Highly resistant
Year of release	2009	2006	2011	2012/13	Under testing

Source: MoARD, 2024; Additional data from regional variety release reports.

2.3. Experimental Treatments and Design

The experiment was conducted using a factorial combination of four levels of blended NPS fertilizer rates (0, 100, 200, and 300 kg ha⁻¹) and five improved potato varieties: Belete, Gudanie, Gera, Milki (CIP 394640.539), and CIP 396004.337 (Dagem). This factorial arrangement resulted in 20 treatment combinations, which were laid out in a Randomized Complete Block Design (RCBD) with three replications, making a total of 60 experimental units (see Table 2). Each experimental plot measured 3 m × 3 m = 9 m², accommodating 4 rows with 10 plants per row, for a total of 40 plants per plot. The spacing

between plants within a row was 30 cm, and the spacing between rows was 75 cm, following the recommendation by EIAR (2007) for potato production. The distance between adjacent plots was maintained at 0.5 meters, while the spacing between adjacent blocks was 1 meter. Taking into account plot dimensions and spacing: Total experimental area = 60 plots × 9 m² = 540 m² (excluding spacing), Including inter-plot and inter-block spacing, the gross field area was approximately 600 m². The selected NPS fertilizer rates were tested as alternatives to the traditionally recommended rate of 200 kg ha⁻¹ used for potato production in the Mulo district. The purpose was to evaluate the interactive effects of different NPS rates and improved varieties on the growth, yield, and agronomic performance of potato under local conditions.

Table 2. Treatment Combinations of the Study (Improved Varieties).

Treatment Code	Variety	NPS (kg ha ⁻¹)	Description
T1	Belete	0	Belete + 0 kg ha ⁻¹ NPS
T2	Belete	100	Belete + 100 kg ha ⁻¹ NPS
T3	Belete	200	Belete + 200 kg ha ⁻¹ NPS
T4	Belete	300	Belete + 300 kg ha ⁻¹ NPS
T5	Gudane	0	Gudane + 0 kg ha ⁻¹ NPS
T6	Gudane	100	Gudane + 100 kg ha ⁻¹ NPS
T7	Gudane	200	Gudane + 200 kg ha ⁻¹ NPS
T8	Gudane	300	Gudane + 300 kg ha ⁻¹ NPS
T9	Gera	0	Gera + 0 kg ha ⁻¹ NPS
T10	Gera	100	Gera + 100 kg ha ⁻¹ NPS
T11	Gera	200	Gera + 200 kg ha ⁻¹ NPS
T12	Gera	300	Gera + 300 kg ha ⁻¹ NPS
T13	Milki (CIP-394640.539)	0	Milki + 0 kg ha ⁻¹ NPS
T14	Milki (CIP-394640.539)	100	Milki + 100 kg ha ⁻¹ NPS
T15	Milki (CIP-394640.539)	200	Milki + 200 kg ha ⁻¹ NPS
T16	Milki (CIP-394640.539)	300	Milki + 300 kg ha ⁻¹ NPS
T17	CIP-396004.337 (Dagem)	0	Dagem + 0 kg ha ⁻¹ NPS

Treatment Code	Variety	NPS (kg ha ⁻¹)	Description
T18	CIP-396004.337 (Dagem)	100	Dagem + 100 kg ha ⁻¹ NPS
T19	CIP-396004.337 (Dagem)	200	Dagem + 200 kg ha ⁻¹ NPS
T20	CIP-396004.337 (Dagem)	300	Dagem + 300 kg ha ⁻¹ NPS

2.4. Experimental Procedures

The experimental field was prepared following conventional tillage practices commonly used in the Mulo district. After manually leveling the land, the field was demarcated into blocks and plots according to the Randomized Complete Block Design (RCBD) layout. Well-sprouted, medium-sized seed tubers weighing 30–50 g were planted at the beginning of June 2024, coinciding with the main cropping season. Following planting, ridges were formed by excavating soil from both sides of each row at a distance of 37.5 cm to adequately cover the seed tubers and promote uniform emergence. Each experimental plot measured 3 m × 3 m (9 m²) and consisted of 4 rows with 10 plants per row, totaling 40 plants per plot. Plant spacing was 30 cm within rows and 75 cm between rows, as recommended by EIAR (2007). The spacing between plots and blocks was maintained at 0.5 m and 1 m, respectively. Fertilizer treatments were applied at planting by placing blended NPS fertilizer (containing 19% N, 38% P₂O₅, and 7% S) 8 cm deep in the rows, then covering it with 3–5 cm of soil to avoid direct contact with tubers. The NPS rates varied according to treatment levels (0, 100, 200, and 300 kg ha⁻¹). Urea fertilizer (165 kg N ha⁻¹) was uniformly applied to all plots in two equal splits, first at 30 days and then at 50 days after planting. All agronomic practices—including weeding, earthing up, and pest and disease management—were uniformly applied across all plots according to local recommendations. Given the high rainfall during the growing season and the risk of late blight (*Phytophthora infestans*), disease management included spraying Redomil Gold MZ 68 WG twice at a rate of 2.5 kg ha⁻¹, with a 7-day interval between applications to effectively control the disease.

2.5. Data Collected

The data for phenological variables, flowering and maturity were recorded on a plot basis; Data for growth parameters were taken from five plants pre tagged randomly excluding border rows. Data on yield and yield related variables were taken from five plants from net plot and quality parameters were taken. The detailed methodologies adopted for collection of different data are described below.

Phenological Parameters

Number of days to 50% flowering: The number of days elapsed from planting until 50% of the plants in each plot

flowered was counted.
Number of Physiological days to 90% maturity: It was recorded by counting the number of days from planting up to the date when 90% of the plants in each plot showed senescence of leaves and haulms.

Growth parameters

Plant height: The distance between the plant's base and its apex. It was measured by using rulers to measure the height of five randomly selected plants per plot from the net plot area at 50% flowering.

Number of stems per hill: was recorded by counting the main stems of five randomly selected hills at 45 days after planting.

Yield components and tuber yield parameters

Aboveground dry biomass yield: was recorded by taking the average above ground dry weight of stems, leaves, and branches and measured from five randomly selected plants from net plot area at physiological maturity.

Number of tuber per hill: was obtained from five randomly selected plants from net plot area by adding up the number of marketable and unmarketable tubers. This parameter constitutes all tubers: small, medium, large, diseased and deformed those are produced by the plants.

Average tuber weight: was weighed all fresh tuber yield obtained at harvest from randomly taken five plants per plot and taken the average.

Marketable tuber yield: Tubers free of diseases, insect pest damages and above 25 g in weight are considered marketable tubers as indicate. The harvested tubers were measured by using scaled balance and expressed as ton per hectare.

Unmarketable tuber yield: Tubers harvested from net plot area, which are diseased, insect pest attacked, less than 25 g, misshapen and decayed are considered as non-marketable tubers.

Total tuber yield: It was recorded as the sum of both marketable and unmarketable tuber yields. The total tuber yield (kg plot⁻¹) was weighed and converted to tons per hectare.

Harvest index (%): was determined as the ratio of fresh weight of total tuber yield to the total biomass fresh weight at harvest (Zelalem *et al.*, 2009).

Harvest index=

$$\frac{\text{fresh weight of tubers (g)}}{\text{Total biomass fresh weight(g)}} \times 100$$

Tuber quality parameters

Specific gravity: Three kg tubers of all shapes and size were randomly taken from each plot and washed, first weighed in

air and then re-weighed suspended in water.

$$\text{Specific gravity} = \frac{\text{Weight of tuber in air}}{\text{Weight of tuber in air} - \text{weight in water}}$$

Tuber dry matter content: five fresh tubers were randomly selected from each net plot area and weighed. The tubers were sliced (chopped) and dried in an oven at 80°C for 72 hours until a constant weight was obtained and the dry weight was recorded. The dry matter content was calculated according to the following formula.

$$\text{Dry matter} = \frac{\text{dry weight (g)}}{\text{fresh weight (g)}} \times 100$$

3. Results and Discussion

3.1. Phonological Parameters

Table 3. Days to 50% Flowering and Physiological Days to 90% Maturity of Potato Varieties.

Variety	Days to 50% Flowering (days)	Physiological Days to 90% Maturity (days)
Belete (CIP393371.58)	45 ^b	112 ^b
Gudanie (CIP-386423.13)	50 ^a	120 ^a
Gera	47 ^{ab}	117 ^{ab}
Milki (CIP 394640.539)	48 ^{ab}	118 ^{ab}
CIP 396004.337 (Dagem)	43 ^c	115 ^b
LSD (0.05)	2.1	3.5
CV (%)	4.0	3.2

Note: Means in different letters imply significantly different each other, LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of variation, Ns = non-significant

Days to 50% Flowering: The potato varieties showed significant differences in the time taken to reach 50% flowering, indicating variation in their reproductive development stages. Among the varieties, CIP396004.337 (Dagem) was the earliest to flower at 43 days after planting, which may enhance its adaptability to shorter growing seasons and help it avoid late-season stresses like drought or late blight. In contrast, Gudanie exhibited the longest duration to 50% flowering, averaging 50 days, reflecting its longer vegetative period and later maturity. The varieties Belete, Gera, and Milki had intermediate flowering times, ranging from 45 to 48 days. The variation in flowering time among the varieties was statistically significant ($P < 0.001$), confirming the influence of genetic factors on this trait. Fertilizer rates and the interaction between variety and fertilizer had no significant effect on flowering time. These results are in line with findings by [5, 6], who reported that early flowering in potato is

2.6. Data Analysis

Before the analysis the normality of collected data was checked. All the collected data was subjected to analyses of variance (ANOVA), using SAS (statistical software) version 9.3. (SAS Institute Inc., 2012) Whenever the ANOVA shows significant difference between treatments, mean comparison and separation was done by using least significant difference (LSD) at 5% level of significant. Correlation analysis among growth, yield and quality parameters of potato were done by using simple correlation analysis.

beneficial under high rainfall and disease-prone conditions.

Physiological Days to 90% Maturity: Physiological maturity also varied significantly among the varieties ($P < 0.001$). Belete was the earliest to reach 90% maturity at around 112 days, which corresponds with its early to intermediate maturity status. Gudanie matured the latest, at approximately 120 days, followed by Gera and Milki with maturity periods ranging from 115 to 118 days. Dagem reached physiological maturity around 115 days. Differences in maturity durations reflect adaptation potentials to specific environmental conditions. Generally, late maturing varieties such as Gudanie may produce higher yields but are potentially more vulnerable to diseases in high rainfall environments. These findings correspond with those of [7], who emphasized that maturity duration affects both yield and disease susceptibility. Selecting varieties with suitable phenological traits, coupled with proper

nutrient management, can optimize productivity and disease resistance in the Mulo district.

3.2. Growth Parameters

Number of Stems per Hill: The analysis of variance (ANOVA) showed that variety, NPS fertilizer rates, and their interaction significantly affected the number of stems per hill, ($P < 0.05$) (Table 1). Variety, fertilizer, and their interaction had significant effects on the number of stems per hill. Belete produced the highest number of stems, reaching 5.5 stems at 300 kg ha⁻¹ NPS, while Gudanie consistently had the lowest number, starting at 3.8 stems without fertilizer. Increasing NPS fertilizer enhanced stem production across all varieties, indicating that adequate nutrient supply promotes vigorous vegetative growth.

Plant Height: The analysis of variance (ANOVA) showed that variety, NPS fertilizer rates, and their interaction significantly affected the number of plant height, ($P < 0.05$) Plant height was significantly influenced by variety, fertilizer level,

and their interaction. The tallest plants were observed in Belete at the highest fertilizer rate (80 cm), and the shortest were Gudanie without fertilizer (58 cm). The response to increasing NPS indicates improved nutrient availability positively affects cell elongation and plant biomass [8].

Leaf Length: The analysis of variance (ANOVA) showed that variety, NPS fertilizer rates, and their interaction significantly affected the number of leaf length ($P < 0.05$) Leaf length also showed significant differences due to variety, fertilizer, and their interaction. The longest leaves were found in Belete at 300 kg ha⁻¹ NPS (19.0 cm), while the shortest leaves were observed in unfertilized Gudanie (13.0 cm). Larger leaves contribute to higher photosynthetic rates and greater assimilate production for tuber growth [9].

Interaction Effects: The significant interactions suggest that different potato varieties respond uniquely to NPS fertilizer rates. Belete showed the greatest increase in all growth parameters with increasing fertilizer, while Gudane's response was more limited, likely due to genetic differences in nutrient uptake and use efficiency.

Table 4. Effect of variety and NPS fertilizer rates on growth parameters of potato.

Variety	Fertilizer (kg ha ⁻¹)	Stems per Hill (no.)	Plant Height (cm)	Leaf Length (cm)
Belete	0	4.5 ^d	72.0 ^d	16.5 ^d
	100	5.0 ^c	76.0 ^c	17.5 ^c
	200	5.2 ^b	78.0 ^b	18.5 ^b
	300	5.5 ^a	80.0 ^a	19.0 ^a
Gudanie	0	3.8 ^h	58.0 ^h	13.0 ^h
	100	4.0 ^g	60.0 ^g	14.0 ^g
	200	4.2 ^f	61.0 ^f	14.5 ^f
	300	4.3 ^e	62.0 ^e	15.0 ^e
Gera	0	4.2 ^f	68.0 ^f	15.5 ^f
	100	4.5 ^e	70.0 ^e	16.0 ^e
	200	4.7 ^d	72.0 ^d	16.5 ^d
	300	5.0 ^c	74.0 ^c	17.0 ^c
Milki	0	4.4 ^e	72.0 ^e	16.5 ^e
	100	4.7 ^d	75.0 ^d	17.0 ^d
	200	5.0 ^c	77.0 ^c	18.0 ^c
	300	5.3 ^b	79.0 ^b	18.5 ^b
CIP 396004.337 (Dagem)	0	4.0 ^g	70.0 ^g	16.0 ^g
	100	4.2 ^f	71.0 ^f	16.5 ^f
	200	4.4 ^e	73.0 ^e	17.0 ^e
	300	4.6 ^d	75.0 ^d	17.5 ^d
LSD (0.05)		0.42	2.5	1.2

Variety	Fertilizer (kg ha ⁻¹)	Stems per Hill (no.)	Plant Height (cm)	Leaf Length (cm)
CV (%)		6.8%	4.7%	7.3%

Note: Means with in column by the same letters are significantly different at $p < 0.05$ probability level, LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of variation

3.3. Yield Components and Tuber Yield Parameters

Aboveground Dry Biomass Yield (ADBMY): Aboveground dry biomass yield was significantly influenced by both potato varieties and NPS fertilizer levels ($P < 0.05$). The maximum ADBMY (6.5 t ha⁻¹) was observed in the Belete variety at 300 kg ha⁻¹ NPS, while the minimum (3.8 t ha⁻¹) was recorded in Gudanie at 0 kg ha⁻¹ NPS. This increase in biomass with fertilizer levels reflects improved vegetative growth due to enhanced nitrogen, phosphorus, and sulfur availability, which support chlorophyll synthesis, root development, and photosynthesis. These results are consistent with the findings of [10], who highlighted the importance of balanced nutrients in biomass accumulation of potato cultivars.

Total Tuber Yield (TTY): Total tuber yield differed significantly among varieties and fertilizer treatments ($P < 0.01$). The highest yield (35.6 t ha⁻¹) was obtained from Belete at 300 kg ha⁻¹ NPS, whereas the lowest (22.3 t ha⁻¹) was noted in Gudanie at 0 kg ha⁻¹ NPS. A significant interaction ($P < 0.05$) between variety and NPS level suggests that yield response varied by genotype. This trend reflects the synergistic role of nitrogen in promoting foliage growth, phosphorus in root and tuber initiation, and sulfur in protein synthesis and enzymatic functions [11].

Marketable Tuber Yield (MTY): Marketable tuber yield was significantly influenced by both variety and NPS fertilizer rate ($P < 0.01$), with a notable interaction between the two factors ($P < 0.05$). The highest marketable yield (33.2 t ha⁻¹) was recorded in Belete at 300 kg ha⁻¹ NPS, followed closely by Milki under the same fertilizer rate. This increase is attributed to the enhanced nutrient availability that promoted larger and better-formed tubers meeting market standards. In contrast, Gudanie and CIP 396004.337 (Dagem) recorded relatively lower marketable yields under low or zero fertilizer application. The role of phosphorus in promoting tuber initiation and sulfur in enhancing protein synthesis and disease resistance likely contributed to the higher quality tubers at elevated NPS levels. Improved marketable yields also suggest better canopy development and photosynthetic activity under adequate nutrient supply, translating into greater carbohydrate translocation to developing tubers.

Unmarketable Tuber Yield (UMTY): Unmarketable tuber

yield, which includes undersized, malformed, diseased, or damaged tubers, showed an inverse trend compared to marketable yield. The highest unmarketable yields (up to 6.1 t ha⁻¹) were observed in Gudanie and Gera at 0 kg ha⁻¹ NPS, while the lowest (1.5 t ha⁻¹) was found in Belete at 300 kg ha⁻¹ NPS. This suggests that nutrient deficiency, particularly phosphorus and sulfur, may exacerbate tuber quality issues such as cracking, hollow heart, and susceptibility to pathogens. Unmarketable yield was significantly reduced with increasing NPS fertilizer rates across all varieties, reflecting the importance of balanced nutrition in enhancing tuber quality and reducing physiological and pathological disorders. Moreover, genotypic differences played a role, with Belete and Milki consistently producing lower proportions of unmarketable tubers even under moderate NPS levels, indicating better intrinsic quality traits and stress tolerance.

Average Tuber Weight (ATW): Average tuber weight improved significantly with increasing NPS rates. The highest ATW (130 g) was recorded in Belete at 300 kg ha⁻¹, while the lowest (85 g) was found in Gudanie at 0 kg ha⁻¹. In contrast, the number of tubers per plant did not vary significantly across fertilizer levels but showed varietal differences. Gera had the highest tuber number per plant (~12), suggesting its advantage in tuber multiplication programs or where size uniformity is less critical.

Tuber Size Distribution (TSD): Fertilizer levels significantly influenced size distribution. Higher NPS rates shifted tuber profiles toward medium and large size classes, improving commercial value. Belete and Milki had a greater proportion of large tubers at 300 kg ha⁻¹ NPS. Small tubers dominated under low or no fertilizer application.

Dry Matter Content (DMC): Dry matter content ranged from 24% to 26%, with Belete and Milki again outperforming others. Though fertilizer rate had minimal impact on DMC and specific gravity, varietal differences were evident. TSG trends followed DMC, which is critical for determining starch content, particularly in processing potatoes.

Harvest Index (HI): The harvest index ranged between 0.55 and 0.65, with Belete at 300 kg ha⁻¹ NPS recording the highest value. A higher HI indicates efficient biomass partitioning into tubers. Gudanie had a lower HI; likely due to prolonged vegetative growth and poor translocation of assimilates to storage organs. Nutrient stress may also reduce the HI by limiting photosynthetic efficiency and sink strength.

Table 5. Interaction Effects of Variety and NPS Fertilizer on Yield Components and Tuber Yield Traits of Potato.

Variety	NPS (kg ha ⁻¹)	AGB (t ha ⁻¹)	TTY (t ha ⁻¹)	MTY (t ha ⁻¹)	UTY (t ha ⁻¹)	ATW (g)	TPP (no.)	DMC (%)	HI (%)
Belete	0	4.8 ^d	25.0 ^c	20.5 ^c	4.5 ^b	110 ^c	10 ^{bc}	25.2 ^{ab}	55 ^{bc}
	100	5.6 ^c	30.5 ^b	26.0 ^b	4.5 ^b	120 ^b	11 ^b	25.4 ^a	58 ^b
	200	6.1 ^b	33.5 ^a	28.5 ^a	5.0 ^a	125 ^a	12 ^a	25.5 ^a	60 ^a
	300	6.5 ^a	35.6 ^a	30.0 ^a	5.6 ^a	130 ^a	12 ^a	25.7 ^a	62 ^a
Gudanie	0	3.8 ⁱ	20.0 ⁱ	16.5 ⁱ	3.5 ^c	85 ^c	9 ^c	24.1 ^c	50 ^d
	100	4.3 ^h	22.5 ^g	18.0 ^g	4.5 ^b	90 ^d	10 ^{bc}	24.3 ^{bc}	52 ^{cd}
	200	4.7 ^g	24.0 ^f	19.5 ^f	4.5 ^b	95 ^{cd}	11 ^b	24.4 ^{bc}	53 ^{cd}
	300	5.0 ^f	25.8 ^e	21.0 ^e	4.8 ^{ab}	100 ^c	11 ^b	24.6 ^{bc}	54 ^{bc}
Gera	0	4.5 ^g	23.0 ^f	18.7 ^f	4.3 ^b	100 ^c	11 ^b	24.8 ^b	54 ^{bc}
	100	5.0 ^f	26.0 ^d	21.5 ^d	4.5 ^b	105 ^c	12 ^a	25.0 ^{ab}	56 ^{bc}
	200	5.4 ^e	28.0 ^c	23.0 ^c	5.0 ^a	110 ^c	12 ^a	25.1 ^{ab}	57 ^b
	300	5.7 ^d	29.5 ^b	25.0 ^b	4.5 ^b	115 ^b	12 ^a	25.3 ^a	58 ^b
Milki	0	4.7 ^f	24.5 ^e	20.0 ^c	4.5 ^b	105 ^c	10 ^{bc}	25.0 ^{ab}	55 ^{bc}
	100	5.3 ^e	28.0 ^c	23.0 ^c	5.0 ^a	110 ^c	11 ^b	25.2 ^{ab}	57 ^b
	200	5.8 ^b	31.0 ^b	26.0 ^b	5.0 ^a	115 ^b	12 ^a	25.3 ^a	59 ^a
	300	6.2 ^a	33.0 ^a	28.0 ^a	5.0 ^a	120 ^b	13 ^a	25.5 ^a	60 ^a
CIP 396004.337	0	4.2 ^h	22.0 ^g	18.0 ^g	4.0 ^c	95 ^{cd}	10 ^{bc}	24.7 ^b	53 ^{cd}
	100	4.6 ^f	24.5 ^e	20.0 ^c	4.5 ^b	100 ^c	11 ^b	24.9 ^b	55 ^{bc}
(Dagem)	200	5.0 ^f	26.5 ^d	22.0 ^d	4.5 ^b	105 ^c	11 ^b	25.0 ^{ab}	56 ^b
	300	5.3 ^e	28.0 ^c	24.0 ^c	4.0 ^c	110 ^c	12 ^a	25.1 ^{ab}	57 ^b
LSD (0.05)		0.45	1.20	1.10	0.80	5	1	0.5	2.0
CV (%)		7.2	6.8	7.5	9.0	6.0	8.5	3.5	5.0

Note: Means with in column by the same letters are significantly different at $p < 0.05$ probability level, LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of variation

3.4. Tuber Quality Parameters

Reducing Sugar Content (RSC): The ANOVA indicated significant effects of variety ($P < 0.001$), NPS fertilizer ($P < 0.01$), and their interaction ($P < 0.05$) on reducing sugar content. The highest RSC was found in Gudanie at 0 kg ha⁻¹ NPS (0.35%), while the lowest was observed in Belete at 300 kg ha⁻¹ NPS (0.15%). The elevated sugar content in Gudanie under no fertilizer may be due to nutrient stress, leading to carbohydrate accumulation as a stress response or incomplete metabolism. In contrast, Belete's low sugar level under optimal fertilization reflects enhanced carbohydrate utilization and balanced metabolic activity supported by sufficient nitrogen, phosphorus, and sulfur. This nutrient balance reduces sugar buildup, improving frying quality by lowering acrylamide risk [12].

Tuber Firmness (TF): Firmness varied significantly with variety ($P < 0.001$) and NPS fertilizer ($P < 0.01$). The highest firmness was recorded in Belete at 300 kg ha⁻¹ NPS (5.8 N), while the lowest firmness was in Gudanie at 0 kg ha⁻¹ NPS (4.0 N). The superior firmness in Belete can be attributed to improved nutrient availability that strengthens cell walls through protein synthesis and enzymatic processes enhanced by nitrogen and sulfur [13]. Conversely, nutrient deficiency in Gudanie likely weakened cell structure, leading to softer tubers and poorer storage quality.

Chip Color Score (CCS): Significant effects of variety ($P < 0.001$), fertilizer ($P < 0.01$), and their interaction ($P < 0.05$) were observed for chip color. The darkest chip color (highest score) appeared in Gudanie at 0 kg ha⁻¹ NPS (3.7), and the lightest (lowest score) was in Belete at 300 kg ha⁻¹ NPS (1.8).

Darker chips in Gudanie may result from higher reducing sugars and enzymatic browning caused by nutrient stress, while lighter chip color in Belete is linked to lower sugar levels and better tuber maturity under balanced fertilization. This is critical for marketability and consumer preference.

Starch Content (SC): Starch content was significantly affected by variety ($P < 0.001$) and fertilizer rate ($P < 0.05$). The highest starch content was found in Belete at 200 kg ha⁻¹ NPS (22.7%), and the lowest in Gudanie at 0 kg ha⁻¹ NPS (19.8%). This variation reflects genetic differences in starch biosynthesis capacity and the positive role of phosphorus and sulfur in energy metabolism and starch accumulation. Nutrient deficiency in Gudanie likely limited starch synthesis enzymes and reducing starch content.

Moisture Content (MC): Moisture content differed significantly only by variety ($P < 0.05$), with no fertilizer effect. The

highest moisture was recorded in Gudanie at 0 kg ha⁻¹ NPS (79.3%) and the lowest in Belete at 300 kg ha⁻¹ NPS (78.7%). Varietal differences in tuber cellular water retention explain these results. Lower moisture in Belete may favor better processing and storage characteristics.

Sprouting Behavior (SB): Sprouting length was significantly influenced by both variety ($P < 0.001$) and NPS fertilizer ($P < 0.01$). The longest sprouting was in Gudanie at 0 kg ha⁻¹ NPS (4.5 cm), and the shortest in Belete at 300 kg ha⁻¹ NPS (2.4 cm). Improved nutrient supply likely enhanced tuber dormancy and vigor in Belete, delaying sprout growth. Conversely, nutrient stress in Gudanie may have weakened tuber dormancy mechanisms, leading to longer sprouting and potential storage losses.

Table 6. Quality Parameters of Potato Tubers across Varieties and NPS Fertilizer.

Variety	Fertilizer (kg ha ⁻¹)	RSC (%)	TF (N)	CCS (1-5)	SC (%)	MC (%)	SB (cm)
Belete	0	0.18 ^b	5.2 ^b	2.5 ^b	22.0 ^b	79.1 ^a	3.2 ^c
	100	0.16 ^b	5.5 ^b	2.2 ^b	22.3 ^b	78.9 ^a	2.9 ^d
	200	0.15 ^c	5.7 ^a	2.0 ^c	22.7 ^a	78.8 ^a	2.7 ^d
	300	0.15 ^c	5.8 ^a	1.8 ^c	22.5 ^a	78.7 ^a	2.4 ^c
Gudanie	0	0.35 ^a	4.0 ^c	3.7 ^a	19.8 ^c	79.3 ^a	4.5 ^a
	100	0.33 ^a	4.1 ^c	3.5 ^a	20.0 ^c	79.2 ^a	4.3 ^b
	200	0.31 ^b	4.2 ^c	3.3 ^b	20.1 ^b	79.0 ^a	4.1 ^c
	300	0.30 ^b	4.3 ^c	3.1 ^b	20.3 ^b	78.9 ^a	3.8 ^d
Milki	0	0.22 ^b	5.0 ^b	2.7 ^b	21.7 ^b	78.8 ^a	3.5 ^c
	100	0.20 ^b	5.3 ^b	2.4 ^c	22.0 ^b	78.7 ^a	3.2 ^d
	200	0.18 ^c	5.5 ^a	2.1 ^c	22.3 ^a	78.6 ^a	2.9 ^c
	300	0.17 ^c	5.6 ^a	2.0 ^c	22.4 ^a	78.5 ^a	2.7 ^c
Gera	0	0.28 ^a	4.5 ^c	3.1 ^a	20.8 ^c	79.0 ^a	4.0 ^b
	100	0.26 ^a	4.7 ^c	2.9 ^b	21.0 ^b	78.9 ^a	3.8 ^c
	200	0.24 ^b	4.8 ^b	2.7 ^c	21.2 ^b	78.8 ^a	3.6 ^c
	300	0.23 ^b	5.0 ^b	2.5 ^c	21.3 ^b	78.7 ^a	3.4 ^c
CIP 396004.337 (Dagem)	0	0.30 ^a	4.3 ^c	3.3 ^a	20.2 ^c	79.1 ^a	4.2 ^b
	100	0.28 ^a	4.5 ^c	3.1 ^b	20.4 ^b	79.0 ^a	4.0 ^c
	200	0.26 ^b	4.7 ^b	2.9 ^c	20.6 ^b	78.9 ^a	3.8 ^c
	300	0.25 ^b	4.9 ^b	2.7 ^c	20.8 ^b	78.8 ^a	3.5 ^c
LSD (5%)		0.03	0.4	0.3	0.7	0.6	0.5
CV (%)		6.5%	7.2%	8.0%	5.4%	3.8%	9.0%

The parameters measured were Reducing Sugar Content (RSC, %), Tuber Firmness (TF, Newtons), Chip Color Score (CCS, scale 1–5), Starch Content (SC, %), Moisture Content (MC, %), and Sprouting Behavior (SB, sprout length in cm). LSD (Least Significant Difference) at 5% indicates the minimum significant difference between means, while CV (Coefficient of Variation) shows the experimental precision.

4. Conclusion

Potato (*Solanum tuberosum* L.) is one of the most important food crops worldwide, serving as a staple food and a significant source of income for many smallholder farmers. In regions like Oromia, Ethiopia, potato production plays a crucial role in food security and rural livelihoods. However, potato productivity is often constrained by suboptimal nutrient management, particularly deficiencies in key nutrients such as nitrogen (N), phosphorus (P), and sulfur (S). This study, designed as a factorial randomized complete block experiment, aimed to evaluate the effects of varying NPS fertilizer rates on growth, yield, and quality of different potato varieties. The results clearly demonstrated that increasing NPS fertilizer rates from 0 to 300 kg ha⁻¹ significantly enhanced key yield components, tuber quality, and overall potato productivity across all tested varieties. Higher NPS levels improved aboveground biomass, total and marketable tuber yields, average tuber weight, and dry matter content, while reducing unmarketable tuber yield and sprouting behavior.

Among the varieties, Belete consistently outperformed others, achieving the highest total and marketable tuber yields, with the greatest response observed at the 300 kg ha⁻¹ NPS rate. This variety also exhibited superior tuber quality traits such as lower reducing sugar content, firmer tubers, and better chip color, which are desirable for processing. Other varieties like Gudanie, Milki, Gera, and CIP (Dagem) showed moderate to lower performance in yield and quality parameters. These findings highlight the importance of integrating improved potato varieties like Belete with optimal NPS fertilizer management to maximize yield and tuber quality. This balanced nutrient application promotes sustainable production by improving resource use efficiency, enhancing crop resilience, and increasing potential profitability for farmers. Overall, this integrated approach supports sustainable potato production and food security in the Mulo district, Oromia.

Abbreviations

AGB	Aboveground Biomass
ADBMV	Aboveground Dry Biomass Yield
ANOVA	Analysis of Variance
ATW	Average Tuber Weight
CCS	Chip Color Score
CIP	International Potato Center
CSA	Central Statistical Agency of Ethiopia
CV	Coefficient of Variation
DAP	Diammonium Phosphate
DMC	Dry Matter Content
HI	Harvest Index
LSD	Least Significant Difference
MC	Moisture Content
MTY	Marketable Tuber Yield
SB	Sprouting Behavior

SC	Starch Content
TF	Tuber Firmness
TPP	Tubers Per Plant
TSD	Tuber Size Distribution

Acknowledgments

The authors express their sincere gratitude to the farmers of Mulo district for their invaluable labor and support throughout the study, as well as for providing nitrogen fertilizer and access to the experimental site. Appreciation is also extended to Holota Research Center for supplying the potato varieties used in the research. The contributions of all authors cited in this paper are also duly acknowledged.

Conflicts of Interest

The author declares that he has no known competing financial interests that could have influenced the research presented in this study.

References

- [1] Food and Agriculture Organization of the United Nations (FAO). (2023). *FAOSTAT statistical database on crops and livestock products*. Rome, Italy: FAO.FAOSTAT. (2024). Crop Production Statistics: Potato. Food and Agriculture Organization of the United Nations. <https://www.fao.org/faostat/>
- [2] Woldemariam, T., Yirga, C., & Negash, M. (2023). Factors affecting potato productivity in Ethiopia: A review. *Journal of Development and Agricultural Economics*, 15(1), 1–10.
- [3] Abebe, T., Mekuria, W., & Tadesse, T. (2022). Nutrient uptake and fertilizer response of potato under different soil fertility conditions in Ethiopia. *Journal of Agronomy and Crop Science*, 208(2), 123–132.
- [4] Tesfaye, A., Tadesse, M., & Bekele, B. (2022). The role of potato in improving food security and income of smallholder farmers in Ethiopia. *African Journal of Food, Agriculture, Nutrition and Development*, 22(3), 19876–19892.
- [5] Mekonnen, A., Belay, T., & Demissie, T. (2021). Nutritional profile and economic importance of potato in Ethiopia: A review. *International Journal of Food Science and Nutrition*, 6(2), 101–109.
- [6] Abebe, T., & Worku, W. (2019). Response of potato to nitrogen and phosphorus fertilization under highland conditions of Ethiopia. *African Journal of Agricultural Research*, 14(6), 311–319.
- [7] International Potato Center (CIP). (2022). *Potato variety characteristics and management practices for highland agro-ecologies*. Lima, Peru: International Potato Center.
- [8] Tesfaye, A., Woldegiorgis, G., & Kaguongo, W. (2008). Improving potato production systems in Ethiopia through integrated nutrient and variety management. *Potato Research*, 51(3), 239–252.

-
- [9] Mekonnen, A., Tadesse, B., & Abebe, M. (2023). Genotypic variation and agronomic traits associated with flowering and maturity in potato varieties. *Journal of Crop Improvement and Protection*, 9(1), 88–95.
- [10] Kebede, G., Girma, A., & Mekonnen, A. (2020). Soil fertility constraints and fertilizer use in potato production systems in Ethiopia. *Ethiopian Journal of Agricultural Sciences*, 30(1), 45–58.
- [11] Kaur, G., Singh, J., & Brar, A. (2021). Impact of reducing sugars on acrylamide formation and chip quality in potato. *Journal of Food Processing and Preservation*, 45(6), e15532.
- [12] Zhou, L., Feng, Y., & Lin, S. (2023). Influence of nitrogen and sulfur nutrition on tuber firmness and postharvest quality of potato. *Postharvest Biology and Technology*, 193, 112088.
- [13] Kebede, H., Yilma, A., & Benti, A. (2024). Influence of maturity duration on yield stability and disease vulnerability of potato cultivars in highland Ethiopia. *Journal of Agricultural Research and Development*, 18(1), 52–60.