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Research Article

Growth, yield, and quality of selected watermelon (*Citrullus lanatus* L.) varieties as influenced by NPS+UREA fertilizer rates over the seasons at Arba Minch, Gamo Zone, Southern Ethiopia

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Abstract

Watermelon (*Citrullus lanatus*) has been produced in Ethiopia in small land coverage for economic value. The production of watermelon is hindered by diminished quality and yield, primarily due to insufficient agronomic practices, the unavailability of suitable varieties, and inadequate fertilization. The research was conducted at the Research Farm of Arba Minch University, Ethiopia, in the 2023 Belg and Meher seasons to evaluate the effect of watermelon varieties and NPS+UREA fertilizer rates on the watermelon growth, yield, and quality over seasons. The experiment was structured using a randomized complete block design in a factorial configuration with three replications, and the treatments consisted of a combination of three varieties, Polymer, Lahat, and Liyu, with four fertilizer rates: control, 0.05 t/ha, 0.1 t/ha, and 0.15 t/ha NPS+UREA. Growth, yield, quality, and meteorology data were collected, and R software version 4.4.1 was used perform a two-way ANOVA. Results indicated that more leaves, the longest and widest leaf, the longest vine length, and more secondary vines were recorded by the combination effect of the Liyu variety with 0.15 t/ha NPS+UREA at 30 DAS, 45 DAS, and 60 DAS at the Belg and Meher seasons, respectively. In addition to a higher fruit number of 8.3 and the highest fruit length of 28.6 cm. Whereas, the highest fruit width (23.1 cm), highest fruit weight (3 kg), and highest marketable yield (30.4 t/ha) were recorded with the effect of the Liyu variety in the Meher season. Moreover, a total soluble sugar of 8.5° Brix and Vitamin C of 8.5 mg/100 g were recorded with the interaction of the Liyu variety with the 0.15 t/ha NPS+UREA fertilizer rate at Meher and Belg, respectively. Therefore, it was concluded that 0.15 t/ha NPS+UREA/ha and the Liyu variety in the Meher rainy season revealed the highest growth, yield, and good fruit quality. This combination showed better performance than other varieties and NPS+UREA fertilizer rates.

Keywords: Growth, NPS+UREA, Quality, Season, Variety, Watermelon, Yield

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1. Introduction

Watermelon (*Citrullus lanatus*) is a fruit vegetable that belong to the family Cucurbitaceae (Kyriacou, 2018). The crop was first domesticated in Africa before spreading to Asia around 800

AD, reaching Europe by 961 AD, and later being introduced to the Americas by European settlers during the 17th century (Adeoye et al., 2011).

The exact time when watermelon was introduced to Ethiopia is not known; however, farmers in East Shoa (near Koka Lake) state that the crop was introduced by Italians in the 1950's (Amenti et al., 2014). Its main production is currently limited to lakeshore areas of the East Shoa Zone, with little expansion to other parts of the country (Fanos, 2015).

Currently, Asia produces over 80% of the world's watermelon supply, with China alone contributing about 67.6% of global output. Africa, Europe, and North America each produce between three and four million tons per year. In 2008, watermelon in Africa represented 5.4% of the total harvested vegetable area and accounted for 4.6% of global watermelon production, amounting to 99,194,223 tons (Gichimu et al., 2008). At present, Africa ranks as the third largest watermelon-producing region globally. In Ethiopia, farmers achieve yields up to 40 t ha^{-1} and earn gross returns of less than half a million ETB per hectare (Tegen et al., 2024).

Watermelon fruit has a thick rind (exocarp) that has variable pigmentation with a solid appearance, a fleshy mesocarp, and an endo carp that varies in color from white to yellow or red (Bahari et al., 2012; Munisse et al., 2013). Its flesh and rinds are a source of antioxidants like carotenoids and vitamins and contain many nutrients (Jensen et al., 2011). Watermelon consumption has increased due to its nutritional profile and allied health benefits, which are effective in reducing cancer, cardiovascular disorders, diabetes, blood pressure, and obesity (Edwards et al., 2003; Lum et al., 2019; Naz et al., 2014). According to a quantitative analysis, watermelon offers 46% calories, 20% vitamin C, 17% vitamin A, and more lycopene than tomatoes (Biswas et al., 2017).

Watermelons are typically grown on light-textured soils such as sandy loam, which warm up and are therefore favored for early production. Its production is optimal when soil pH is maintained within the slightly acidic range of approximately 5.8 to 6.6, in addition to the average temperatures between 18°C and 35°C, as temperatures outside this range can inhibit growth and maturation. Watermelon production in the study area has expanded in response to growing market demand and increasing economic returns. To sustain this growth, it is important to monitor the crop's nutritional condition during development, particularly with respect to macronutrient availability. Adequate levels of essential nutrients are known to enhance fruit appearance, nutritional composition, and flavor characteristics (Jifon et al., 2009; Bassiony et al., 2012).

Watermelon production in Ethiopia has not improved as expected, despite rising market demand. Major challenges include relatively low fruit quality and modest yields. Ethiopian watermelon quality remains below the world average, as noted by Zhang et al. (2011). In addition, soil assessments in the study area indicate deficiencies in key nutrients, including nitrogen, phosphorus, sulfur, and exchangeable potassium, along with micronutrients such as iron, zinc, and boron (EthioSIS, 2014). Technological advancement in watermelon production—such as the adoption of improved hybrids and fertilizer packages—is also limited in Africa compared with other crops (Dube et al., 2020). Therefore, this research evaluated how three watermelon varieties respond to different rates of NPS + UREA fertilizer across seasons, focusing on growth, yield, and fruit quality.

2. Materials and Methods

2.1. Description of the study area

The investigation was conducted at the Research Farm of Arba Minch University, Ethiopia, in the 2023 Belg (March to May) and Meher (August to October) cropping seasons. The research site is at latitude 6°03'32"N and longitude 37°33'79"E at 1200 m above sea level. The annual rainfall ranges from 925 mm to 1100 mm, and the temperature ranges from 19°C in August (minimum) to 27°C in February (maximum). Relative humidity was in the range of 60% to 75%.

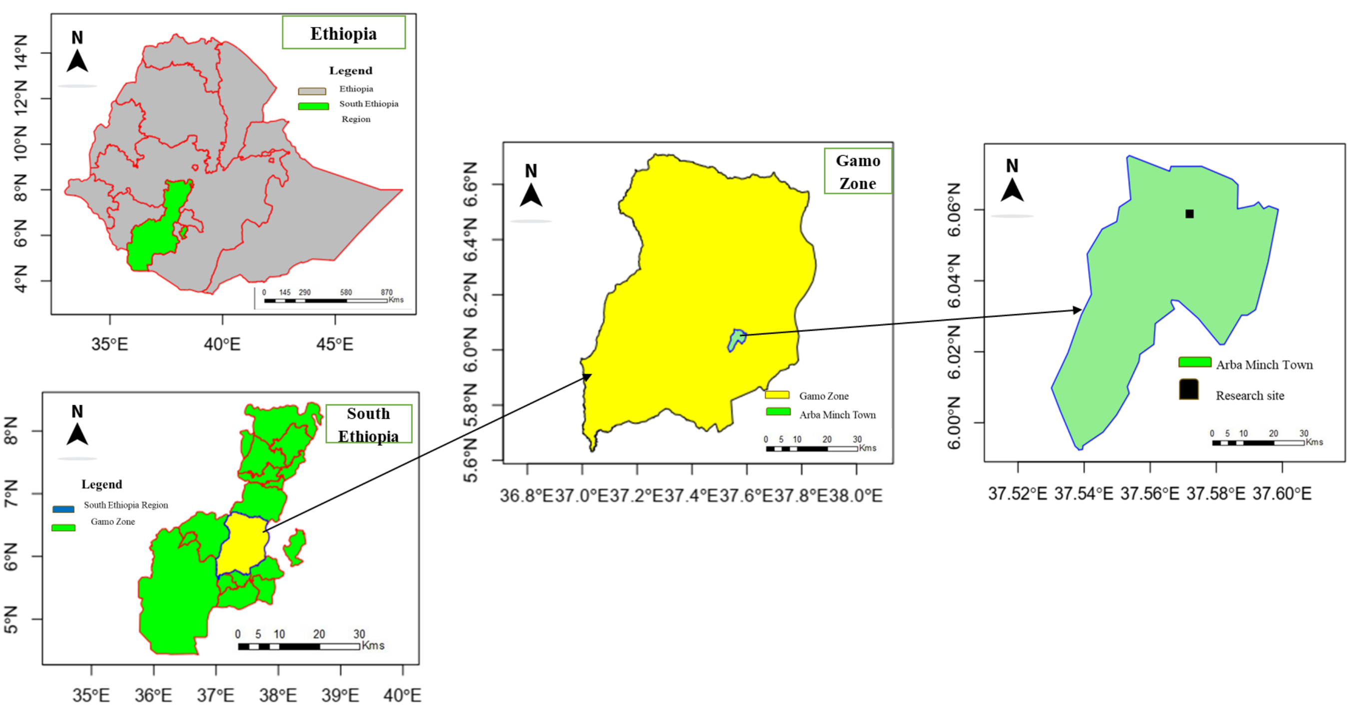

Figure 1. Map of the study area

2.2. Experimental materials

The experiment used three F1 varieties and NPS+UREA fertilizer. The varieties Polimor and Lahat were supplied by the AZERA private company, and Liyu F1 was from Joy Tech Plc. Among the F1 varieties, Liyu has been cultivating them around the study area by private farms.

2.3. Experimental design and treatments

The experiment was structured using a randomized complete block design in a factorial configuration with three replications. The randomization of treatments was done with the help of a random number table (Fisher, 1950).

Twelve experimental treatments were designed with a combination of three hybrid watermelon varieties with four NPS+UREA fertilizer rates. The treatments consisted of Polimor (0kg NPS+UREA), Lahat (0kg NPS+UREA), Liyu (0kg NPS+UREA), Polimor (50kg NPS+UREA), Lahat (50kg NPS+UREA), Liyu (50kg NPS+UREA), Polimor (100kg NPS+UREA), Lahat (100kg NPS+UREA), Liyu (100kg NPS+UREA), Polimor (150kg NPS+UREA), Lahat (150kg NPS+UREA), and Liyu (150kg NPS+UREA). The plot area was 12.25 m^2 (length 3.5 m x width 3.5 m) with a 1.5 m margin round, and the total study area was 1,344.75 m^2. Each plot contained 16 plants with a spacing of 1 m between rows and 1 m from each plant (James et al., 2009). The fertilizer resources were urea (46% N) and NPS (19% N, 46% P_2O_5, and 7% SO_2).

2.4. Data collection and analysis

2.4.1. Soil sampling and analysis

Topsoil samples were collected using the zigzag method from 0-30 cm depth, and a composite sample was collected for physicochemical characterization before planting. Soil texture with the soil textural triangle method (Bouyoucos, 1962), soil pH with a pH meter (Thomas, 1982), organic carbon using the oxidation method (Olsen and Sommers, 1982), total nitrogen using the Kjeldahl method (Bremner, 1982), available phosphorus using the Bray No. 1 method (Kuo, 1996), exchangeable K was analyzed with the method of flame photometry (Kacar & Inal, 2008), and CEC using the atomic absorption method (Harada & Inoko, 1990).

Soil pH 6.0 to 7.5 is acceptable for most plants. Before ploughing, physio-chemical soil results of the experimental site indicated that the soil had a clay loam texture with a slightly alkaline pH and optimum cation exchange capacity (Table 1). However, at this pH level, total nitrogen, available phosphorus, and exchangeable potassium were medium. It might be indicated that the soil had insufficient nutrients for watermelon production, which grows best at a pH range between 5.0 and 6.5.

Table 1. Soil physicochemical analysis

Soil properties	Values	Status	Source
Physical properties			
Sand (%)	25	-	
Silt (%)	35	-	EthioSIS, 2014
Clay (%)	40	-	
textural class	Clay loam		
Chemical properties			
pH (H_2O 1:2.5)	7.96	Moderately alkaline	EthioSIS, 2014
Organic carbon (%)	2.50	Medium	EthioSIS, 2014
Available P (mg kg^{-1})	21.40	Medium	EthioSIS, 2014
Total nitrogen (%)	0.19	Medium	EthioSIS, 2014
Ex. K (mg kg^{-1})	138.00	Medium	EthioSIS, 2014
CEC (Cmol $_{(+)}$ kg^{-})	20.15	Optimum	Landon (1984)

P=Phosphorus, CEC=Cation exchange capacity, Ex. K=Exchangeable potassium

2.4.2. Growth, yield, and fruit quality data

Data on the number of leaves, vine length, and number of secondary vines was recorded from six randomly selected plants per plot at the 30th, 45th, and 60th days after sowing (DAS). In addition to leaf length and leaf width from the shoot tip.

Fruit numbers and fruit weights were used to quantify the yield of the crop. The first harvest was done 75-90 days from emerging depending on cultivars. The number of fruits was counted when they reached physiological maturity. From each plot four fruits were collected, and fruit length was measured using measuring tape; fruit width and fruit weight were measured using a caliper and electronic weighing scale (Model: Tanita KD 200-510, 5000g x 5g), respectively. Marketable fruits per plant were recorded based on fruits that were well developed, tender, edible, free from diseases, insect pests, and physical defects, and had a minimum weight of 1.7 kg (Awere, S. U., & Onyeacholem, 2014).

Three fruits were included from each replicate to measure fruit length, fruit width, and fruit rind thickness, and fruit and rind firmness were measured using a tape meter, veneer caliper, and penetrometer, respectively. Total soluble solids (^{0} Brix) were determined according to the standard method of A.O.A.C. (2000), and pH and total acidity were determined by pH meter. Vitamin C content (mg/100g) was measured according to the method of Hashimoto & Yamafuji (2001).

The research was conducting during the Belg and Meher seasons in the Ethiopian crop-growing context. So, in both seasons, the weather climate data, such as minimum and maximum temperature in ^{0}C, relative humidity in %, and rainfall in mm, was collected from the Arba Minch University meteorological data center in monthly intervals.

Climate data are presented (Table 2). The data in 2013 indicated that the average monthly rainfall and relative humidity were higher in the Meher season (3.11 mm and 71.04%) than in the Belg season (1.84 mm, and 63.3%). Whereas, temperature (min.) was below optimum, and the max. was at optimum level for watermelon growth in both seasons. The climate data for the two seasons clearly indicated that the lowest monthly average rainfall, maximum temperature, and optimum relative humidity were experienced during the cultivating seasons. This result was supported by Hamad et al. (2023); climatic parameters exert a significant influence on watermelon production, as they can either enhance yield performance or contribute to yield reduction.

Table 2. Climate data of the experimental site (AMU Meteorological Data Center), 2023

Season	Months	Rainfall (mm)	Temperature (℃)		Relative humidity (%)
			Minimum	Maximum	
Belg	January	0.03	15.82	31.88	47.81
	February	0.16	16.49	33.35	41.59
	March	2.97	19.13	30.74	66.53
	April	0.23	18.99	30.75	71.41
	May	5.00	18.60	28.78	77.91
	June	2.67	19.15	28.97	74.83
	Average	**1.84**	**18.00**	**30.00**	**63.34**
Meher	July	0.01	19.37	28.57	65.48
	August	0.96	18.80	29.95	62.21
	September	2.01	19.27	30.01	70.83
	November	7.85	18.88	30.92	75.01
	October	6.46	17.65	29.23	79.33
	December	1.34	16.81	30.30	73.37
	Average	**3.11**	**18.50**	**29.80**	**71.04**

2.5. Statistical analysis

Data was subjected to two-way analysis of variance using R software version 4.4.1. When significant interaction and main effects were detected, means were compared using the DMRT test at the 0.05 significance level. Correlation was carried out to test the association between marketable yield along with growth and yield parameters.

3. Results and Discussions

3.1. The interaction effect of variety and NPS+UREA fertilizer rate on growth over the season

The combined ANOVA showed that the interaction effect of variety and NPS+UREA significantly ($P \leq 0.05$) influenced leaf length and leaf width at the Belg season and the number of secondary vines at the Meher season at 30 DAS, 45 DAS, and 60 DAS, respectively (Figures 2 and 3). The maximum leaf length (20.7cm & 20.7cm) at Belg and (41.2cm) at Meher, leaf width (18.7cm & 18.7cm) at Belg and (41.3cm) at Meher, and number of secondary vines (5.3, 7, and 12) at Meher were recorded from the Liyu variety with 0.15 t/ha NPS+UREA fertilizer at 30 DAS, 45 DAS, and 60 DAS, respectively.

Improved watermelon varieties that respond to nutrients in mineral fertilizer may increase the watermelon growth performance. The experiment demonstrated that the Liyu variety exhibited a considerable increase in both leaf length and width with the augmented application of mineral fertilizer. The experiment also demonstrated that variety and mineral fertilizer did not interact to generate a substantial effect on leaf number and vine length. The finding is supported by different findings. The number of leaves (30 DAS: 30.7; 45 DAS: 93.3; 60 DAS: 109.7) obtained in the plot treated with NPK (0.11 t/ha) were not significantly different from each other but were significantly higher than the control and other treatments (Aitbayeva et al., 2021).

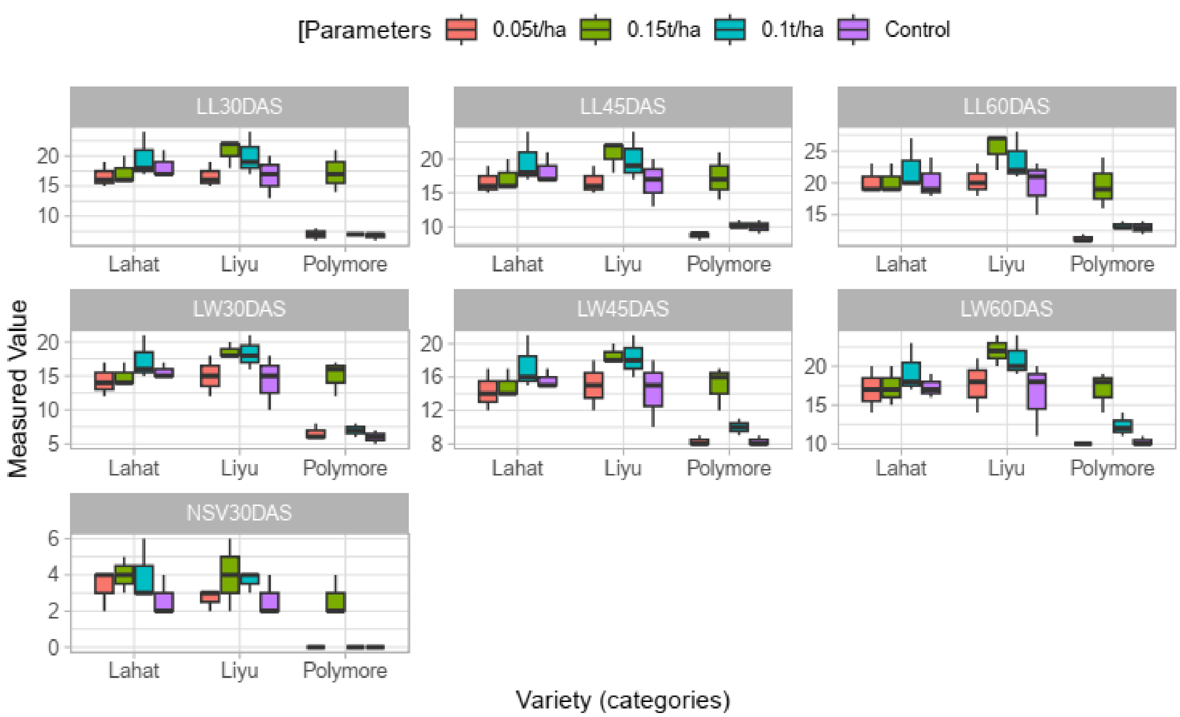

Figure 2. The interaction effect of variety and NPS+UREA on growth during the Belg season

The recommended inorganic fertilizer dose (0.2 t/ha) has shown a great influence on main shoot length (2.13 cm), stem numbers (5.28), leaf width (8.30 cm), and leaf length (9.76 cm) (Aitbayeva et al., 2021). NPK fertilizer at 120 kg/ha produced the highest number of vines (74.82), while the shortest vine was recorded at the control (64.33) (Oga, I. O., & Umekwe, 2015), and the longest vine length (Silifatu & Igyuve, 2023). A significant increase in the number of leaves and branches was recorded with an increase in mineral fertilizer (Wailare et al., 2013).

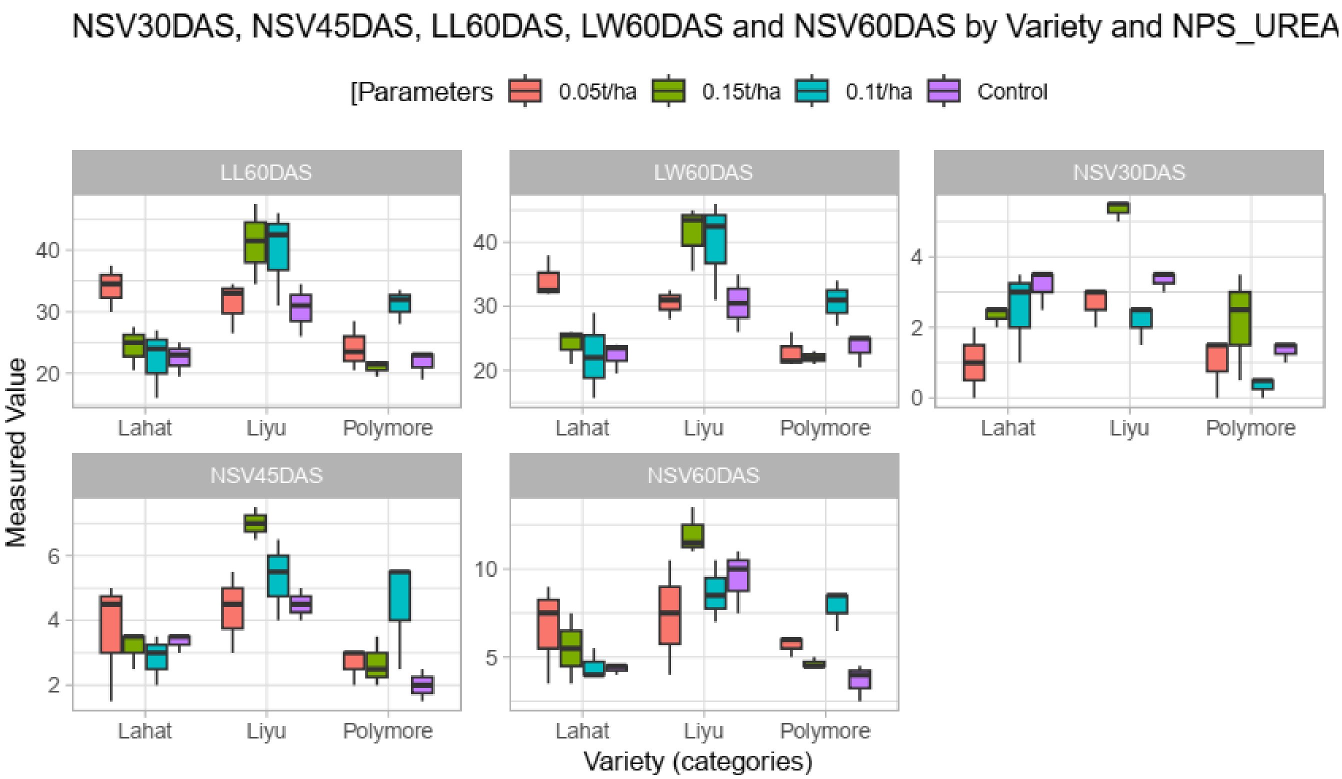

Figure 2. The interaction effect of variety and NPS+UREA on watermelon growth during the Meher season.

3.2. Effect of variety on leaf number and vine length over season

The ANOVA result showed that the Liyu variety significantly ($P \leq 0.05$) influenced leaf number and vine length at 30 DAS, 45 DAS, and 60 DAS at the Belg and Meher seasons (Table 3). The maximum leaf number (22, 26, and 40.1) and vine length (127 cm, 159 cm, and 194 cm) were recorded at 30 DAS, 45 DAS, and 60 DAS of Belg and Meher, respectively. From the result, improved watermelon cultivars do differ genetically for traits like leaf number and vine length. According to Silifatu & Igyuve (2023), watermelon genotypes differ significantly in characteristics, like vine length and leaf count, and these variables have high heritability, and genetic advancement.

Table 2. Effect of variety on growth parameters over season

Variety	Belg			Meher			Meher		
	LN 30 DAS	LN 45 DAS	LN 60 DAS	LN 30 DAS	LN 45 DAS	LN 60 DAS	VL 30 DAS	VL 45 DAS	VL 60 DAS
Polymer	9.6	12.7	16.6	11.1	17.1	26.9	68.9	105.7	145.6
Lahat	22.0	22.0	25.5	12.8	18.3	28.0	90.0	127.5	162.9
Liyu	21.3	21.3	26.6	17.2	26.0	40.1	127.7	159.0	194.7
p-value	***	***	***	***	***	***	***	***	*

LN=Leaf number, VL= Vine length

3.3. Interaction effect of variety and NPS+UREA fertilizer rate on fruit number and length

The result on fruit number per hectare was significantly ($p \leq 0.05$) influenced by variety and NPS+UREA fertilizer rate over season was presented in Figure 4. In the Meher season, the Liyu variety with a 0.15 t/ha NPS+UREA fertilizer rate and the Polimor variety with a 0 t/ha & 0.05 t/ha NPS+UREA fertilizer rate combination produced the highest fruit number (8.7) and length (28.6 cm) and the lowest fruit number (2.7) and length (11.6 cm), respectively. The reason for differences was the diversity of watermelon varieties and climate variability (Gusmini & Wehner, 2005).

This difference in the number and length of fruits could be due to high competition among plants for soil nutrients, which is especially serious for plants grown in different agronomic seasons. The results are in total agreement with Massri & Labban (2014), who found that chemical fertilizers had a positive impact on watermelon productivity. Phosphorus at the rate of 100 kg had a significant effect on watermelon fruit per plant in both seasons (Maluki et al., 2016). NPK fertilizer had a significant effect on the number of fruits produced (5.66), which was recorded at 60 kg/ha NPK, while the minimum (3.82) was at the control (Oga, I. O., & Umekwe, 2015).

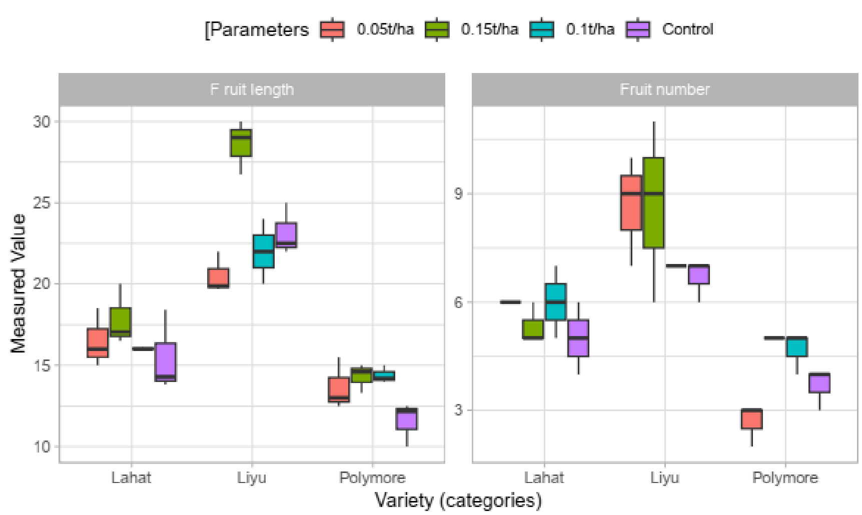

Figure 3. The interaction effect of variety and NPS+UREA on fruit number & fruit length,

3.4. Effect of variety on fruit width, fruit weight, & marketable yield of watermelon

The result on fruit width, fruit weight, and marketable yield per hectare significantly ($p \leq 0.05$) influenced by improved variety was presented in Figures 5 and 6, respectively. As a result of the variety effect, the highest fruit width (23.1 cm) and the lowest (12.1 cm) were measured from the Liyu and Polimor varieties in the Meher season, respectively. Whereas, the highest fruit weight (3.03 kg) and marketable yield (30.4 t/ha) were obtained from the Liyu variety in the Meher season. However, the lowest fruit weight (1.02 kg) and the lowest marketable yield (10.2 t/ha) were obtained from the Polimor variety in the Belg season.

The findings may be attributed to variety differences in growth characteristics, including increased foliar development and extended vine length. Enhanced foliage density likely supports higher photosynthetic activity and assimilates production, which ultimately contributes to increased fruit formation. This finding agrees with the findings of Dalorima et al. (2022), who noted that watermelon yield differed with variety differences. The reason for these differences was the diversity of watermelon varieties and climate variability (Gusmini & Wehner, 2005). The research area's average fruit output of 30.4 t/ha was more in line with the global yield of 32.1 t ha^{-1} in 2018. (Aitbayeva et al., 2021).

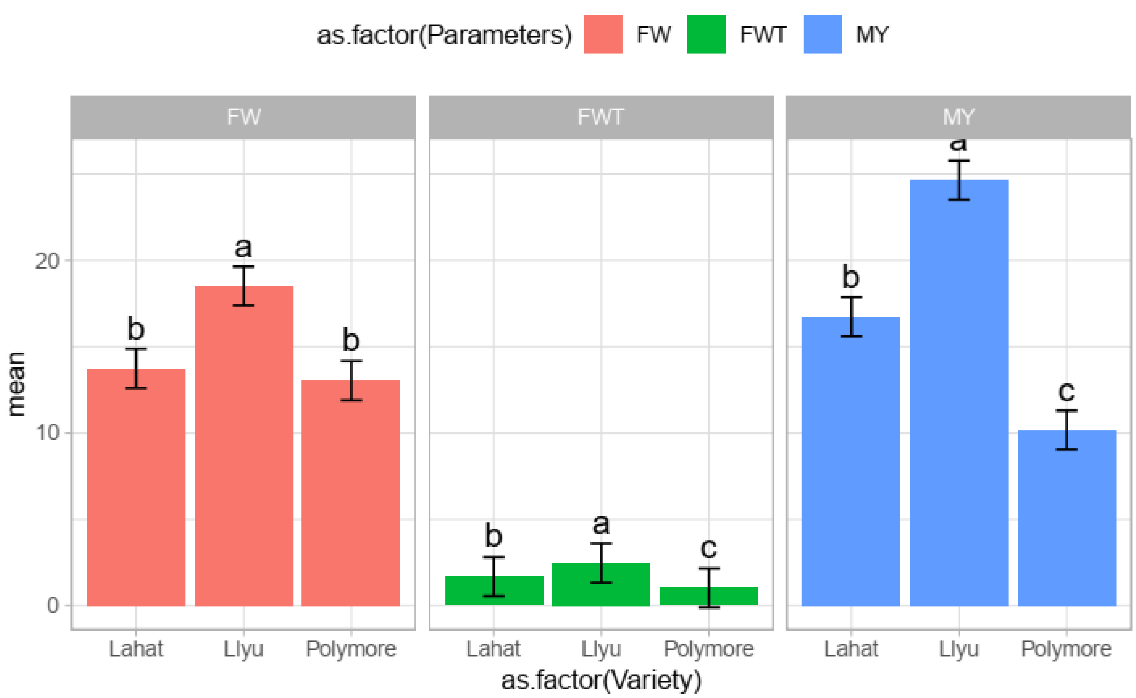

Figure 5. Effect of variety on fruit width, fruit weight, and marketable yield during Belg

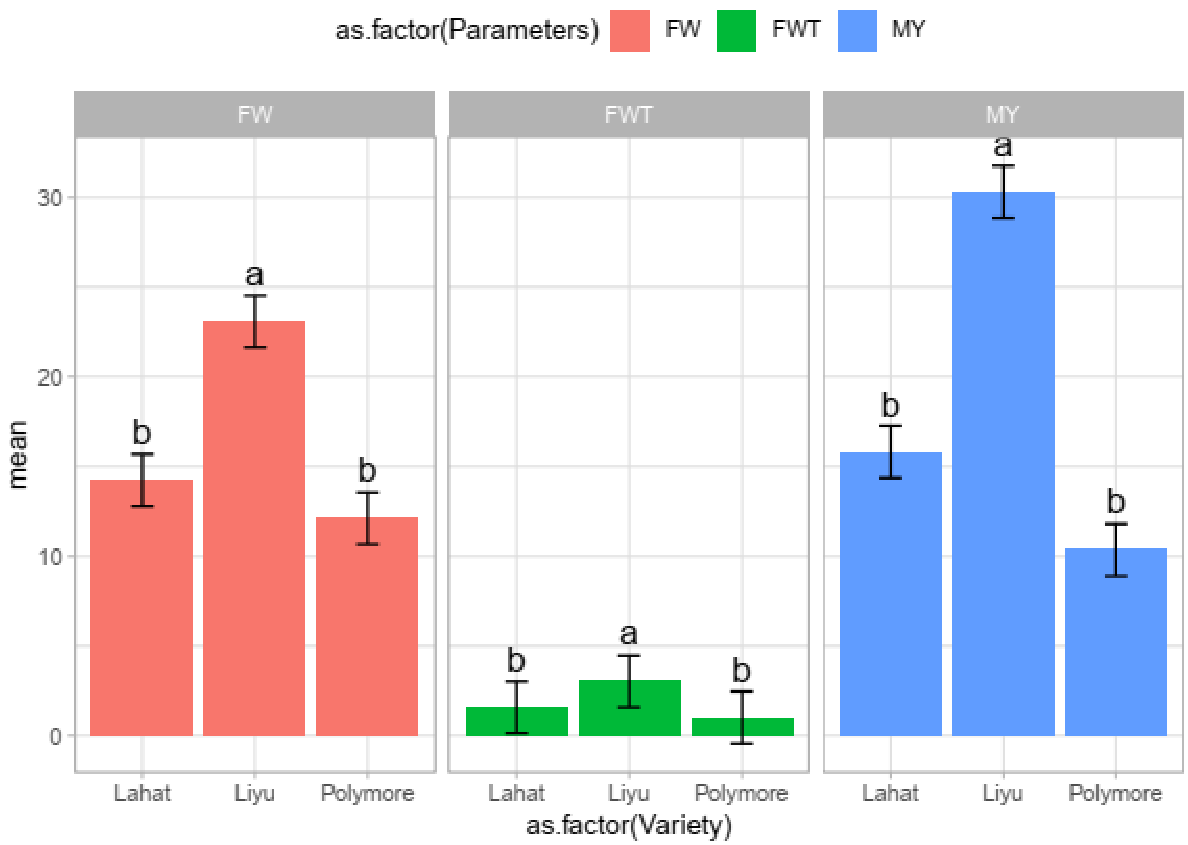

Figure 6. Effect of variety on fruit width, weight, and marketable yield during Meher

3.5. Interaction effect of the variety and NPS+UREA fertilizer rate on rind and fruit firmness, TSS & vitamin C

The study revealed that rind and fruit firmness, TSS & vitamin C are influenced by the interaction effect of variety & NPS+UREA fertilizer rate and showed significant ($p \leq 0.05$) differences among them (Figures 7 & 8). The highest rind firmness (1.3), fruit firmness (8.2), TSS (8.5° Brix), and vitamin C (8.5) were obtained from the interaction effect of Liyu with 0.05 t/ha and 0.15 t/ha at the Meher and Belg seasons, respectively. Whereas, the minimum result rind firmness (0.5), fruit firmness (2.8), TSS (4.5°Brix), and vitamin C (4.5) were obtained from the interaction effect of the Polimor variety with 0 t/ha, Liyu with 0.15 t/ha, and Lahat with 0 t/ha in the Meher season, respectively. Improved cultivars with good nutrient management frequently have higher total soluble solids (TSS), better sugar profiles, and sometimes higher antioxidant activity. This result agrees with different findings. According to Gusmini & Wehner (2005), in addition to production, effective cultivars must possess acceptable quality attributes. Additionally, during fruit formation, temperature treatment at 18°C significantly increased the soluble solid content (11.5%) in comparison to 14°C (10.6%), and the control (10.8 %) (Noh *et al*. (2013). Recommended inorganic fertilizer dose (200 kg/ha) has shown a great influence on the quantity of fruits (Aitbayeva et al., 2021).

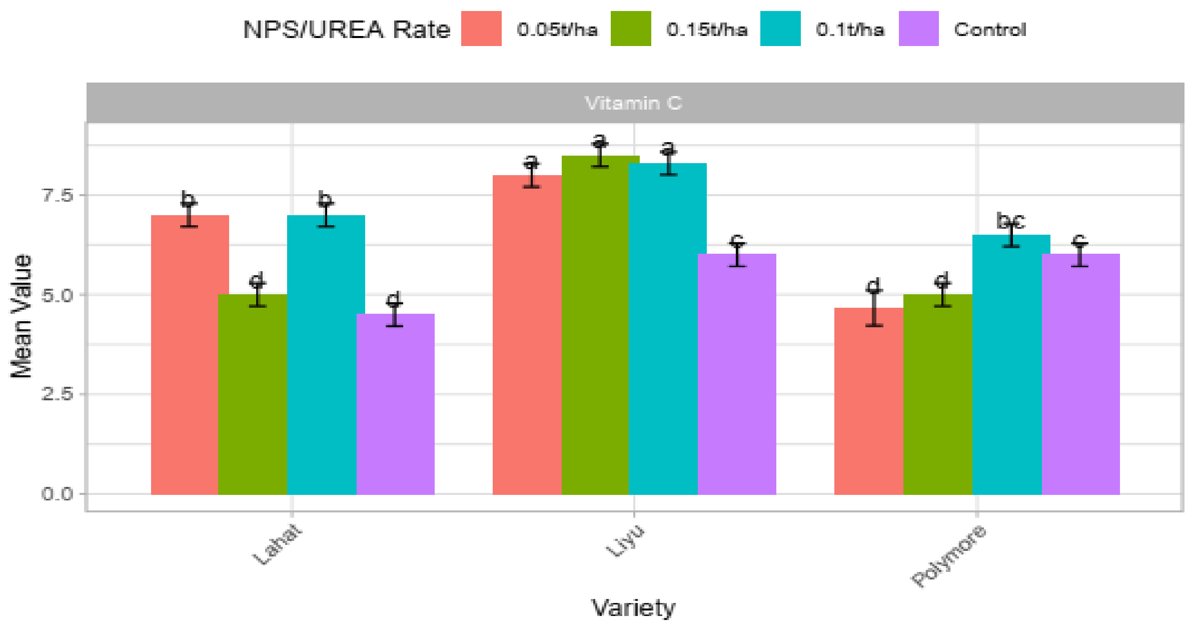

Figure 4. The interaction effect of variety and NPS+UREA fertilizer rate on vitamin C during Belg season

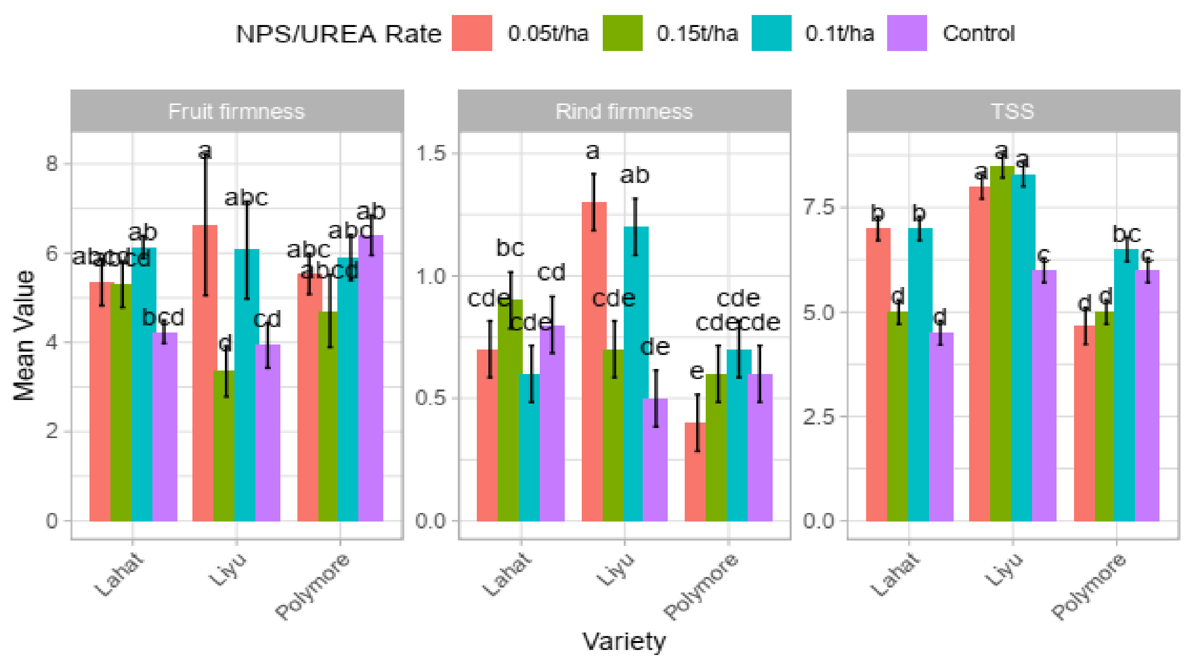

Figure 8. The interaction effect of variety and NPS+UREA fertilizer rate on fruit firmness, rind firmness, and TSS during the Meher season

3.6. Correlation between marketable yield with growth parameters of watermelon

The data on correlation (Table 4) revealed that marketable yield was significant and positively correlated with all growth parameters at 30 DAS, 45 DAS, and 60 DAS except number of secondary vines at 30 DAS and 45 DAS. A significant and positive correlation was also found by Dalorima et al. (2022).

Table 4. Correlation between marketable yield and growth parameters

Parameter	Days after sowing	LN	LL	LW	VL	NSV3
Marketable	30 DAS	0.610*	0.637*	0.688*	0.620*	0.510
Yield	45 DAS	0.583*	0.633*	0.696*	0.714**	0.461
	60 DAS	0.631*	0.685*	0.734**	0.783**	0.687*

4. Conclusion

Numerous variables have influenced the nation's improved watermelon output, regardless of the need for the fruit at the moment. Reduced yield and quality are the main contributing causes. The research area's farmers are not producing improved watermelon varieties, and soils are found to be lacking in fertilizer use, and important macronutrients and micronutrients. This study therefore sought to examine the effects of applying NPS+UREA fertilizer rates throughout the seasons on the growth, production, and quality of watermelon fruit in three chosen watermelon cultivars. In the Meher rainy season, the Liyu variety produced the highest yield (30.4 t/ha) and improved quality attributes like TSS (8.5° brix) in accordance with market preference. It was also observed that there was a significant interaction at 0.15 t/ha NPS+UREA/ha. Farmers in the research area are advised to enhance the profitability of watermelon farming. Mehir season is more preferable than Belg season; in addition, the Liyu watermelon variety with more NPS+UREA fertilizer rate (0.15 t/ha) than the blanket recommendation should be used. Further research should be conducted with other watermelon varieties with more than 0.15 t/ha inorganic fertilizer rate. In addition to investigating pruning of secondary vines in relation to yield increment.

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Conflict of Interest

The authors declare no conflict of interest.

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