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RESPONSES OF MAIZE VARIETIES TO VARYING UREA FERTILIZER REGIMES IN THE SOUTHERN GUINEA SAVANNAH AGROECOLOGICAL ZONE OF NIGERIA

[*1,2]Ilozobhie E. Nicholas, [1,2]Agha U. Agha, [1]Usman B. Ejura, [1]Chorio P. Timothy, [1]Azzuwut P. Andrew, [2]Baba N. Mohammed, [2]Sani Adamu, [2]Mustapha Abdul, [2]Aliyu Suleiman, [3]Ojekunle Fatimoh, [3]Aihebhoria O. Daniel, and [4]Okorie M. Joseph

[1]National Biosafety Management Agency (NBMA), Plot 3, Kalahari Close,Off ICS Drive, Dakibiyu, Jabi, FCT- Abuja, Nigeria.
[2]Department of Crop Science (Agronomy), Faculty of Agriculture,University of Abuja, Nigeria.
[3]International Institute of Tropical Agriculture (IITA), FCT-Abuja, Nigeria.
[4]Department of Biotechnology, Kaduna State University (KASU), Kaduna -Nigeria.

*Corresponding authors' email: iloz5nich@gmail.com

ABSTRACT

Maize is a vital crop in Nigeria, requiring optimal plant density and good agronomic practices to achieve enhanced yields. A two-year field trial (2023-2024) was conducted at the University of Abuja's farm in the Southern Guinea Savannah agroecological zone to evaluate maize response to varying urea application rates. A 4 × 5 factorial experiment was conducted using a Randomised Complete Block Design (RCBD) with three replications, combining four maize varieties (Sammaz-43, 44, 57, and 58) and five urea (46% N) application ranges (0, 50, 100, 150, and 200 kg/ha) with a uniform application of 45 kg/ha of phosphorus and potassium using NPK 15:15:15. Plant height, leaf count, leaf area, shelling percentage, thousand-seed weight, and grain yield were among the data collected. The results indicated that crop performance was significantly influenced by both maize cultivars and urea applications ($p \leq 0.05$). Higher urea rates improved yield parameters, with Sammaz-57 achieving top yields (3.8 t/ha in 2023 and 5.5 t/ha in 2024) with 200 kg/ha, showing unique varietal responses to urea rates. The study found a significant interaction ($P \leq 0.05$) between fertilizer application and maize variety, indicating that maize varieties responded differently to urea application. However, there was no significant difference in grain yield among the varieties, suggesting that none consistently outperformed the others across fertilizer treatments. The study recommends that farmers in the region use Sammaz-57 with 100 kg/ha urea or Sammaz-58 with 200 kg/ha urea to optimize maize growth and yield.

Keywords: Fertilizer, Growth, Sammaz maize varieties, Urea levels, and Yields

INTRODUCTION

Maize (*Zea mays* L.), a multifaceted crop within the Poaceae family, is renowned for its widespread cultivation and use, earning it the title of the most widely grown cereal globally. While it ranks third in overall production volume, surpassed only by wheat and rice, Maize's versatility and adaptability have cemented its status as a staple crop across diverse agricultural systems worldwide (FAOSTAT, 2016; Jandong, 2023). Maize is the world's most widely cultivated crop, with origins in Central America (Kennett *et al.,* 2020). Maize is a highly versatile crop with a wide range of applications, playing a crucial role in global food security, cultural practices, and economic systems. Its adaptability and diverse uses make it a valuable commodity worldwide. Globally, Maize is sometimes referred to as the "queen of cereals" due to its high genetic yield potential.

Maize is the only cereal crop that can be cultivated across a variety of climates, environments, and ecosystem types (Murdia *et al.,* 2016). Maize comes in a wide variety, each with its own requirements and applications. Popcorn, waxy corn, sweet corn, baby corn, ordinary yellow and white grain, high-protein corn, high-amylose corn, and high-oil corn are among them (Dass *et al.,* 2018). Furthermore, Maize has significant potential for value creation as a versatile industrial raw material, contributing to sectors such as biofuel production, biodegradable plastics, and others (Murdia *et al.,* 2016; Ramos *et al.,* 2022). Maize has multiple uses, ranging from human consumption and animal feed to industrial applications, where it is processed into products like flakes, syrup, dextrose, and starch (Gul *et al.,* 2021; Zhang *et al.,* 2021; Kumar *et al.,* 2022; Albahri *et al.,* 2023). To achieve successful maize production, it is vital to understand the interplay between management practices and environmental conditions that impact crop performance (Morugán-Coronado *et al.,* 2020). Appropriate plant densities, ideal planting dates, and cultivar selection are essential determinants of maize production potential and stability.

Global maize production reached 1,147.7 million metric tons, harvested from approximately 193 million hectares (Thakur *et al.,* 2023). Nigeria, which ranks second in Africa and 12th globally in terms of maize production (The Nation, 2021), has seen remarkable development in its output, which increased from 931,000 tons in 1971 to 10 million tons in 2020 at an average annual growth rate of 7.29% (Knoema *et al.,* 2020). Despite progress, Nigeria still faces challenges in meeting its domestic maize requirement of about 15 million metric tons, underscoring the need to enhance production and streamline supply chains (Njue *et al.,* 2020). Despite projections that Nigeria's population and food consumption will increase by 50% by 2050, the estimated potential maize yields of 9-12 t/ha (Tofa *et al.,* 2020) remain largely unattained (Worldometer, 2023). Sub-Saharan maize production in Africa faces significant constraints due to a complex interplay of soil fertility issues, inadequate pest and weed management practices, and climate-induced stressors such as irregular rainfall and temperature extremes, ultimately impacting crop yields and exacerbating food insecurity (Gage and Schwartz, 2019; Nwosisi *et al.,* 2019; Tibugari *et al.,* 2020; Abraham *et al.,* 2021).

Effective management strategies, including improved agronomic practices and climate-resilient varieties, are crucial to addressing these challenges and enhancing maize productivity. Optimizing fertilizer inputs is vital to maintaining soil fertility and achieving high grain yields in the Savannah region of Nigeria, where nitrogen is the most limiting nutrient. Leaching causes significant losses, particularly in the early stages of plant growth when nitrogen requirements are low. Studies have shown that applying the optimal amount of fertilizer can boost economic gains while minimizing expenditure (Digal & Placencia, 2019; Bui &

Nguyen, 2020; Yazdanpanah *et al.,* 2022). Effective crop nutrition management is essential for efficient fertilizer application, enhancing grain yield and quality, and ultimately ensuring sustainable agricultural productivity in the region. Proper urea application timing and rate are crucial for maize production, as they significantly affect yield-contributing traits such as plant height, leaf size, and ear development, ultimately improving maize yields and quality (Digal & Placencia, 2019; Atoma *et al.,* 2020).

Although fertilizers, especially urea, are essential for increasing agricultural output and replenishing soil nutrients, their improper use can have serious adverse effects on the environment and human health (Bui & Nguyen, 2020; Zhang *et al.,* 2020; Hossain *et al.,* 2022). Utilizing technologies such as fertilizer optimization and effective nutrient management is necessary to reduce these risks and strike a balance between productivity and environmental and public health protection.

To maximize Maize production and help alleviate the food crisis, farmers need to apply fertilizers wisely. With the ultimate goal of guiding fertilizer application decisions and increasing maize production in Nigeria, this study sought to determine the optimal urea application rate for maize growth by assessing how various maize varieties responded to varying urea rates while maintaining consistent potassium and phosphorus dosages.

MATERIALS AND METHODS

Study Area

Two field trials were conducted at the University of Abuja's Teaching and Research Farm in Gwagwalada, Nigeria, during the 2023 and 2024 cropping seasons. The experimental farm is located at a geographic coordinate of latitude 8°59'41.43" North and longitude 7°10'39.62" East with a climate characterized by average temperatures of 30°C and 14% humidity during the rainy season, and annual rainfall of 1,100-1,600 mm (Idoko & Bisong, 2010; Barnabas & Nwaka, 2014). The region's rainy season typically lasts from April to October, with precipitation ranging from 1,100mm to 1,800mm (Barnabas and Nwaka, 2014). The soil is a deep, well-draining sandy loam with moderate runoff potential, average fertility, and a pH of 5.6-5.8 (Ishaya and Grace, 2007).

Land Preparation and Soil Sample Collection

Soil samples were randomly collected from 10 locations within each experimental site in the field at a depth of 0-30 cm using a handheld soil auger, and a composite soil sample was taken after bulking. The composite sample was air-dried, sieved through a 2mm sieve, and subjected to laboratory analysis following the standard procedure outlined by the Food and Agriculture Organization of the United Nations (FAO, 2019). The experimental site was prepared for field evaluation by clearing, stumping, and packing using tools such as machetes, rakes, and dibbers. Subsequently, the site was ploughed, harrowed, and pulverized into a fine tilth. Beds measuring 3 m x 3 m were marked out using 60 cm-long pegs.

Experimental Material, Treatment, and Design

The study used conventionally bred maize varieties (Sammaz-43, Sammaz-44, Sammaz-57, and Sammaz-58) developed by Ahmadu Bello University's Institute for Agricultural Research (IAR) and sourced from the National Seed Council of Nigeria, Abuja. The experiment assessed the impact of five urea levels (46% N): 50 kg/ha (N1), 100 kg/ha (N2), 150 kg/ha (N3), 200 kg/ha (N4), and 0 kg/ha (N5, control), with a uniform application of 45 kg/ha of phosphorus and potassium using NPK 15:15:15.

The experiment was laid out in a Randomized Complete Block Design (RCBD) with a factorial treatment structure and three replicates. Each replicate contained 20 plots; thus, a total of 60 plots were used in the experiment. Each Plot measured 3 m x 3 m and was separated from the other within the replicate by a 0.5 m pathway. Each replicate was separated from the others by a 1-meter (1 m) alley for easy assessment of the experiment in the field. The farm size was 69.5 m × 11 m.

Agronomic Practices

Maize seeds were sown at a depth of 2-4 cm, with three seeds per hole, and spaced 75 cm x 50 cm apart following the National Agricultural Seed Council's (NASC) guidelines. Before planting, seeds were treated with Apron Star, a seed dressing product containing fungicides and insecticides, at a rate of 1.5 litres per hectare to control fungal diseases and early-season pests. Two weeks after planting, all the vacant stands were filled. The plants were thinned to 2 plants per stand 4-5 weeks after germination, resulting in a plant population of 53,333 plants/ha. At four and eight weeks after sowing (WAS), weeding was done by hand using a hoe. Two split applications of the fertilizer were applied at 3 and 6 WAS using the broadcast method. A basal dose of NPK (15:15:15) fertilizer was applied at 45 kg/ha, followed by urea applications at rates of 5 kg/ha, 55 kg/ha, 105 kg/ha, and 155 kg/ha.

Data Collection and Analysis

Data on plant height, number of leaves, leaf area, grain weight, shelling percentage, 1,000-seed weight, and grain yield were collected and analyzed using ANOVA in the R Statistical Program "agricolae" package (Version 4.5.1). Treatment means were separated using LSD ($p \leq 0.05$), and LSMEANS were calculated for significant interactions, with significance determined by standard errors (SE) and p values ($p \leq 0.05$).

RESULTS AND DISCUSSION

The physical and chemical characteristics of the soil at the experimental site, both before and after harvesting, are presented in Table 1. Initially, the soil was acidic, with a pH of 4.4 in water and 4.6 in KCl. Following harvest, the pH significantly increased to 6.4 in water and 6.1 in KCl. Additionally, phosphorus levels rose from 4.53 mg/kg to 7.08 mg/kg, and total nitrogen increased from 0.014 to 0.096 after harvest.

Effective Cation Exchange Capacity of the soil showed notable increases in key cations: sodium (0.15 to 0.37 $Cmol^{-1}$/100g), potassium (0.55 to 1.56 $Cmol^{-1}$/100g), magnesium (1.23 to 1.83 $Cmol^{-1}$/100g), and calcium (2.46 to 3.66 $Cmol^{-1}$/100g) and the Total Exchangeable Bases (TEB) also rose from 5.83 to 7.48 $Cmol^{-1}$/100g respectively, suggesting that the basic cations existed at relatively low concentrations before the two-year research period.

The initial soil assessment revealed low organic matter (1.01%) and organic carbon (0.35%), with an electrical conductivity of 0.22 mS/cm and inadequate base saturation, indicating poor fertility. This finding aligns with Anyaegbu's (2013) research, which highlights that acidic soils with pH levels around 4.5 can significantly limit agricultural productivity due to nutrient constraints and reduced crop performance. Furthermore, Nedunchezhiyan and Ray (2010) emphasized that sweet potatoes and Maize achieve optimal yields within a pH range of 5.5-6.5. Deviations from this range can trigger nutrient toxicity, increased pest pressure, and heightened disease susceptibility, compromising crop health and productivity (Kunito et al., 2016; Gou *et al.,* 2022; Guo *et al.,* 2024).

Since the sites had a history of prolonged sorghum and maize cultivation without adequate soil amendments, soil fertility depletion likely occurred, leading to low initial fertility. The application of fertilizers improved soil fertility, as indicated by increased urea concentrations post-harvest, which aligns with the findings that bio-based fertilizer production can contribute to a resource-efficient economy by bridging the gap between nutrient imports and losses, as reported by Chojnacka *et al.* (2020).

Table 1: Results of Laboratory Soil Analysis for the Pre-Planting and Post-Harvest Soil Tests

								Effective Cation Exchangeable Capacity (Cmol/Kg)							Particle size analysis			
Code	**pH in H_20**	**pH in KCL**	**% OC**	**% OM**	**% TN**	**EC mS/cm**	**P mg/kg**	**Na**	**K**	**Mg**	**Ca**	**TEB**	**Ex Acidit**	**ECEC**	**SILT gkg^{-1}**	**CLAY gkg^{-1}**	**SAND gkg^{-1}**	**TC**
Pre-Planting	**4.4**	**4.6**	**0.35**	**1.02**	**0.014**	**0.22**	**4.53**	**0.15**	**0.55**	**1.23**	**2.46**	**5.83**	**0.79**	**6.55**	**102.13**	**188.30**	**693.42**	**SL**
Post-Harvest	**6.4**	**6.1**	**1.46**	**2.53**	**0.096**	**0.33**	**7.08**	**0.37**	**1.56**	**1.83**	**3.66**	**7.48**	**1.11**	**8.55**	**118.31**	**190.29**	**691.41**	**SL**

OC = Organic Carbon. OM = Organic Matter. EC = Electrical Conductivity. mS/cm = milliSiemens per Centimeter. mg/kg = Milligrams Per Kilogram. TEB = Total Exchangeable Bases. ECEC = Effective Cation Exchange Capacity

Tables 2 illustrate the influence of varying urea levels on the plant height of specific maize varieties during the 2023 and 2024 cropping seasons. In the 2023 trial, higher urea levels resulted in the highest plant height. At 8 weeks after sowing, plants treated with 200 kg urea/ha recorded the highest height of 104.8 cm, statistically similar to those treated with 100 kg urea/ha and 150 kg N/ha. In contrast, the smallest plants (87.9 cm) were observed in plots that received 50 kg of urea per hectare, although this difference was not significant ($P \leq 0.05$) compared to control plots (0 kg urea per hectare). At 12 WAS, the pattern persisted, with 200 kg urea/ha maintaining the tallest plants (120.8 cm). The heights attained with 100 kg of urea per hectare (113.1 cm) and 150 kg of urea per hectare (109.3 cm) were statistically equal. Plots containing 50 kg urea/ha (97.6 cm) and control plots (103.5 cm) had the shortest plant heights at 12 WAS.

In 2024, a similar general trend in plant height was observed concerning urea application. Compared to 2023, plant heights showed minimal variation regardless of fertilizer application at 12 WAS in both trials, indicating no significant difference. Throughout both seasons, the plant heights varied significantly among the maize varieties, with Sammaz-44 consistently being taller than Sammaz-43, while Sammaz-57 and Sammaz-58 exhibited similar heights. The interaction between fertilizer and variety (F x V) significantly affected growth at 8 WAS in both the 2023 and 2024 experiments ($p < 0.05$).

Table 2: Plant Height of Selected Varieties of Maize as Influenced by Urea Levels in 2023 and 2024 Cropping Seasons

Treatments		**8 WAS**	**12 WAS**
Year	**Fertilizer levels**		
2023	0kg	11.3^{bc}	103.5
	50kg	87.9^{c}	97.6
	100kg	98.9^{ab}	113.1
	150kg	95.3^{ab}	109.2
	200kg	102.8^{a}	120.8
	LSD (0.05%)	10.37	17.93
	Significance	*	NS
	Varieties		
	Sammaz-43	105.1^{a}	124.3^{a}
	Sammaz-44	92.4^{b}	104.8^{b}
	Sammaz-57	89.9^{b}	99.0^{b}
	Sammaz-58	94.3^{b}	104.2^{b}
	LSD (0.05%)	10.39	14.31
	Significance	*	*
Year	**Fertilizer levels**		
2024	0kg	91.9	102.5
	50kg	87.8	98.5
	100kg	98.5	110.1
	150kg	98.2	108.6
	200kg	96.3	106.7
	LSD (0.05%)	8.56	9.35
	Significance	NS	NS
	Varieties		
	Sammaz-43	106.7^{a}	116.8^{a}
	Sammaz-44	101.0^{b}	103.1^{b}
	Sammaz-57	85.9^{b}	96.7
	Sammaz-58	93.6^{b}	104.5^{b}
	LSD (0.05%)	9.51	4.51
	Significance	*	*
	Interaction		
	F x V	*	NS

Means with different letters across columns differ significantly (P<0.05). *= statistically significant at 5% level; NS = not statistically significant. WAS = Weeks after sowing

Table 3 provides more details on the specific relationships between urea concentrations and maize varieties. Sammaz-43 with a 200-kilogram urea/ha treatment produced the most significant reported plant height of 124.2 cm, while Sammaz-57 and 50 kg urea/ha produced the lowest height of 76.8 cm. Additionally, in the same table, another set of findings indicates that Sammaz-43 with 100 kg urea/ha reached a maximum height of 54.0 cm, whereas Sammaz-57 with 50 kg urea/ha produced the minimum height of 34.0 cm.

Table 3: The Interaction Effect of Urea and Maize Variety on Plant Height at 8 WAP in both Cropping Seasons

		Fertilizer Levels (F)				
Year	**Varieties**	**0kg/ha**	**50kg/ha**	**100kg/ha**	**150kg/ha**	**200kg/ha**
2023	Sammaz-43	97.5^{bcde}	97.5^{bcde}	101.7^{bc}	106.8^{ab}	124.2^{a}
	Sammaz-44	90.1^{bcd}	83.2^{def}	101.5^{bc}	83.6^{def}	93.7^{bcde}
	Sammaz-57	90.7^{bcdef}	76.8^{f}	86.0^{cdef}	104.8^{bc}	93.2^{bcde}
	Sammaz-58	81.1^{def}	87.9^{cdef}	106.2^{ab}	94.0^{bcde}	102.3^{bc}
		LSD = 17.30				
2024	Sammaz-43	40.6^{cdef}	45.6^{abc}	54.0^{a}	49.5^{ab}	44.3^{abcd}
	Sammaz-44	39.3^{cdef}	43.3^{bcde}	41.0^{cdef}	35.4^{ef}	43.9^{abcd}
	Sammaz-57	38.6^{cdef}	34.0^{f}	41.7^{bcde}	43.9^{abcd}	36.8^{def}
	Sammaz-58	42.8^{bcde}	38.9^{cdef}	46.4^{abc}	41.7^{bcde}	44.1^{abcd}
		LSD = 8.73				

Means with different letters across columns differ significantly (P<0.05). *= statistically significant at 5% level; NS = not statistically significant

Table 4 depicts that different urea levels had a significant effect on these parameters throughout the 2023 cropping season (P≤0.05). Plots receiving 200 kg of urea/ha exhibited the highest number of leaves per plant (152.9), although this was not significantly different from those treated with 150 kg of urea /ha (152.3 leaves/plant). In contrast, during the 2024 growing season, Maize stands showed a robust, statistically significant response (P≤0.05) to varying urea fertilizer levels. At 8 and 12 WAS, 200 kg/ha of urea produced the most leaves per plant; however, this result was not significantly different from 150 kg/ha and 100 kg/ha of urea.

Additionally, at 8 and 12 WAS, there was no significant difference in the number of leaves per plant between the control plots and those receiving 50 kg/ha of urea. During both growth seasons, there was no discernible effect of varietal modifications on leaf count at 8 and 12 WAS.

Table 4: Number of Leaves of Specific Maize Varieties as Impacted by Urea Levels and Variety Interactions in the 2023 and 2024 Cropping Seasons

Treatments		**8 WAS**	**12 WAS**
Year	**Fertilizer levels**		
2023	0kg	130.8	135.2
	50kg	118.4	146.2
	100kg	122.8	150.2
	150kg	127.2	152.3
	200kg	123.8	152.9
	LSD (0.05%)	12.78	18.30
	Significance	NS	NS
	Varieties		
	Sammaz-43	127.9	137.5
	Sammaz-44	107.5	132.5
	Sammaz-57	151.1	151.1
	Sammaz-58	136.0	137.0
	LSD (0.05%)	41.21	14.94
	Significance	NS	NS
	Interaction		
	FxV	NS	*
Year			
2024	**Fertilizer levels**		
	0kg	93.3^{b}	111.8^{b}
	50kg	96.6^{b}	106.8^{b}
	100kg	143.0^{a}	144.0^{a}
	150kg	138.5^{a}	146.7^{a}
	200kg	152.3^{a}	152.8^{a}
	LSD (0.05%)	26.47	28.36

Treatments		8 WAS	12 WAS
Year	**Fertilizer levels**		
2023	0kg	130.8	135.2
	Significance	*	*
	Varieties		
	Sammaz-43	126.1	133.2
	Sammaz-44	123.1	131.4
	Sammaz-57	124.9	134.4
	Sammaz-58	129.5	139.8
	LSD (0.05%)	5.87	7.44
	Significance	NS	NS
	Interaction		
	F x V	*	*

Means with different letters across columns differ significantly (P<0.05). *= statistically significant at 5% level; NS = not statistically significant. WAS = Weeks after sowing

Table 5 shows that, apart from 0 kg/ha and Sammaz-57 and 100 kg of urea/ha, there was no significant variation in the leaf count at 12 WAS due to the interaction between F x V during both years for Sammaz-44 in the initial and subsequent cropping seasons, respectively.

Table 5: The Combined Impact of Maize Cultivars and Urea Levels on the Number of Leaves at 12 WAS in the 2023 and 2024 Planting Seasons

		Fertilizer Levels (F)				
Years	**Varieties**	**0kg/ha**	**50kg/ha**	**100kg/ha**	**150kg/ha**	**200kg/ha**
2023	Sammaz-43	99.3^{ef}	91.7^{f}	149.3^{abcde}	166.3^{abc}	178.7^{ab}
	Sammaz-44	143.0^{abcde}	125.0^{cdef}	134.3^{bcdef}	130.0^{bcdef}	130.0^{bcdef}
	Sammaz-57	187.0^{a}	114.3^{cdef}	149.3^{abcde}	155.0^{abcd}	144.0^{abcde}
	Sammaz-58	109.3^{def}	134.0^{bcdef}	167.7^{abc}	132.0^{bcdef}	142.0^{abcde}
	LSD = 51.08					
2024	Sammaz-43	93.3^{g}	105.3^{fg}	150.0^{abcde}	168.7^{abc}	163.7^{abcd}
	Sammaz-44	118.3^{efg}	107.7^{fg}	134.0^{cdefg}	117.7^{efg}	189.3^{a}
	Sammaz-57	131.3^{cdefg}	109.7^{fg}	140.0^{bcdef}	133.0^{cdefg}	163.7^{abcd}
	Sammaz-58	104.3^{g}	104.7^{g}	188.0^{a}	175.3^{ab}	126.7^{defg}
				LSD = 41.05		

Means with Different Letters Across Columns Differ Significantly (P<0.05). *= Statistically Significant at 5% Level; NS = not Statistically Significant

The data on maize leaf area for the 2023 and 2024 cropping seasons are presented in Tables 6 and 7, highlighting the effects of different urea levels, maize varieties, and their interactions (F × V). The influence of urea on maize leaf area varied with season. In 2023, urea application showed no significant effect at 12 WAS, whereas in 2024, increasing urea levels significantly enhanced leaf area at both 8 and 12 WAS. The highest leaf area in 2024 was recorded at 100 kg/ha of urea, with no notable difference between 150 and 200 kg/ha. The leaf area among the four maize varieties did not differ significantly between the two cropping seasons. The interaction between urea and variety (F × V) also varied by season, being non-significant (P < 0.05) at 8 WAS in 2023 but significant (P < 0.05) at both 8 and 12 WAS in 2024.

Table 6: Leaf Area of Specific Maize Varieties as Impacted by Urea Levels, Fertilizer, and Variety Interactions in the 2023 and 2024 Cropping Seasons

Treatments		8 WAS	12 WAS
Year	**Fertilizer levels**		
2023	0kg	38.1^{b}	61.6
	50kg	38.4^{b}	60.5
	100kg	49.3^{a}	63.7
	150kg	49.9^{a}	63.7
	200kg	52.6^{a}	61.9
		LSD =9.41	
	Significance	NS	NS
	Varieties		
	Sammaz-43	49.0	63.8
	Sammaz-44	49.5	63.6
	Sammaz-57	43.6	62.8
	Sammaz-58	45.2	59.8

	LSD (0.05%)	4.33	3.19
	Significance	NS	NS
	Interaction		
	FxV	NS	*
Year			
2024	**Fertilizer levels**		
	0kg	42.9^{b}	55.8^{b}
	50kg	39.4^{b}	51.2$^{\mathbf{b}}$
	100kg	53.4^{a}	69.9^{a}
	150kg	46.6^{ab}	61.5^{ab}
	200kg	48.6^{ab}	63.4^{ab}
	LSD (0.05%)	9.55	12.73
	Significance	NS	NS
	Varieties		
	Sammaz-43	48.9	63.9
	Sammaz-44	50.7	66.2
	Sammaz-57	40.6	53.3
	Sammaz-58	44.5	58.0
	LSD (0.05%)	8.56	11.08
	Significance	NS	NS
	Interaction		
	F x V	*	*

Means with different letters across columns differ significantly (P<0.05). *= statistically significant at 5% level; NS = not statistically significant. WAS = Weeks after sowing

Table 7 presents the effects of the interaction between urea levels and maize varieties (F × V) on leaf area at 12 weeks after sowing (WAS) during the 2023 and 2024 growing seasons. The combination of Sammaz-44 with 200 kg/ha of urea recorded the highest leaf area (79.2 cm²), while Sammaz-57 combined with 50 kg/ha of urea produced the lowest (39.9 cm²).

Table 7: Effects of Urea and maize variety interactions on leaf area at 12 WAS across the 2023 and 2024 growing seasons

		Fertilizer levels (F)				
Year	**Varieties**	**0kg/ha**	**50kg/ha**	**100kg/ha**	**150kg/ha**	**200kg/ha**
2023						
	Sammaz-43	60.2^{abcd}	46.17^{d}	74.0^{ab}	73.6^{ab}	64.8^{abcd}
	Sammaz-44	70.1^{ab}	63.8^{abcd}	52.5^{bcd}	55.0^{abcd}	77.0^{a}
	Sammaz-57	59.4^{abcd}	62.9^{abcd}	65.8^{abcd}	67.5^{abcd}	62.6^{abcd}
	Sammaz-58	56.7^{abcd}	69.4^{abc}	62.5^{abcd}	58.5^{abcd}	47.1^{acd}
		LSD = 24.37				
2024	Sammaz-43	55.0^{cde}	46.1^{de}	74.9^{abc}	78.9^{abcd}	64.6^{abcd}
	Sammaz-44	52.9^{de}	66.9^{abcd}	78.2^{ab}	54.0^{de}	79.2^{a}
	Sammaz-57	57.3^{bcde}	39.9^{e}	59.9^{abcde}	59.8^{abcde}	49.8^{de}
	Sammaz-58	58.0^{bcde}	51.7^{de}	66.7^{abcd}	53.4^{de}	60.2^{abcde}
		LSD= 22.92				

Means with different letters across columns differ significantly (P<0.05). *= statistically significant at 5% level; NS = not statistically significant

Table 8 presents the shelling percentage of maize as influenced by different urea application rates and maize varieties across the 2023 and 2024 growing seasons. The findings indicate that neither urea rate nor maize variety had a significant effect on shelling percentage in both years. However, in the 2023 season, urea levels significantly affected shelling percentage, while no significant effect was observed in 2024. Among the varieties, Sammaz-58 recorded the highest shelling percentage, whereas Sammaz-43 had the lowest. The interaction between urea levels and maize varieties was not significant.

Fertilizer rates also had a notable effect on the thousand-seed weight of maize. In 2024, plots treated with 0–100 kg/ha of urea produced the heaviest seeds, while those receiving 150–200 kg/ha yielded the lowest seed weight. Maize variety significantly influenced thousand-seed weight in both trials, with Sammaz-58 producing the largest seeds. Similar to the shelling percentage, no significant interaction was observed between urea levels and maize varieties.

Table 8: Shelling Percentage (%) And Thousand-Seed Weight (G) Of Maize As Impacted By Various Fertilizer Levels, Varieties, And F X V Interactions In The 2023 And 2024 Cropping Seasons

2023		2024		
Treatments	**Shelling Percentage**	**1,000 Seed Weight**	**Shellin Percentage**	**1,000.Seed Weight (kg)**
Fertilizer levels				
0kg	40.0	0.4^{a}	41.2	0.4^{a}
50kg	40.0	0.4^{a}	41.3	0.4^{a}
100kg	57.4	0.4^{a}	53.4	0.3^{ab}
150kg	50.9	0.3^{b}	46.7	0.31^{b}
200kg	17.7	0.02	16.90	0.02
Significance	NS	*	NS	*
Varieties				
Sammaz-43	36.7^{b}	0.3^{b}	38.1	0.3^{b}
Sammaz-44	46.5^{ab}	0.3^{b}	42.0	0.3^{b}
Sammaz-57	54.6^{ab}	0.3^{b}	51.4	0.3^{b}
Sammaz-58	59.9^{a}	0.4^{a}	57.0	0.4^{a}
LSD (0.05%)	20.44	0.02	19.51	0.02
Significance	*	*	NS	*
Interaction				
F x V	NS	NS	NS	NS

Means with different letters across columns differ significantly (P<0.05). *= statistically significant at 5% level; NS = not statistically significant

Table 9 presents the effects of different fertilizer levels and maize varieties on grain yield. Although variations were observed, the grain yields obtained with 100 kg and 150 kg urea applications across the two cropping seasons were not significantly different. However, the interaction between fertilizer rate and maize variety was significant (P≤0.05), suggesting that the varieties responded differently to fertilizer levels, even though their overall productivity did not vary significantly.

Table 9: Grain yield (t/ha) of Maize as impacted by various fertilizer levels, varieties, and F x V interactions in the 2023 and 2024 cropping seasons

	2023	**2024**
Fertilizer levels		
0kg	2.1	2.1
50kg	2.3	2.9
100kg	3.3	5.4
150kg	3.4	5.2
200kg	3.8	5.5
LSD (0.05%)	0.05	0.09
Varieties		
Sammaz-43	3.3	4.7
Sammaz-44	3.2	4.4
Sammaz-57	3.6	5.3
Sammaz-58	3.5	4.9
LSD (0.05%)		
Significance	NS	NS
F x V	*	*

Means with different letters across columns differ significantly (P<0.05). *= statistically significant at 5% level; NS = not statistically significant.

able 10 indicates that the highest grain weight (2.9 kg) was obtained in the 2023 cropping season from the combination of Sammaz-57 with 100 kg/ha of fertilizer, while the lowest grain weight (1.4 kg) was recorded with Sammaz-43 grown without fertilizer application.

Table 10: Interaction of F x V on Grain Weight in 2023 and 2024 cropping seasons

	Fertilizer levels (F)				
Variety (V)	**0kg/ha**	**50kg/ha**	**100kg/ha**	**150kg/ha**	**200kg/ha**
Sammaz-43	1.4^{d}	1.6^{bcd}	2.0^{abcd}	2.3^{abc}	2.1^{abcd}
Sammaz-44	1.6^{bcd}	1.8^{bcd}	2.1^{abcd}	1.5^{cd}	2.4^{abc}

	Fertilizer levels (F)				
Sammaz-57	2.2abcd	1.6cd	2.9a	2.3abcd	2.2abcd
Sammaz-58	1.9bcd	1.8bcd	2.2abcd	2.6ab	2.6ab
			LSD = 0.97		

Means with different letters across columns differ significantly (P<0.05). *= statistically significant at 5% level; NS = not statistically significant

Discussion

The application of urea fertilizer significantly influenced plant growth, with plants treated with 200 kg/ha exhibiting the greatest height at eight weeks after sowing (WAS) in both trials. However, this was statistically similar to those treated with 100 kg/ha and 150 kg/ha. In contrast, control plots showed stunted growth, underscoring the importance of urea for vegetative development. This finding aligns with Gewaily *et al.* (2021), who reported that urea promotes plant growth by enhancing internode elongation and expansion, resulting in taller plants. The poor growth observed in the control plots can be attributed to urea deficiency, consistent with Jaham's (2014) findings on sorghum. Moreover, our results corroborate Sigaye *et al.* (2020) and Muhammad *et al.* (2014), who demonstrated that fertilizer application significantly affects above-ground biomass, grain yield, and straw yield in Maize and sorghum, respectively. These findings underscore the crucial role of urea in enhancing crop productivity.

The application of 50 kg of urea did not significantly impact maize plant height compared to control plots eight weeks after sowing. Maize height varied significantly among the four cultivars, with Sammaz-43 consistently exhibiting greater height regardless of urea application, potentially due to enhanced nutrient uptake, improved weed competitiveness, or more efficient nutrient utilization (Burlacot, 2024; Huang *et al.,* 2023). Urea application generally increased plant height, likely due to its stimulating effect on cell division and elongation (Alim, 2012; Liverpool-Tasie *et al.,* 2017; Agbede *et al.,* 2019).

Urea fertilizer application enhanced maize growth characteristics by providing adequate nitrogen, which in turn encouraged grain filling and ear development, in line with research by The *et al.* (2020) and Negash *et al.* (2021). A significant genotype x urea interaction was observed, indicating that the performance of different maize varieties was influenced by the varying urea application rates, resulting in unique responses to nitrogen levels. This finding aligns with previous research by Bocianowski *et al.* (2019) and Zeng *et al.* (2022), highlighting the critical role of genotype-specific responses to fertilizer applications in optimizing crop productivity and informing tailored agronomic practices.

The number of leaves per maize plant was not significantly impacted by varying urea application levels at 8 weeks after sowing (WAS) in either season. The observed outcome may be attributed to the plant's genetic constitution, which determines its natural growth patterns, such as leaf development (Ihenetu *et al.,* 2021). The varieties' basic developmental patterns and responses may also be influenced by their growth cycles, which are determined by their genetic makeup.

Although urea application may not affect leaf number, it can trigger nutrient remobilization from leaves to grains, potentially compromising leaf nutritional value as the plant matures (Fang *et al.,* 2024). According to Yu *et al.* (2022), biomass accumulation and its transfer to reproductive structures, as well as the dispersal of photosynthetic products from leaves during the reproductive growth stage, are critical factors in crop yield. Therefore, to produce high yields, it is essential to apply a higher rate of urea to boost the accumulation of photosynthetic products during this phase.

The second study revealed that urea application significantly influenced the number of leaves produced by maize plants. The largest number of leaves per plant was observed at 200 kg of urea, whereas leaf output in the control plots was comparable to that at 50 kg of urea. In general, applying urea increased the area and productivity of maize leaves. The increased leaf area per plant enhances photosynthetic activity, contributing to a higher Leaf Area Index (LAI) per unit land area (Herve, 2017). Notably, the four maize cultivars in this study exhibited minimal variation in leaf area, consistent with other observed parameters.

In the 2024 trial, the highest seed weight was achieved with 0-100 kg/ha urea, while the lowest yield was recorded at 150-200 kg/ha. Maize variety significantly affected thousand-seed weight, with Sammaz-58 producing the heaviest seeds in both trials, consistent with findings from Yusuf *et al.* (2019). However, no significant interaction between urea levels and maize varieties was observed.

Maize grain yield increased continuously with urea application. Fertilizers containing urea are generally thought to be more successful in increasing crop yields than those containing phosphate or potassium. Dry matter, harvest index, oil content, seed output per plant, and other yield characteristics are among the growth and yield metrics significantly affected by urea treatment (Ibrahim *et al.,* 2023). In both experiments, 200 kg of urea produced the highest grain yields (3.8 t/ha in 2023 and 5.5 t/ha in 2024).

According to research by Hawkesford and Griffiths (2019) and Adhikari *et al.* (2021), increased grain yield at higher nitrogen levels can be attributed to reduced nutrient competition, allowing plants to accumulate more biomass and enhance their capacity to convert photosynthetic products into sinks, ultimately resulting in increased grain production. However, Aminul *et al.* (2015) recommended that the urea rate should not exceed 150–200 kg/ha and found that the optimal rate was 150–200 kg N/ha in combination with 118 kg P_2O_5/ha. Grain yields were consistently lowest in the control plots, most likely due to the trial site's uneven fertility. The interaction between fertilizer and maize variety was significant, indicating that different varieties responded uniquely to urea application, although variety differences did not significantly impact grain yield.

The study's findings suggest that the majority of growth characteristics, including plant height, leaf count, and leaf area, did not differ significantly between varieties, corroborating earlier studies (Ogundare *et al.,* 2015). This consistency can be attributed to effective agronomic practices, which likely contributed to the similar growth patterns observed across varieties, ultimately reducing variability in crop traits and leading to more uniform growth and productivity (Gebregergs, 2024).

CONCLUSION

The application of urea fertilizer significantly enhanced maize growth and yield, with the optimal rate of 200 kg/ha resulting in maximum grain yields of 3.8 t/ha in 2023 and 5.5 t/ha in 2024. Vegetative growth was substantially promoted by high urea levels, specifically within the 150-200 kg/ha range. However, the response of different maize varieties to urea application varied, indicating that specific varieties may require tailored fertilizer management strategies.

To optimize maize growth and yield in Nigeria's Southern Guinea Savannah Agroecological Zone, farmers are advised to use Sammaz-57 with 100 kg/ha urea or Sammaz-58 with 200 kg/ha urea, as these tailored approaches can enhance grain yield while considering cost-effectiveness and environmental sustainability

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