



## EVALUATING THE EFFECTS OF NEEM COATED UREA AND *MORINGA* LEAF EXTRACTS ON GROWTH AND YIELD OF MAIZE (*Zea mays* L.)

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### ABSTRACT

The study investigated the individual and combined effects of Neem Coated Urea (NCU), a slow-release nitrogen source, and *Moringa* Leaf Extract (MLE), a natural biostimulant, on the growth and yield of maize during the 2024 rainy season at two locations in Kano State, Nigeria. The treatments comprised of five levels of nitrogen source (0%, 75%, 100%, 125% NCU, and conventional Urea) and four levels of foliar-applied MLE (0%, 5%, 7%, and 9%). These were factorially combined and laid out in a Randomized Complete Block Design (RCBD) with three replications. Results of the experiment showed that both NCU and MLE significantly enhanced all measured growth parameters, including plant height, leaf area, total dry weight, and chlorophyll content, compared to the control and conventional urea. NCU, particularly at the 125% application rate, consistently produced the highest values for vegetative growth and yield components. Similarly, the 9% MLE concentration resulted in the most significant improvements in plant performance. The highest yield was achieved with the combined application of 125% NCU and 9% MLE. This combination significantly outperformed conventional urea, demonstrating the superior efficiency of NCU in reducing nitrogen losses and the complementary role of MLE in stimulating plant metabolism and nutrient uptake. The study concludes that integrating Neem Coated Urea with foliar *Moringa* Leaf Extract is a highly effective and sustainable strategy for maximizing maize productivity in the Sudan Savanna. Farmers in the region are recommended to adopt the application of 125% NCU combined with 9% MLE for optimal maize production.

**Keywords:** Neem, Coated, Urea, *Moringa*, Leaf, Maize.

### INTRODUCTION

Improving crop yield, especially with the growing pressure on limited arable land, depends heavily on proper crop nutrition that supplies plants with all the essential nutrients they need (FAO, 2017). Maize is a major staple in Nigeria and across Africa, and years of breeding by institutions such as IITA and IAR have led to the release of improved varieties that yield well and adapt to different environments. As a result, maize production has expanded dramatically, making Nigeria the second-largest producer in Africa (FAOSTAT, 2019). Yet, despite its potential, maize yields in Nigeria remain far below what is achievable less than 1.8 t ha<sup>-1</sup> compared to over 5 t ha<sup>-1</sup> in well-managed fields. Poor and inconsistent soil fertility, limited fertilizer access, high fertilizer costs, and inefficient nutrient recovery all contribute to this gap. Traditional urea fertilizers also lose nitrogen rapidly through volatilization and leaching, lowering nutrient use efficiency and harming the environment (Tofa *et al.*, 2020).

Because of these challenges, researchers are exploring more sustainable nutrient-management solutions. Two promising options are neem-coated urea (NCU), which slows nitrogen release and reduces losses, and *Moringa* leaf extract (MLE), a natural growth enhancer rich in essential nutrients.



Both have shown potential to boost fertilizer efficiency and improve crop performance, yet their combined effects on maize production remain under-studied (Aliyu *et al.*, 2020).

This study therefore aims to evaluate how NCU and MLE used alone and together affect the growth and yield of maize. The goal is to support sustainable practices that improve productivity, nutrient use, and food security in maize-growing regions.

## **MATERIALS AND METHODS**

### **Experimental Sites**

The research was conducted during the 2024 rainy season at two locations; Faculty of Agriculture research farm, Bayero University, Kano (Latitude 11°58N and Longitude 8°24E) and Mainawa in Kobo Local Government Area, Kano state (Latitude 11°52N and Longitude 8°10E). Both the trial locations were in Sudan Savanna Zone of Nigeria.

### **Treatments and Experimental Design**

The treatments consisted of five levels of Neem Coated Urea (0%, 75%, 100%, 125% and urea) and four levels of *Moringa* Leaf Extracts (0%, 5%, 7% and 9%). These were factorially combined and laid out in a randomized complete block design (RCBD) with three (3) Replications.

### **Soil Analysis**

Four soil samples were collected from the 0-30cm sampling depth in the experimental field before establishing the experiment using an Auger, which were mixed into one composite sample, the four samples were collected in N-shape sampling scheme line. Therefore, one sample was collected at each experimental site

### **Plot Size**

Each plot consisted of 5 rows spaced at 0.75m apart of 4m length giving a gross plot area of 12m<sup>2</sup>. The 3 Inner rows with an area of 6m<sup>2</sup> were used as the net plot.

### **Fertilizer Application**

The fertilizer recommendation for maize in Sudan savanna (120kgN: 60kgP<sub>2</sub>O<sub>5</sub>:60kgK<sub>2</sub>O) was used. Rate of 60kgN:60kgP<sub>2</sub>O<sub>5</sub>:60kgK<sub>2</sub>O was applied at two weeks after sowing using NPK 15:15:15 as basal application to supply half of N and whole P and K in all the plots except three plots of MLE (5%, 7% and 9%) this was to see the effect of MLE alone throughout the period. In those treatments 25ml of MLE per plant was used in the interval of 1 week as foliar application. The second dose of fertilizer were applied at 4 weeks after sowing. The neem coated urea was applied at the rate of 75kgN/ha, 60kgN/ha, and 45kgN/ha (to supply 125% NCU, 100% NCU, and 75% NCU respectively), Normal Urea was supplied at the rate of 60kgN/ha.

### **Preparation of Aqueous *Moringa* Leaf Extracts**

The aqueous solution of *Moringa* leaf extract was prepared by pounding a measured quantity of *Moringa* leaf in a mortar. For each 5kg crushed, 1 L of water were poured in to it. Stirred properly for about 5minutes, allowed to stay for 30minutes and then filtered to collect the concentrated MLE (Yasmeen, 2011). A 5% MLE were prepared by adding 95millimeter of water to 5millimeter of concentrated aqueous *Moringa* leaf extract (Adamu *et al.*, 2019). 7% by adding 93millimeter of water to 7millimeter of Concentrated MLE and also 9% 9millimeter of MLE were be added to 91millimeter of water.

### **Data Collection**

Data were collected at bi-weekly interval from five randomly tagged plants starting from 3 weeks after sowing (WAS) on Plant Height (cm), Stem Diameter (mm), Leaf Area (LA), Chlorophyll Content, Crop Growth Rate (CGR), Total dry matter (g) per m<sup>2</sup> and Number of days to 50% flowering.

### **Data Analysis**

The data collected were subjected to analysis of variance (ANOVA) using GENSTAT statistical software (Version 17<sup>th</sup> Edition). The treatment group that are significantly differences were separated using Student-Newman-Keuls (SNK).



## RESULTS

### Physical and Chemical Properties of the Experimental Soils

The soils from BUK and Kabo were both sandy loam, with high sand content and low clay. Their slightly acidic pH values (6.09 and 6.24) fall within the ideal range for maize. Electrical conductivity was low, confirming non-saline conditions suitable for crop growth. Organic carbon levels were moderate, but both nitrogen and available phosphorus were low, indicating the need for fertilization. Calcium was the dominant exchangeable base, followed by magnesium, potassium, and sodium. BUK had a slightly higher cation exchange capacity than Kabo, suggesting marginally better nutrient-holding capacity at that site.

**Table 1:** Physical and Chemical Properties of the Soil during 2024 Rainy Season at BUK and Kabo

Soil parameter	BUK	Kabo
Sand (%)	53.4	54.3
Silt (%)	33.39	37
Clay (%)	13.21	8.7
Textural Class	Sandy loam	Sandy loam
pH (H <sub>2</sub> O)	6.09	6.24
EC (dSm <sup>-1</sup> )	1.09	1.25
OC (gkg <sup>-1</sup> )	4.5	4.6
N (gkg <sup>-1</sup> )	0.5	0.6
P (mg/kg)	0.58	0.75
Ca (cmol (+) kg <sup>-1</sup> )	2.68	2.27
Mg (cmol (+) kg <sup>-1</sup> )	0.87	0.94
K (cmol (+) kg <sup>-1</sup> )	0.16	0.24
Na (cmol (+) kg <sup>-1</sup> )	0.1	0.07
E.A (cmol (+) kg <sup>-1</sup> )	0.62	0.55
ECEC (cmol (+) kg <sup>-1</sup> )	3.81	3.52
Zn (mgkg <sup>-1</sup> )	7.38	5.04
Cu (mgkg <sup>-1</sup> )	2.79	1.84
Mn (mgkg <sup>-1</sup> )	4.5	3.21
Fe (mgkg <sup>-1</sup> )	16.38	13.75

Analysed at the Soil Science laboratory, BUK.

### Response of Maize Plant Height to Neem Coated Urea and Moringa Leaf Extract

Maize plant height was not significantly influenced by Neem Coated Urea (NCU) or Moringa Leaf Extract (MLE) at 3 weeks after sowing. However, by 7 weeks, NCU had a strong effect at both locations: the 125% NCU rate consistently produced the tallest plants, followed by 100% and 75%, with the control showing the shortest height. Conventional urea resulted in moderate plant height.

For MLE, no differences appeared at 3 weeks, but at BUK, higher concentrations (7% and 9%) significantly increased plant height at 7 weeks compared to the control. At Kabo, the increases were not statistically significant but showed a positive trend. There was no significant interaction between NCU and MLE at any stage, indicating that their effects were independent rather than synergistic.



**Table 2:** Effects of Neem Coated Urea and *Moringa* Leaf Extract on Plant Height (cm) of Maize in BUK and Kobo, Kano State

Treatments	BUK		KABO	
	3 WAS	7 WAS	3 WAS	7 WAS
0%NCU	64.40	125.46d	57.75	162.10d
75%NCU	63.94	177.80c	59.50	171.70c
100%NCU	62.74	197.83b	62.02	182.62b
125%NCU	60.67	219.00a	60.49	190.23a
UREA	65.40	177.75c	60.33	178.71bc
SE±	2.500	1.247	2.062	2.634
P-value	0.73	0.0001	0.88	0.0001
MLE				
0%	60.83	172.25c	59.46	165.98
5%	62.70	178.22b	59.82	171.38
7%	66.69	182.39a	61.63	172.60
9%	63.48	185.41a	57.55	174.32
SE±	2.27	1.11	1.84	2.35
P-value	0.33	0.0001	0.48	0.08
NCU x MLE				
P-value	0.75	0.49	0.35	0.69

Means followed by the same letter (s) within a column are not significantly different at  $P \leq 0.05$

### Response of Maize Stem Diameter to Neem Coated Urea and *Moringa* Leaf Extract

At 3 weeks after sowing, Neem Coated Urea (NCU) and *Moringa* Leaf Extract (MLE) had no significant effect on maize stem diameter at either BUK or Kobo. Stem thickness only ranged slightly from about 0.60–0.70 mm. By 7 weeks, however, NCU had a clear and significant impact: the 125% NCU rate produced the thickest stems at both sites, followed by the 100% rate, while the control recorded the smallest stem diameters. This shows that higher NCU application improved stem growth.

**Table 3:** Effects of Neem Coated Urea and *Moringa* Leaf Extract on Stem Diameter of Maize in BUK and Kobo, Kano State

Treatments	BUK		KABO	
	3 WAS	7 WAS	3 WAS	7 WAS
0%NCU	0.60	1.52d	0.61	1.50e
75%NCU	0.70	2.02c	0.63	1.95d
100%NCU	0.67	2.02b	0.64	2.27b
125%NCU	0.64	2.30a	0.61	2.45a
UREA	0.61	2.42c	0.63	2.06c
SE±	0.03	0.02	0.01	0.02
P-value	0.27	0.0001	0.62	0.0001
MLE				
0%	0.60	1.98c	0.62	1.99d
5%	0.64	2.03b	0.63	2.03c
7%	0.64	2.08b	0.62	2.06b
9%	0.69	2.14a	0.63	2.10a
SE±	0.03	0.01	0.01	0.01
P-value	0.28	0.0001	0.84	0.0004
NCU x MLE				
P-value	0.71	0.44	0.25	0.97

Means followed by the same letter (s) within a column are not significantly different at  $P \leq 0.05$

### Response of Maize Leaf Area to Neem Coated Urea and Moringa Leaf Extract

At 3 weeks after sowing, Neem Coated Urea (NCU) did not affect leaf area at BUK, but at Kobo, leaf area increased steadily with higher NCU rates. By 7 weeks, NCU had a strong and significant effect at both sites: the 125% NCU rate produced the largest leaf area, followed by 100% NCU, while the control plots had the smallest leaves. Conventional urea gave moderate leaf expansion similar to the 75% NCU rate. Moringa Leaf Extract (MLE) patterns were not highlighted as significant in this stage based on the provided data.

**Table 4:** Effects of Neem Coated Urea and *Moringa* Leaf Extract on Leaf Area of Maize in BUK and Kobo, Kano State

Treatments	BUK		KABO	
	3 WAS	7 WAS	3 WAS	7 WAS
0%NCU	281.61	574.92d	124.43d	463.40d
75%NCU	288.88	831.90c	152.43c	686.17c
100%NCU	290.05	893.02b	176.58b	775.40b
125%NCU	285.95	939.50a	194.41a	854.64a
UREA	280.43	837.21c	152.86c	727.31bc
SE±	3.33	3.83	1.92	22.83
P-value	0.18	0.0001	0.0001	0.0001
MLE				
0%	287.26	800.47c	154.24c	659.03a
5%	282.65	811.84b	158.66bc	687.28ab
7%	290.10	820.71a	162.04ab	714.75ab
9%	281.53	828.22ab	165.63a	744.48a
SE±	2.97	3.42	1.72	20.41
P-value	0.16	0.0001	0.0003	0.032
NCU x MLE				
P-value	0.55	0.93	0.99	0.91

Means followed by the same letter (s) within a column are not significantly different at  $P \leq 0.05$

### Chlorophyll Content

Chlorophyll content was not affected by treatments at 3 weeks after sowing, but by 7 weeks, Neem Coated Urea (NCU) had a strong and significant impact at both BUK and Kobo. The 125% NCU rate produced the highest chlorophyll levels, closely followed by 100% NCU and conventional urea, while the control consistently showed the lowest values.

For Moringa Leaf Extract (MLE), no significant differences were observed at BUK, though chlorophyll levels increased slightly with higher concentrations. At Kobo, however, MLE significantly improved chlorophyll content, with the 9% extract giving the highest readings. There was no significant interaction between NCU and MLE, meaning each acted independently rather than enhancing each other's effects.



**Table 5:** Effects of Neem Coated Urea and *Moringa* Leaf Extract on Chlorophyll content of Maize in BUK and Kobo, Kano State

Treatments	BUK		KABO	
	3 WAS	7 WAS	3 WAS	7 WAS
0%NCU	53.92	63.19c	61.94	65.75d
75%NCU	61.21	77.86b	63.14	76.04c
100%NCU	57.66	81.17ab	60.08	78.90b
125%NCU	59.51	82.42a	58.76	84.52a
UREA	59.36	80.37ab	61.27	75.25c
SE±	2.65	2.96	1.78	0.66
P-value	0.12	0.0001	0.47	0.0001
MLE				
0%	52.02	59.81	60.49	74.28c
5%	61.74	69.50	61.01	75.83bc
7%	50.67	70.68	61.15	76.53ab
9%	60.95	78.17	61.50	77.70a
SE±	2.37	2.66	1.59	0.59
P-value	0.23	0.22	0.97	0.0024
NCU x MLE				
P-value	0.71	0.96	0.81	0.59

Means followed by the same letter (s) within a column are not significantly different at  $P \leq 0.05$

**Table 6:** Effects of Neem Coated Urea and *Moringa* Leaf Extract on CGR ( $\text{gm}^2\text{day}$ ) and Days 50% Flowering of Maize in BUK and Kobo, Kano State

Treatments	BUK		KABO	
	CGR ( $\text{gm}^2\text{day}$ )	Days Flowering	CGR ( $\text{gm}^2\text{day}$ )	Days Flowering
0%NCU	12.99e	61	13.15	59
75%NCU	26.41d	59	23.59	58
100%NCU	41.60b	60	38.23	59
125%NCU	46.34a	59	41.72	57
UREA	34.66c	60	31.47	58
SE±	0.30	0.23	1.45	0.92
P-value	0.0001	0.57	0.0001	0.76
MLE				
0%	12.99	61	14.15	59
5%	13.52	61	14.21	59
7%	13.74	60	14.66	58
9%	13.93	60	14.99	58
SE±	1.26	0.46	0.18	0.23
P-value	0.09	0.06	0.001	0.0001
NCU x MLE				
P-value	1.06	0.56	0.41	0.65

Means followed by the same letter (s) within a column are not significantly different at  $P \leq 0.05$

### Plant Fresh Weight and Total Dry Weight

Both Neem Coated Urea (NCU) and *Moringa* Leaf Extract (MLE) significantly increased maize fresh and dry weights at BUK and Kobo. At both sites, biomass rose steadily with higher NCU rates, with the 125% NCU treatment producing the highest fresh and dry weights and the control the lowest.

MLE also improved biomass at increasing concentrations, with 9% MLE giving the best results at both locations. Notably, interactions between NCU and MLE were significant at BUK for





both fresh and dry weight, and at Kabo for total dry weight, indicating that the two inputs worked synergistically to boost maize growth and biomass production.

**Table 7:** Effects of Neem Coated Urea and *Moringa* Leaf Extract on Plant Fresh Weight (kg)/Plot and Total Dry Weight (kg)/Plot of Maize at BUK and Kabo, Kano State

Treatments	BUK		KABO	
	Plant fresh weight (kg)/Plot	Total dry weight (kg)/Plot	Plant fresh weight (kg)/Plot	Total dry weight (kg)/Plot
0%NCU	0.09e	15.17e	0.10e	15.97e
75%NCU	0.19d	30.83d	0.19d	28.64d
100%NCU	0.30b	48.58b	0.30b	46.40b
125%NCU	0.33a	54.10a	0.33a	50.64a
UREA	0.25c	40.46c	0.25c	38.20c
SE±	0.0018	0.28	0.001	0.10
P-value	0.0001	0.0001	0.0001	0.0001
MLE				
0%	0.22c	36.29d	0.22d	33.19d
5%	0.23b	37.75c	0.23c	35.86c
7%	0.23ab	38.38b	0.24b	37.09b
9%	0.24a	38.90a	0.25a	37.83a
SE±	0.0016	0.25	0.001	0.09
P-value	0.0001	0.0001	0.0001	0.0001
NCU x MLE				
P-value	0.03	0.03	0.34	0.0001

Means followed by the same letter (s) within a column are not significantly different at  $P \leq 0.05$

## DISCUSSION

### Physical and Chemical Properties of the Experimental Soils

The sandy loam soils used in the study showed good drainage and aeration, typical of the Sudan Savanna (Yakubu *et al.*, 2020), and their slightly acidic pH (6.09–6.24) is ideal for maize nutrient availability (Brady & Weil, 2019). Both soils were non-saline (Ogunwole *et al.*, 2018) and contained moderate organic carbon, but low nitrogen and phosphorus reflecting the nutrient depletion common in Nigerian savanna soils (Esu, 2010; Akinrinde & Obigbesan, 2000). These deficiencies justify using fertilizers like NCU and MLE to boost soil fertility. The soils also showed  $\text{Ca}^{2+}$  dominance and moderate ECEC, consistent with moderately fertile but fertilizer-responsive savanna Alfisols (FAO, 2015). Micronutrients were within maize sufficiency ranges (Alloway, 2008), with slight site differences linked to parent material.

### Response of Maize Plant Height to Neem Coated Urea and *Moringa* Leaf Extract

Maize plant height increased steadily with higher rates of Neem-Coated Urea (NCU), especially by 7 WAS, due to its slow-release nitrogen that supports continuous vegetative growth (Sharma *et al.*, 2019). The tallest plants at 125% NCU confirm that nitrogen was a limiting factor in both soils matching the low nitrogen levels observed earlier. *Moringa* Leaf Extract (MLE) also improved height, likely because its natural growth stimulants (zeatin, ascorbic acid, phenolics) promote cell division and elongation (Mbinda *et al.*, 2020; Fakayode *et al.*, 2021). Early-stage growth (3 WAS) showed no major differences, which is expected before nitrogen and growth hormones fully take effect.

The lack of a significant  $\text{NCU} \times \text{MLE}$  interaction suggests that both treatments boosted growth independently rather than synergistically. This aligns with earlier findings that controlled-release nitrogen and foliar MLE each enhance maize growth (Chianu *et al.*, 2018; Masuda & Goldsmith, 2019). Overall, the results underscore the value of combining organic and inorganic inputs to support strong vegetative development in maize.



### **Response of Maize Stem Diameter to Neem Coated Urea and *Moringa* Leaf Extract**

Neem-Coated Urea (NCU) significantly increased maize stem diameter at 7 WAS, confirming that its slow, steady nitrogen release improved nutrient uptake and vegetative strength (Singh *et al.*, 2020). The thicker stems observed at 125% NCU highlight that nitrogen was initially limiting in the soil and that neem coating helped reduce losses and boost nitrogen-use efficiency (Ghosh *et al.*, 2015). Since stem diameter is closely linked to vigor, photosynthetic capacity, and lodging resistance, this improvement reflects stronger, healthier maize plants (Amujoyegbe *et al.*, 2019).

*Moringa* Leaf Extract (MLE) also enhanced stem diameter due to its cytokinins, vitamins, and antioxidants, which promote cell division and elongation (Anwar *et al.*, 2021; Mbinda *et al.*, 2020).

The strong response at 9% MLE supports earlier findings that foliar *Moringa* extract improves stem girth and biomass (Fakayode *et al.*, 2021). Although NCU and MLE did not interact significantly, each improved stem development independently NCU by improving nitrogen availability and MLE by stimulating physiological processes (Chianu *et al.*, 2018). Overall, the results emphasize the value of combining organic and inorganic inputs for stronger maize growth in the savanna soils of northern Nigeria.

### **Response of Maize Leaf Area to Neem Coated Urea and *Moringa* Leaf Extract**

Neem-Coated Urea (NCU) significantly increased maize leaf area at 7 WAS, mainly because its slow nitrogen release improved chlorophyll formation, leaf expansion, and overall vegetative vigor (Fageria *et al.*, 2011). The steady rise in leaf area up to the 125% NCU rate shows that nitrogen was limiting in the soils, aligning with earlier findings that neem coating reduces nitrogen losses and enhances nitrogen uptake efficiency (Singh *et al.*, 2020; Ghosh *et al.*, 2015).

*Moringa* Leaf Extract (MLE) also boosted leaf area due to its natural growth regulators and nutrients, which stimulate leaf initiation and expansion (Anwar *et al.*, 2021). The stronger response at higher MLE concentrations agrees with studies showing that foliar *Moringa* enhances leaf area, chlorophyll content, and photosynthesis in maize (Mbinda *et al.*, 2020; Fakayode *et al.*, 2021). The lack of NCU  $\times$  MLE interaction indicates that each treatment worked independently NCU by improving nitrogen supply and MLE by enhancing physiological processes (Chianu *et al.*, 2018). Overall, both inputs increased leaf area, supporting greater photosynthetic capacity and potential grain yield under the semi-arid conditions of Kano State.

### **Chlorophyll Content**

Higher NCU rates led to increased chlorophyll content at both sites, showing that neem coating improved nitrogen availability and slowed nutrient losses, supporting chlorophyll formation and delaying leaf aging (Alam *et al.*, 2020; Yousaf *et al.*, 2022). *Moringa* Leaf Extract (especially at 9%) also enhanced chlorophyll levels due to its cytokinins, antioxidants, and minerals that stimulate chlorophyll synthesis and reduce degradation (Yameogo *et al.*, 2011; Howladar, 2014; Glover-Amengor & Aryeetey, 2019). Since the NCU  $\times$  MLE interaction was not significant, each treatment improved chlorophyll independently. Differences between sites likely reflect variations in soil fertility and microclimate, as nutrient-richer Kobo soils supported better chlorophyll development, consistent with Rahman *et al.* (2021). Overall, both NCU and MLE improved chlorophyll content, boosting photosynthetic efficiency and contributing to stronger maize growth and yield.

### **Crop Growth Rate (CGR) and Days to 50% Flowering**

Crop Growth Rate increased with higher NCU levels at both sites because neem coating improved nitrogen retention and steady supply, supporting photosynthesis and biomass buildup. This matches reports that NCU enhances CGR and productivity through better nitrogen conservation (Mishra *et al.*, 2020; Bhuiyan *et al.*, 2021; Shah *et al.*, 2023). Days to 50% flowering, however, remained largely unchanged, showing that the treatments influenced vegetative growth more than flowering time consistent with Khan *et al.* (2022). MLE also improved CGR, especially at Kobo, due to its zeatin, antioxidants, and minerals that stimulate photosynthesis and cell division (Nouman *et al.*, 2012; Yasmeen *et al.*, 2013; Ali *et al.*, 2021). Slightly earlier flowering at higher MLE rates supports previous observations of *Moringa* acting as a natural biostimulant (Marrufo *et al.*, 2020). Although the NCU  $\times$  MLE interaction was not significant, both independently boosted growth and





physiological efficiency, contributing to stronger vegetative development and stable flowering patterns.

#### **Plant Fresh Weight and Total Dry Weight**

Plant fresh weight and total dry weight increased sharply with higher levels of Neem-Coated Urea (NCU), showing that its slow and steady nitrogen release improved nutrient uptake and overall plant vigor. By reducing nitrogen losses, NCU supported continuous growth and biomass accumulation findings consistent with Alam *et al.* (2020) and Yousaf *et al.* (2022). This stronger biomass production also relates to earlier improvements in leaf area and chlorophyll, which enhance photosynthesis and assimilate formation (Bhuiyan *et al.*, 2021).

*Moringa* Leaf Extract (MLE) also boosted biomass because its cytokinins, vitamins, amino acids, and antioxidants stimulate metabolism and nutrient absorption (Nouman *et al.*, 2012; Yasmeen *et al.*, 2013). Similar results from Glover-Amengor and Aryeetey (2019) show that MLE strengthens physiological efficiency and dry matter production. The significant NCU  $\times$  MLE interaction indicates a synergistic effect: NCU enhances nutrient availability while MLE accelerates metabolic processes, creating optimal conditions for growth (Ali *et al.*, 2021).

Overall, greater fresh and dry weight under both NCU and MLE reflects improved nutrient use and plant productivity, forming the foundation for higher grain yield and more sustainable maize production.

#### **CONCLUSION AND RECOMMENDATION**

This study shows that Neem Coated Urea (NCU) outperforms conventional urea for maize cultivation in the Sudan Savanna, with the 125% recommended nitrogen rate delivering the highest grain yields and improved growth. *Moringa* Leaf Extract (MLE), particularly at 9%, effectively enhances maize growth and yield when applied as a foliar spray. Combining NCU and MLE produces a synergistic effect, with the slow-release nitrogen from NCU and the growth-promoting properties of MLE together maximizing maize yield and nutrient use efficiency. The optimal strategy for maize production in this region is 125% NCU paired with 9% MLE, consistently giving the best results across the study sites.

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