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Optimizing Okra (*Abelmoschus esculentus*) Productivity through Integrated Nutrient Management: Effects of NPK Fertilizer and Cow Dung Manure in the Sudan Savanna, Nigeria

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Abstract

This study evaluated the influence of NPK fertilizer and cow dung manure (CDM) on okra (*Abelmoschus esculentus*) yield and its components under the Sudan Savanna conditions of Nigeria. A 4 × 4 factorial experiment in a randomized complete block design with four replications was conducted at Teaching and Research farm, Bayero University, Kano. Treatments included four levels each of NPK fertilizer (0, 200, 300, and 400 kg ha^{-1}) and CDM (0, 2.5, 5.0, and 7.5 t ha^{-1}). Results indicated that NPK and CDM significantly ($P < 0.001$) influenced pod yield, with the highest yields obtained at 200 kg ha^{-1} NPK and 7.5 t ha^{-1} CDM (4367.00 kg ha^{-1} in 2019 and 9148.00 kg ha^{-1} in 2020), representing a 391% and 384% increase, respectively, over the control (888.00 kg ha^{-1} in 2019 and 1889.00 kg ha^{-1} in 2020). Pod length increased significantly ($P < 0.001$) with 100–200 kg ha^{-1} NPK in 2019 but was not significantly affected in 2020, suggesting seasonal variability. CDM at 7.5 t ha^{-1} produced the highest pod count (18.47 in 2019 and 24.73 in 2020), outperforming lower rates. The findings underscore the benefits of integrated nutrient management, as the combination of NPK and CDM enhanced soil fertility, increased pod number, and improved total yield. These results confirm that organic and inorganic fertilizers complement each other in optimizing okra productivity. Thus, integrated nutrient management using 200 kg ha^{-1} NPK and 7.5 t ha^{-1} CDM could be adopted by the farmers for sustainable okra production in nutrient-deficient soils of the Sudan Savanna region.

Keywords: *Fertilization strategy, okra, yield optimization, soil fertility, Sudan savanna*

Introductıon

Okra (*Abelmoschus esculentus* L. Moench) is an economically important vegetable crop widely cultivated in tropical and subtropical regions, including Nigeria. It is rich in vitamins, minerals, and antioxidants, making it an essential part of human nutrition (Ibitoye and Kolawole, 2022). However, the yield of okra in the Sudan Savanna ecology of Nigeria remains low due to poor soil fertility and inadequate nutrient management practices (Hamisu *et al.,* 2021). Integrated Nutrient Management (INM), incorporating the principles of Integrated Soil Fertility Management (ISFM), is a sustainable approach to enhancing soil health, crop productivity, and long-term agricultural viability (Pathan *et al.,* 2024). By combining organic and inorganic fertilizers, this approach optimizes nutrient availability, where organic amendments improve soil structure and microbial activity, while inorganic fertilizers provide essential nutrients for plant growth (Liu *et al.,* 2024). Additionally, Justus von Liebig's law of the minimum states that plant growth is limited by the most deficient nutrient, reinforcing the need for balanced fertilization to maximize okra yield (Bimpe *et al.,* 2023).
Despite the importance of okra in Nigeria, its yield remains suboptimal due to nutrient depletion, poor soil fertility, and over-reliance on synthetic fertilizers (Badu Brempong and Addo-Danso*,* 2022). Conventional fertilization methods often lead to soil degradation, nutrient imbalances, and declining crop productivity (Akter *et al*., 2020; Ayodele *et al*., 2020). Additionally, excessive use of inorganic fertilizers contributes to environmental pollution and increased production costs (Abdalla *et al*., 2024). The limited adoption of integrated nutrient management strategies in the Sudan Savanna region exacerbates the problem, necessitating research on the most effective nutrient management approach to enhance okra yield while maintaining soil health.
Previous studies indicate that INM enhances soil structure, microbial activity, and nutrient availability, leading to higher crop productivity (Yusuf *et al*., 2020; Gupta *et al.,* 2022). However, in the Sudan Savanna region, erratic rainfall, high temperatures, and nutrient-deficient soils pose significant challenges to crop production (Olowolafe and Dibal, 2019), highlighting the need to assess INM’s impact on okra yield and its components to optimize nutrient management for sustainable agriculture in Nigeria. This study aims to evaluate the impact of different rates of NPK fertilizer and CDM on the yield and yield components of okra under Sudan Savanna conditions.

Materials And Methods

The trials were conducted at the Teaching and Research Farm of Bayero University, Kano (Latitude 11º 58.861ˈN and Longitude 08º 31.177ˈE, with altitude of 476m above sea level). The experimental field was properly cleared of debris ad stumps. The land was then ploughed, harrowed to fine tilt and ridged. The field was demarcated into three replicates consisting of sixteen plots of gross plot size of 3 m x 3 m (9 m^2) and a net plot of 3 m x 1.5 m (4.5 m^2) which consists of the two inner rows. A pathway of 0.5 m and 1.0 m was between plots and replication was maintained to provide ease of movement and prevent nutrient drift. The experiment was a 4 x 4 factorial combination laid out in a randomized complete block design with four replications. The treatments comprised of varied rates of NPK fertilizer (0, 200, 300, and 400 kg ha^{-1}) and cow dung manure (CDM) (0, 2.5, 5.0, and 7.5 t ha^{-1}), resulting in 16 treatment combinations.

The okra seeds variety NHB-AI-13 was sourced from the National Horticultural Research (NIHORT) substation, Bagauda, Kano state. The cow dung was sourced from the livestock unit of the department of Animal Science of Bayero University Kano while the NPK fertilizer was from the department of Agronomy, BUK. The cow dung manure was applied as a basal application by broadcasting and incorporating it into the soil two weeks prior to sowing for ease of decomposition and to allow CO_2 escape, thus preventing scorching of the tender okra seedlings. NPK fertilizer (15-15-15) was applied according to the designated rates at 2 WAS about 10 cm radius away from the plant stand using ring method. For the treatments without CDM and NPK, no manure was applied throughout the growing season.

Three to four seed s of okra (NBH-AI-13) were sown directly into the soil at a depth of 2 cm with a spacing of 30 cm x 30 cm. the seedlings were later thinned to one plant per stand at 2 WAS. The crops were managed using standard agronomic practices for okra cultivation, including weeding, and pest control. Weeding was done manually as at when due using hoe. The defoliating insect pest were managed using Lampda (Cyhalothrin 2.5 EC) a contact insecticide applied at 2 L ha^{-1} using Cp3 knapsack sprayer set at a pressure of 2.1 kg m^{-2}.
Data were collected using standard agronomic procedure on the following yield component and yield of okra: Number of pods per plant, Individual pod weight, pod length, pod diameter and total pod yield (kg ha^{-1}). All data collected was subjected to analysis of variance (ANOVA) using SAS (Version 9.1) and significant means were separated using Duncan Multiple Range Test (DMRT) at 5% probability level.

Results And Dıscussıon

Effects of NPK Fertilizers and Cow dung manure on pods count per plant and pod weight per plant

Table 1 presents the effect of NPK fertilizer and cow dung manure (CDM) on the pods count per plant and individual pod weight of okra during the 2019 and 2020 wet seasons. The results show that while both inputs significantly ($P < 0.001$) influenced pod number, they had no significant ($P > 0.05$) effect on individual pod weight. Higher pods count were recorded with NPK application (100-300 kg ha^{-1}), whereas the control resulted in the lowest values across both seasons. Similarly, CDM at 7.5 t ha^{-1} produced the highest pod count, followed by 5.0 t ha^{-1}, outperforming lower rates in both years. The effectiveness of high-rate NPK in enhancing pods count highlights its role in promoting reproductive growth, while CDM's success at 7.5 t ha^{-1} suggests that organic fertilization is a viable alternative to synthetic fertilizers for increasing okra yield. This underscores the importance of balanced nutrient management, particularly in nutrient-deficient soils. These findings align with Muhammad and Sanda (2019), who reported that applying 800 kg ha^{-1} of NPK or a 50:50 combination of NPK and poultry manure significantly increased the number of pods per plant and overall yield. Similarly, Adekiya *et al.* (2020) found that poultry manure application improved okra pod production in comparison to sole NPK fertilizer.

The interaction between NPK and CDM on the pods count per plant was significant across both seasons, as shown in Table 2. The combined application of 200 kg ha^{-1} NPK and 7.5 t ha^{-1} CDM produced the highest pods count per plant in 2019 (18.47) and 2020 (24.73), outperforming other treatment combinations. This suggests that integrating organic and inorganic fertilizers creates a more balanced nutrient supply, enhancing pod formation and overall productivity. These findings align with those of Meena (2024), who reported that combining organic and inorganic fertilizers improved fruit set and pod production in okra. Similarly, Karim *et al.* (2024) found that integrating mineral fertilizers with organic amendments significantly enhanced crop yield by improving soil nutrient availability and plant growth. These results reinforce the benefits of integrated nutrient management in optimizing okra production through improved soil fertility and plant performance.

Table 1: Effect of NPK and Cow dung manure on pods count per plant and pod weight per plant of Okra at BUK during 2019 and 2020 wet season

Treatment	Pods count Plant-1 (#)		Individual Pod weight (g)	
	2019	2020	2019	2020
NPK (kg ha-1)				
0	9.65b	12.82c	22.86	39.25
100	11.36a	15.23ab	26.10	39.91
200	12.53a	16.23a	24.25	43.91
300	11.87a	14.73b	26.18	44.16
LS	**	**	NS	NS
SE±	0.46	0.43	2.45	1.89
Cowdung Manure (t ha-1) [CDM]				
0	9.38c	11.86c	20.01	41.42
2.5	9.83c	12.98bc	26.60	42.83
5.0	11.21b	14.23h	25..04	41.75
7.5	15.00a	19.94a	27.75	41.25
LS	*	**	NS	NS
SE±	0.46	0.43	2.45	1.89
Interaction				
NPK x CDM	**	**	NS	NS

Means followed by the same letter(s) are not significantly different at 5% level of probability according to DMR Test. LS=Level of significance; **and *=Significant at 1and 5%; NS=Not significant

Table 2: Interaction of NPK and Cow dung manure on Pods count per plant of Okra during 2019 and 2020 wet season

Treatment	Cow dung Manure (t ha-1)			
	0	2.5	5.0	7.5
NPK (kg ha-1)		2019		
0	6.97no	7.13j-o	11.40c-g	13.10bcd
100	12.10b-e	8.43i-o	10.87d-i	13.97bc
200	10.07e-m	11.13d-h	10.47d-k	18.47a
300	10.10e-l	10.80d-j	12.10b-f	14.47b
LS		**		
SE±		0.92		
		2020		
0	8.93im	13.13fgh	12.73f-i	16.47c
100	13.50f	13.37fg	12.67f-j	21.40b
200	11.67f-k	12.67f-j	16.40cd	24.73a
300	13.33fg	12.73f-i	15.10de	17.73c
LS		**		
SE±		0.87		

Means followed by same letter(s) are not significantly different at 5% level of probability according to SNK Test.

Effects of NPK Fertilizers and Cow dung manure on Pod length, Pod diameter, and Total pod yield per hectare. The effects of NPK and CDM rates on pod length, pod diameter, and total pod yield of okra in the 2019 and 2020 seasons are presented in Table 3. Results show that applying 100 and 200 kg/ha NPK significantly (P <0.001) increased pod length in 2019 but had no significant (P > 0.05) effect in 2020, suggesting seasonal variability in nutrient response. Similarly, pod diameter was not significantly affected in either season, indicating that factors such as genetics, soil conditions, and environmental variables may play a more dominant role than nutrient application alone. However, the significant increase in total pod yield (3011.14 & 3011.14 kg ha^{-1}) with 200 kg ha^{-1} NPK application across both seasons highlights the importance of adequate nutrient supply in enhancing productivity. This suggests that while pod size may not be directly influenced, optimizing NPK application can significantly boost total yield, making it essential for maximizing okra production. These findings align with Esmond *et al.* (2023), who reported a significant increase in okra pod weight and yield with higher NPK rates, while Sabo and Zubairu (2021) and Sababa *et al.* (2024), who found that optimal NPK and NPS fertilizer rates improved pod length and yield, reinforcing the role of proper nutrient management in enhancing okra productivity, respectively.

Table 3: Effect of NPK and Cow dung manure on Pod length, Pod diameter and Total pod yield of Okra at Bauchi during 2019 and 2020 wet season

Treatment	Pod length (cm)		Pod diameter (cm)		Total pod yield (Kg ha^{-1})	
	2019	2020	2019	2020	2019	2020
NPK (kg ha^{-1})						
0	7.31^{b}	8.21	10.40	10.99	1715.10^{d}	2490.00^{c}
100	7.99^{a}	8.39	10.69	11.26	2348.21^{c}	4463.25^{b}
200	7.65^{a}	8.43	10.34	11.16	3011.14^{a}	5366.83^{a}
300	7.51^{b}	8.58	10.34	11.23	2678.10^{b}	4712.42^{b}
LS	**	NS	0.16	0.17	**	**
SE±	0.12	0.14	NS	NS	81.38	131.09
Cow dung Manure [CDM] (t ha^{-1})						
0	7.75	8.12	10.59	10.58^{b}	1690.20^{c}	2671.25^{d}
2.5	7.45	8.32	10.52	11.28^{a}	2389.12^{b}	4018.25^{c}
5.0	7.66	8.62	10.19	11.31^{a}	2606.00^{b}	5413.83^{b}
7.5	7.57	8.63	10.47	11.52^{a}	3066.10^{a}	6955.17^{a}
LS	NS	0.14	NS	*	**	**
SE±	0.12	0.14	0.16	0.17	81.38	131.09
Interaction						
NPK x CDM	NS	NS	NS	NS	**	**

Means followed by the same letter(s) are not significantly different at 5% level of probability according to DMR Test. LS=Level of significance; **and *=Significant at 1and 5%; NS=Not significant

On the other hand, CDM application had no significant ($P > 0.05$) effect on pod length across both seasons or pod diameter in 2019 but significantly increased pod thickness compared to the control in 2020, indicating improved pod quality. Additionally, the significant rise in pod yield with CDM application underscores its role in enhancing productivity. The highest yield recorded with 7.5 t ha^{-1} CDM in both seasons (3066.10 kg ha^{-1} in 2019 and 955.17 kg ha^{-1} in 2020) suggests this rate provides optimal nutrient availability for okra growth. However, seasonal yield variations indicate possible environmental influences on nutrient efficiency. These findings highlight the benefits of organic fertilization in improving okra yield and pod quality, positioning CDM as a viable alternative or supplement to synthetic fertilizers for sustainable production. This study aligns with Kamunyu *et al*. (2023), who found that applying 5-7 t ha^{-1} of poultry, cattle, or goat manure significantly increased okra yield and pod quality by enhancing soil nutrients and microbial activity. Similarly, Olowokere *et al.* (2021) reported that composted cow dung at 10-30 t/ha improved pod thickness, length, and overall yield, reinforcing the role of organic amendments in sustainable okra production.

The interaction between NPK and CDM on total pod yield was highly significant ($P < 0.001$), as shown in Table 4, where the combined application of 200 kg ha^{-1} NPK and 7.5 t ha^{-1} CDM resulted in the highest yields (4367.00 kg ha^{-1} in 2019 and 9148.00 kg ha^{-1} in 2020). This suggests that integrating organic and inorganic fertilizers provides a balanced and efficient nutrient supply, enhancing crop productivity. In contrast, the lowest yields recorded with the 0×0 combination (888.00 kg ha^{-1} in 2019 and 1889.00 kg ha^{-1} in 2020) highlight the detrimental impact of nutrient deficiency on okra production. The variation in yield between seasons also indicates potential environmental influences on nutrient uptake and efficiency. These findings align with Akinmutimi *et al.* (2023), who reported that combining poultry manure and NPK fertilizer significantly improved okra growth and yield compared to sole applications or control treatments. Similarly, Adekiya *et al*. (2020) and Mondai *et al*. (2022) in their separate studies found that organic manure sources outperformed NPK fertilizer in enhancing soil properties and okra productivity, reinforcing the importance of integrating organic and inorganic fertilizers. This confirms that the synergistic use of organic and synthetic fertilizers optimizes nutrient availability, leading to higher okra yields and sustainable agricultural production.

Table 4: Interaction of NPK and Cow dung manure on Total pod yield of Okra at BUK during 2019 and 2020 wet season

	Cow dung Manure (t ha^{-1})			
Treatment	0	2.5	5.0	7.5

Turkish Science and Technology Publishing (TURSTEP)
www.turstep.com.tr

NPK (kg ha^{-1})		2019		
0	888.00^{o}	1267.00^{mn}	2214.00^{g-k}	2522.00^{f-h}
100	1517.00^{mn}	2239.00^{fghi}	2450.00^{f-i}	3185.00^{cd}
200	1619.00^{klm}	2570.00^{c}	3218.00^{c}	4637.00^{a}
300	2768.00^{cde}	3481.00^{b}	2542.00^{fg}	1918.00^{h-l}
LS		**		
SE±		162.75		
		2020		
0	1889.00^{o}	3792.00^{jk}	5898.00^{cd}	6381.00^{bc}
100	2458.67^{no}	3333.00^{klm}	5177.00^{d-g}	6884.33^{b}
200	2862.33^{mn}	4098.00^{ij}	5359.04^{de}	9148.00^{a}
300	3459.00^{j-l}	4850.00^{e-i}	5133.33^{d-h}	5407.33^{d}
LS		**		
SE±		262.18		

Means followed by same letter(s) are not significantly different at 5% level of probability according to SNK Test.

Conclusıon And Recommendatıon

This study demonstrated that the combined application of NPK fertilizer and cow dung manure significantly improves okra yield and yield components. The highest pod yield was obtained with the interaction of 200 kg ha^{-1} NPK and 7.5 t ha^{-1} CDM, highlighting the effectiveness of integrated nutrient management. While pod size showed seasonal variability, pod yield consistently increased with appropriate fertilization. The results suggest that balanced nutrient supply from organic and inorganic fertilizers enhances soil fertility and maximizes crop productivity. The findings emphasize the need for sustainable soil fertility management to ensure long-term agricultural productivity in the Sudan Savanna region of Nigeria. Therefore, to maximize okra yield, farmers in the study region should adopt integrated nutrient management by applying 200 kg ha^{-1} NPK and 7.5 t ha^{-1} CDM.

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