



**GROWTH AND YIELD RESPONSE OF OKRA (*Abelmoschus esculentus* L.) AS
AFFECTED BY VARYING RATES OF NPK FERTILIZER AND COWDUNG
MANURE IN A SEMI ARID ECOLOGY**

***¹Shittu, E. A., ²Alobo, A. I. and ¹Buhari, F. Z.**

¹Department of Agronomy, Bayero University Kano, PMB 3011, Kano State, Nigeria

²Department of Agricultural Education, Yusuf Maitama University of Education, P.M.B. 3045, Kano State, Nigeria

*Correspondence Email: seabraham.agr@buk.edu.ng;

GSM: +2348024695219

ABSTRACT

A two-year field study (2019–2020) at Bayero University Kano, Nigeria, assessed integrated nutrient management (INM) effects on okra growth and yield using a 4×4 factorial randomized complete block design. Treatments included NPK fertilizer (0, 100, 200, 300 kg ha⁻¹) and cow dung manure (CDM) (0, 2.5, 5.0, 7.5 t ha⁻¹). NPK, CDM, and their interaction significantly ($P < 0.05$) influenced growth and yield. In 2019, 300 kg ha⁻¹ NPK produced taller plants at 4 weeks after sowing (WAS), while 100–300 kg ha⁻¹ NPK enhanced height at 8 WAS. CDM (7.5 t ha⁻¹) consistently increased plant height in both years, with the tallest plants at 4 WAS in 2019 under 300 kg ha⁻¹ NPK + 2.5 t ha⁻¹ CDM. Similar trends were observed for leaf number and area. CDM (7.5 t ha⁻¹) significantly increased branches at 8 and 12 WAS in 2019 and 8 WAS in 2020. Stem girth was highest at 12 WAS in 2019, with 200 kg ha⁻¹ NPK + 7.5 t ha⁻¹ CDM. NPK delayed 50% flowering in 2019. The highest pod yield obtained with 200 kg ha⁻¹ NPK across both seasons, peaking when combined with 7.5 t ha⁻¹ CDM, confirming INM's potential for sustainable okra production in semi-arid regions.

Key words: Growth, Integrated, Nutrient, Management and Yield

INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) is a vital vegetable crop cultivated extensively in tropical and subtropical regions. It is esteemed for its rich nutritional profile, offering significant amounts of vitamins A and C, thiamine, riboflavin, niacin, calcium, phosphorus, and potassium, contributing to both dietary and economic value (Oklahoma State University Extension, 2021).

Despite its significance, okra production in semi-arid regions is constrained by declining soil fertility, severely limiting crop yields. Nutrient-depleted soils, especially in sub-Saharan Africa, pose a major challenge to agricultural productivity (FAO, 2019; Stewart *et al.*, 2020). While inorganic fertilizers like NPK offer a quick fix, overreliance on them can cause soil acidification, nutrient imbalances, and environmental pollution (Adamu and Musa, 2022). Organic amendments such as cow dung manure (CDM) present a sustainable alternative by improving soil structure, boosting microbial activity, and providing slow-release nutrients. However, their delayed nutrient availability may not meet the immediate demands of fast-growing crops (Aryal *et al.*, 2021; Adamu and Musa, 2022).

To optimize okra production, integrated soil fertility management strategies are essential. Combining organic manures like CDM with inorganic fertilizers like NPK has shown promise in enhancing soil health and crop performance. Recent research confirms that such integrated approaches significantly improve okra growth and yield (Adekiya *et al.*, 2020; Ojeniyi and Adeniyi, 2020), offering a viable solution for sustainable cultivation in nutrient-deficient semi-arid soils. The integration of organic and inorganic fertilizers, known as integrated nutrient management (INM), offers a promising solution by combining the quick nutrient availability of chemical fertilizers with the long-term benefits of organic amendments (Ahmed *et al.*, 2022; Bekele *et al.*, 2022). This approach not only enhances crop performance but also contributes to sustainable soil fertility management, reducing the negative environmental impacts associated with the overuse of chemical fertilizers (Sande *et al.*, 2024).

This study investigates the combined use of NPK fertilizers and cow dung manure to improve okra growth in semi-arid regions by balancing nutrients and enhancing soil quality. While integrated nutrient management is known to boost crop performance, specific guidelines for okra in such environments are lacking. The trial aims to assess okra's response to different NPK and cow dung manure rates, with the goal of developing a sustainable soil fertility strategy to increase yields in nutrient-deficient semi-arid soils.

MATERIALS AND METHODS

Experimental Site

The trials were conducted at the Teaching and Research Farm of Bayero University, Kano (11° 58.861' N; 08° 31.177' E; alt. 476 m asl). The experimental field was properly cleared of debris and 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 m²) and a net plot of 3 m x 1.5 m (4.5 m²) 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.

Treatment and Experimental Design

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.

Sources of experimental materials

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.

Fertilizer Application

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 CO₂ 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.

Crop Establishment and Management

Three to four seeds 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 Collection

Data were collected using standard agronomic procedure on the following growth and yield parameters: Plant height, number of leaves, leaf area, number of branches, days to 50% flowering, stem girth, and pod yield were measured at 4, 8, and 12 weeks after sowing (WAS) using a graduated meter rule, leaf area meter, visual counting, and a digital Vernier caliper, with averages recorded; pod yield (t ha⁻¹) was determined by weighing harvested pods and converting to tons per hectare.

Statistical Analysis

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 DISCUSSION

Plant height (cm)

Table 1 presents okra plant height responses to NPK and cow dung manure (CDM) during 2019-2020 wet seasons. NPK and CDM significantly ($P < 0.001$) affected plant height at 4 and 8 WAS in 2019 only. The tallest plants at 4 WAS observed with 300 kg ha⁻¹ NPK, while 100-300 kg ha⁻¹ NPK produced the tallest plants at 8 WAS, likely due to nitrogen's role in vegetative growth, consistent with Kumar *et al.* (2017); Ayoola and Adeniyi (2019). However, excessive nitrogen may promote excessive vegetative growth at the expense of pod yield (Witt and Dobermann, 2016).

Applying 7.5 t ha⁻¹ CDM produced significantly ($P < 0.001$) taller plants at 4 WAS in 2019, although similar to 2.5-5.0 t ha⁻¹ and outperformed other treatments in 2020. This growth enhancement likely stems from CDM's soil-improving properties, as reported by Adeleye *et al.* (2017), including better nutrient availability and water retention from organic matter, consistent with Nyamangara *et al.* (2015). NPK and CDM levels also significantly influenced okra growth in 2020 across sampling periods.

Table 1: Plant height of Okra as affected by NPK and Cow dung manure at 4, 8 and 12 WAS during 2019 and 2020 wet seasons

Treatment	2019			2020		
	Weeks after sowing (WAS)					
	4	8	12	4	8	12
NPK (kg ha⁻¹)						
0	25.67 ^c	41.48 ^b	52.48	12.37	48.57	133.32
100	35.94 ^b	53.05 ^a	84.75	12.57	51.37	154.60
200	35.36 ^b	54.20 ^a	85.01	12.82	56.59	150.70
300	39.30 ^a	56.92 ^a	93.22	12.93	54.69	154.80
LS	**	**	NS	NS	NS	NS
SE±	0.81	1.74	25.34	0.84	4.51	6.73
Cow dung Manure [CDM] (t ha⁻¹)						
0	29.88 ^c	48.32 ^b	77.86	11.13	48.78	147.60
2.5	34.14 ^b	49.70 ^b	77.94	12.37	49.38	149.34
5.0	35.67 ^{ab}	51.68 ^b	136.40	11.80	51.18	149.40
7.5	36.57 ^a	58.86 ^a	83.30	11.83	54.88	148.57
LS	**	**	NS	NS	NS	NS
SE±	0.81	1.74	25.34	0.84	4.51	6.73
Interaction						
NPK x CDM	**	NS	NS	NS	NS	NS

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

Interaction between NPK and Cow dung manure on Plant height (cm) of okra at 4 WAS during 2019 wet season

The interaction between NPK and CDM on plant height at 4 WAS in 2019 was highly significant ($P < 0.001$) and is shown in Table 2. The result revealed that the combination of 300 kg ha⁻¹ NPK and 2.5 t ha⁻¹ of CDM significantly produced the tallest plant, although at par with other interaction combinations compared to the 0 NPK x 0 CDM combination that had the shortest plants. This suggests that combining these fertilizers could create a more balanced

nutrient environment, enhancing plant height more effectively than either input alone, consistent with the findings of Palm *et al.* (2017), who emphasized the benefits of integrated nutrient management.

Table 2: Interaction between NPK and Cow dung manure on Plant height (cm) of Okra at 4 WAS during 2019 wet season

Treatment	Cow dung manure (t ha ⁻¹)			
	0	2.5	5.0	7.5
NPK (Kg ha⁻¹)				
0	19.70 ^o	25.83 ^{l-n}	27.83 ^{i-m}	29.31 ^{h-l}
100	37.47 ^{a-g}	35.08 ^{ef}	30.33 ^{h-k}	40.90 ^{ab}
200	28.60 ^{a-e}	33.93 ^{efg}	40.43 ^{abc}	38.47 ^{a-f}
300	33.73 ^{f-i}	41.73 ^a	40.10 ^{a-d}	33.67 ^{g-j}
SE±		1.62		

Means followed by common letter(s) across rows and columns are not significantly different at 5% level of probability according to DMR Test.

Number of leaves per plant

Leaf production responded strongly ($P < 0.001$) to NPK, with 300 kg ha⁻¹ maximizing leaves at 4 WAS in 2019. While all NPK rates showed similar effects at 8 WAS, 100-300 kg ha⁻¹ outperformed the control at 12 WAS, demonstrating NPK's rapid nutrient mobilization for vegetative growth, consistent with Fageria and Moreira (2016) and Sharma and Saini (2018), though excessive N may not boost yields (Alam *et al.*, 2018). CDM at 5.0-7.5 t ha⁻¹ significantly enhanced leaf count at 4 WAS compared to control, attributable to improved soil fertility and moisture retention as reported by Nyamangara *et al.* (2015) and Shittu and Bassey (2023), underscoring organic amendments' long-term soil benefits.

Table 3: Number of leaves per plant of Okra as affected by NPK and Cow dung manure at 4, 8 and 12 WAS during 2019 and 2020 Wet season

Treatment	2019			2020		
	Weeks after sowing (WAS)					
	4	8	12	4	8	12
NPK (kg ha⁻¹)						
0	6.19 ^c	14.70 ^b	17.42 ^b	6.37	25.29	37.82
100	6.89 ^b	15.02 ^b	24.65 ^a	6.90	29.59	41.78
200	7.00 ^b	16.52 ^{ab}	23.07 ^a	6.50	27.75	40.24
300	7.48 ^a	18.23 ^a	23.31 ^a	7.00	27.80	39.09
LS	**	**	**	NS	NS	NS
SE±	0.05	0.72	1.22	0.33	2.24	3.83
Cow dung manure [CDM] (t ha⁻¹)						
0	6.22 ^c	15.92	20.87	6.65	25.24	36.15
2.5	6.45 ^b	16.13	22.20	6.84	25.28	37.05
5.0	6.95 ^a	16.30	22.68	6.58	25.59	43.27
7.5	6.89 ^a	17.12	22.69	6.70	28.03	37.40
LS	**	NS	NS	NS	NS	NS
SE±	0.05	0.72	1.22	0.33	2.24	3.82
Interaction						
NPK x CDM	**	NS	NS	NS	NS	NS

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

Interaction between NPK and Cow dung manure on Number of leaves of okra at 4 WAS during 2019 wet season

Table 4 shows the interaction between NPK and CDM on number of leaves at 4 WAS in 2019 season, where the combination of 300 kg ha⁻¹ of NPK and 7.5 t ha⁻¹ of CDM produced the highest number of leaves, illustrating the synergistic effect of integrated fertilizer management. This finding supports the work of Goyal and Prasad (2016), who found that balanced fertilization enhances leaf production, crucial for photosynthesis and overall plant health.

Table 4: Interaction between NPK and Cow dung manure on Number of leaves of okra at 4 WAS during 2019 wet season

Treatment	Cow dung manure (t ha ⁻¹)			
	0	2.5	5.0	7.5
NPK (Kg ha⁻¹)				
0	5.70 ^{mn}	6.03 ^{k-n}	6.80 ^{gh}	6.23 ^{kl}
100	7.00 ^{efg}	6.10 ^{klm}	7.27 ^{de}	7.20 ^{def}
200	7.33 ^{cd}	6.33 ^{jk}	6.70 ^{ghi}	7.63 ^{bc}
300	8.78 ^a	7.67 ^k	7.03 ^{def}	6.50 ^{fgh}
SE±		0.33		

Means followed by common letter(s) across rows and columns are not significantly different at 5% level of probability according to DMR Test.

Leaf area per plant (cm²) plant of Okra as affected by NPK and Cow dung manure at 4, 8 and 12 WAS during 2019 and 2020 wet season

Table 5 shows that the largest leaf area was observed with 200 and 300 kg ha⁻¹ of NPK at 4 and 8 WAS in the 2019 season compared with other rates, while it was not significant in the season across the sampling periods. Thus, enhancing the plant's photosynthetic capacity. Larger leaves capture more light, supporting higher photosynthetic rates and potentially leading to increased biomass and yield, which aligns similarly with the findings of Singh and Lal (2017). CDM positive effect on leaf area, particularly at 7.5 t ha⁻¹ during the 2019 season, underscores the importance of organic matter in promoting plant development, as also reported by Nyamangara *et al.* (2015) and Kebede *et al.* (2023).

Table 5: Leaf area per plant (cm²) plant of Okra as affected by NPK and Cow dung manure at 4, 8 and 12 WAS during 2019 and 2020 wet season

Treatment	2019			2020		
	Weeks after sowing (WAS)					
	4	8	12	4	8	12
NPK (kg ha⁻¹)						
0	23.00 ^c	157.87 ^c	190.57	84.05	264.51	280.78
100	37.45 ^b	158.51 ^b	219.09	66.10	294.15	422.54
200	38.87 ^a	196.25 ^a	225.36	72.48	292.60	366.27
300	39.48 ^a	202.19 ^a	248.15	86.54	330.42	439.73
LS	**	**	NS	NS	NS	NS
SE±	0.33	9.75	11.40	18.71	19.78	33.62
Cow dung manure [CDM] (t ha⁻¹)						
0	38.38 ^b	154.73	216.77	83.55	276.68	354.51
2.5	27.18 ^d	166.33	267.11	99.87	305.55	381.30
5.0	31.62 ^c	196.39	246.66	66.32	300.47	436.27
7.5	41.65 ^a	167.37	222.63	59.43	298.95	437.24
LS	**	NS	NS	NS	NS	NS
SE±	0.33	9.75	11.40	18.71	19.78	33.63
Interaction						
NPK x CDM	**	NS	NS	NS	NS	NS

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

Interaction between NPK and Cow dung manure on leaf area (cm²) of Okra at 4 WAS during 2019 wet season

The interaction of NPK fertilizer and CDM on leaves was significant at 4 WAS in 2019 and is presented in Table 6, where significantly larger leaves were achieved by combining 300 kg ha⁻¹ of NPK with 7.5 t ha⁻¹ CDM rates compared with the rest of the interaction combination, suggesting that integrated nutrient management can maximize the photosynthetic potential of okra plants, leading to better growth and yield. This finding corroborates those of Palm *et al.* (2017).

Table 6: Interaction between NPK and Cow dung manure on leaf area (cm²) of Okra at 4 WAS during 2019 wet season

Treatment	Cow dung manure (t ha ⁻¹)			
	0	2.5	5.0	7.5
NPK (Kg ha⁻¹)				
0	12.70 ^p	15.00 ^o	25.97 ^{jk}	38.53 ^{fg}
100	39.10 ^{ef}	21.10 ⁿ	44.80 ^{cd}	50.47 ^b
200	44.73 ^{c-e}	33.97 ^{g-i}	25.87 ^{k-l}	45.23 ^c
300	32.40 ^{ij}	38.67 ^f	26.87 ^{kl}	57.00 ^a
SE±		0.66		

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

Number of branches per plant of Okra as affected by NPK and Cow dung manure at 4, 8 and 12 WAS during 2019 and 2020 wet season

Okra branching patterns (Table 7) revealed NPK rates had no significant ($P > 0.05$) effect across seasons, while CDM significantly increased branch numbers at 8-12 WAS in 2019 and 8 WAS in 2020. The 7.5 t ha⁻¹ CDM rate consistently produced more branches, suggesting optimal effectiveness at this application level during critical growth stages. This response likely stems from CDM's gradual nutrient release, which sustains growth and enhances branching - potentially increasing flowering sites and yield. These findings support Zewide and Ademe's (2025) recent work demonstrating CDM's growth-enhancing effects in faba bean.

Table 7: Number of branches per plant of Okra as affected by NPK and Cow dung manure at 4, 8 and 12 WAS during 2019 and 2020 wet season

Treatment	2019		2020	
	Weeks after sowing (WAS)			
	8	12	8	12
NPK (Kg ha⁻¹)				
0	3.92	7.81	4.50	7.94
100	4.29	7.98	5.89	8.78
200	4.78	8.19	5.69	9.05
300	5.17	8.62	5.50	9.63
LS	NS	NS	NS	NS
SE±	0.47	0.70	0.51	0.63
Cow dung manure [CDM] (t ha⁻¹)				
0	3.78 ^b	5.86 ^b	4.50 ^b	7.81
2.5	3.87 ^b	6.82 ^b	4.78 ^b	9.26
5.0	4.54 ^b	9.80 ^a	5.33 ^b	9.54
7.5	6.60 ^a	10.10 ^a	6.88 ^a	8.79
LS	**	**	*	NS
SE±	0.47	0.70	0.51	0.63
Interaction				
NPK x CDM	NS	NS	NS	NS

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

Stem girth (cm) plant of Okra as affected by NPK and Cow dung manure at 4, 8 and 12 WAS during 2019 and 2020 wet season

Table 8 shows that stem girth, a vital parameter for plant support, increased significantly with NPK application at 8 and 12 WAS during 2019. A robust stem can support more branches and leaves, beneficial for overall plant health, a finding supported by Dobermann and Fairhurst (2015). CDM also contributed to thicker stems, indicating that organic matter improves soil structure and nutrient availability, supporting stronger plant growth.

Table 8: Stem girth (cm) plant of Okra as affected by NPK and Cow dung manure at 4, 8 and 12 WAS during 2019 and 2020 wet season

Treatment	2019			2020		
	Weeks after sowing (WAS)					
	4	8	12	4	8	12
NPK (Kg ha ⁻¹)						
0	1.66	3.73 ^d	7.94 ^d	1.29	6.117	7.40
100	1.70	4.06 ^a	9.15 ^c	1.40	7.46	7.93
200	1.89	4.08 ^a	9.31 ^a	1.45	7.26	8.35
300	1.92	4.27 ^a	9.24 ^b	1.45	7.35	8.36
LS	NS	**	**	NS	NS	NS
SE±	0.66	0.86	0.017	0.14	0.36	0.51
Cow dung manure [CDM] (t ha ⁻¹)						
0	1.63	3.55 ^b	8.05 ^d	1.43	7.08	7.78
2.5	1.81	4.33 ^a	8.72 ^c	1.55	6.91	8.62
5.0	1.85	4.14 ^a	8.77 ^b	1.21	6.85	7.41
7.5	1.90	4.14 ^a	9.11 ^a	1.40	7.34	8.33
LS	*	**	**	NS	NS	NS
SE±	0.66	0.86	0.02	0.14	0.36	0.51
Interaction						
NPK x CDM	NS	NS	**	NS	NS	NS

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

Interaction between NPK and Cow dung manure on stem girth of okra at 12 WAS during 2019 wet season

Stem girth showed a significant NPK × CDM interaction at 12 WAS during the 2019 season and is shown in Table 9. The combination of 200 kg ha⁻¹ NPK with 7.5 t ha⁻¹ CDM produced significantly thicker stems although comparable to other treatments except except 0 NPK x 0 CDM that resulted in thinner stems, indicating enhanced nutrient availability and use efficiency from fertilizer synergy. These results align with Asadu *et al.* (2024) and Farooq *et al.* (2024), demonstrating that integrated fertilization improves soil health, nutrient uptake, and yield potential while potentially reducing input requirements.

Table 9: Interaction between NPK and Cow dung manure on stem girth of okra at 12 WAS during 2019 wet season

Treatment	Cow dung manure (t ha ⁻¹)			
	0	2.5	5.0	7.5
NPK (Kg ha⁻¹)				
0	6.90 ^{mn}	9.50 ^{a-f}	7.83 ^{lm}	7.53 ^{l-n}
100	9.63 ^{a-d}	8.30 ^{g-k}	9.10 ^{b-f}	9.57 ^{a-e}
200	9.80 ^{abc}	8.23 ^{g-l}	8.90 ^{c-s}	10.30 ^a
300	9.90 ^{ab}	9.0 ^{b-h}	9.00 ^{b-i}	9.03 ^{b-h}
SE±		0.33		

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

Days to 50% flowering and Pod yield (t ha⁻¹) of Okra as affected by NPK and Cow dung manure at 4, 8 and 12 WAS during 2019 and 2020 wet season

Days to 50% flowering and pod yield responses to NPK and cow dung manure (CDM) revealed significant effects on okra production (Table 10). NPK application at 100-300 kg ha⁻¹ delayed 50% flowering in the 2019 season, demonstrating nutrients' role in reproductive development, while control plants flowered earlier due to nutrient deficiency stress. CDM similarly improved flowering, supporting Goyal and Prasad's (2016) findings on organic amendments enhancing reproductive growth. Pod yield peaked at 200 kg ha⁻¹ NPK in both seasons ($P < 0.001$), with higher rates reducing yields, indicating optimal nutrient thresholds. Conversely, yield increased progressively with CDM up to 7.5 t ha⁻¹, suggesting potential for even higher organic application rates.

Table 10: Days to 50% flowering and Pod yield (t ha⁻¹) of Okra as affected by NPK and Cow dung manure at 4, 8 and 12 WAS during 2019 and 2020 wet season

Treatment	50% Flowering (#)		Pod Yield (t ha ⁻¹)	
	2019	2020	2019	2020
NPK (kg ha⁻¹)				
0	59.42 ^b	59.41	1.72 ^d	2.49 ^c
100	59.91 ^a	56.83	2.35 ^c	4.46 ^b
200	60.42 ^a	58.08	3.01 ^a	5.37 ^a
300	61.67 ^a	58.75	2.68 ^b	4.71 ^b
LS	**	NS	**	**
SE±	0.82	1.05	0.081	0.131
Cow dung manure [CDM] (t ha⁻¹)				
0	57.50 ^b	59.83	1.70 ^c	2.67 ^d
2.5	57.92	59.08	2.39 ^b	4.02 ^c
5.0	60.67 ^a	59.39	2.61 ^a	5.41 ^b
7.5	62.50 ^a	59.50	3.07 ^a	6.96 ^a
LS	**	NS	**	**
SE±	0.82	1.05	0.081	0.131
Interaction				
NPK x CDM	NS	NS	**	**

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

Interaction between NPK and Cow dung manure on total pod yield (t ha⁻¹) of okra at harvest during 2019 and 2020 wet season

The interaction between NPK and CDM on pod yield of okra in the 2019 and 2020 seasons is shown in Table 11, where the combination of 200 kg ha⁻¹ of NPK and 7.5 t ha⁻¹ of CDM produced the highest total pod yield, indicating that integrated fertilizer use optimizes nutrient availability and supports higher yields. This finding aligns with the work of Adekiya and Agbede (2019), Shittu (2024) and Shittu *et al.* (2024), who highlighted the benefits of integrated nutrient management in enhancing crop yield.

Table 11: Interaction between NPK and Cow dung manure on total pod yield (t ha^{-1}) of okra at harvest during 2019 and 2020 wet season

Treatment	Cow dung manure (t ha^{-1})			
	0	2.5	5.0	7.5
NPK (Kg ha^{-1})				
0	0.89 ⁿ	1.27 ^{mn}	2.21 ^{g-k}	2.52 ^{fg}
100	1.52 ^{mn}	2.24 ^{f-i}	2.45 ^{f-i}	3.19 ^{cd}
200	1.62 ^{klm}	2.57 ^c	3.22 ^c	4.64 ^a
300	2.77 ^{cde}	3.48 ^b	2.54 ^{fg}	1.92 ^{h-l}
SE \pm		0.163		
		2020		
0	1.89 ^o	3.79 ^{jk}	5.90 ^{cd}	6.38 ^{bc}
100	2.46 ^{no}	3.33 ^{klm}	5.18 ^{d-g}	6.88 ^b
200	2.86 ^{mn}	4.10 ^{ij}	5.36 ^{de}	9.15 ^a
300	3.46 ^{kl}	4.85 ^{e-i}	5.13 ^{d-h}	5.41 ^d
SE \pm		0.262		

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

CONCLUSION AND RECOMMENDATIONS

The study demonstrated the significant positive impacts of integrated nutrient management (INM) using NPK fertilizer and cow dung manure (CDM) on okra growth and yield in a semi-arid environment. Application of 200 kg ha^{-1} NPK in conjunction with 7.5 t ha^{-1} CDM proved most effective in maximizing pod yield, highlighting the synergistic benefits of combining organic and inorganic nutrient sources. These findings suggest that INM offers a promising and sustainable approach to enhance okra productivity in nutrient-deficient soils of semi-arid regions, promoting both economic returns for farmers and long-term soil health. Further research could explore the economic viability of this integrated approach and optimize nutrient management strategies for other vegetable crops in similar agro-ecological zones.

REFERENCES

- Adamu, U. K. and Musa, A. (2022). Effect of Cow Dung on Growth and Yield of Okra (*Abelmoschus esculentus* L.) in Gaya, Kano State, Nigeria. *Journal of Agripreneurship and Sustainable Development*, **5**(2): 54-61.
- Adekiya, A. O. and Agbede, T. M. (2019). Effect of poultry manure and NPK fertilizer on soil physical properties, growth, yield, quality and mineral compositions of okra. *BMC Plant Biology*, **19**(1):278*288. <https://doi.org/10.1186/s12870-019-1856-1>.
- Adekiya, A. O., Ejue, W. S., Olayanju, A., Dunsin, O., Aboyeji, C. M., Aremu, C., Adegbite, K. and Akinpelu, O. (2020). Different organic manure sources and NPK fertilizer on soil chemical properties, growth, yield and quality of okra. *Scientific reports*, **10**(1): 160-173. <https://doi.org/10.1038/s41598-020-73291-x>.
- Ahmed, S., Matiullah, K., Taqi, R., Ahmad, R. and Iqbal, J. (2022). Integrated use of bio-organic and chemical fertilizer to enhance yield and nutrients content of tomato. *Eurasian Journal of SoilScience*, **11**(2):126-132. <https://doi.org/10.3389/fenvs.2022.902999>
- Alam, M. S., Khan, M. A., and Ahmed, N. (2018). Effects of different levels of nitrogen and phosphorus fertilizers on growth and yield of okra. *International Journal of Agronomy*, 1-6. <https://doi.org/10.1155/2018/4275024>.
- Aryal, J. P., Sapkota, T. B., Krupnik, T. J., Rahut, D. B., Jat, M. L. and Stirling, C. M. (2021). Factors affecting farmers' use of organic and inorganic fertilizers in South Asia. *Environmental Science and Pollution Research International*, **28**(37):140-149. <https://doi.org/10.1007/s11356-021-13975-7>.
- Asadu, C. O., Ezema, C. A., Ekwueme, B. N., Onu, C. E., Onoh, I. M., Adejoh, T., Timothy Ezeorba, T. P. C., Ogbonna, C. C., Otuh, P. I., Okoye, J. O., and Emmanuel, U. O. (2024). Enhanced efficiency fertilizers: Overview of production methods, materials used, nutrients release mechanisms, benefits and considerations. *Environmental Pollution and Management*, **1**:32-48. <https://doi.org/10.1016/j.epm.2024.07.002>.



- Ayoola, O. T. and Adeniyi, O. N. (2019). Effects of organic and inorganic fertilizer on growth, yield and nutrient content of okra (*Abelmoschus esculentus* L.). *Agriculture and Food Security*, **8**(1):1-9. <https://doi.org/10.1186/s40066-019-0223-9>.
- Bekele, G., Dechassa, N., and Tana, T. (2022). Effect of inorganic and organic fertilizers on productivity of groundnut (*Arachis hypogaea* L.) varieties in East Hararghe, Eastern Ethiopia. *Oil Crop Science*, **7**: 112–121. doi: 10.1016/j.ocsci.2022.07.002.
- Dobermann, A. and Fairhurst, T. (2015). *Nutrient management for sustainable rice production in Asia*. International Rice Research Institute.
- Fageria, N. K. and Moreira, A. (2016). The role of mineral nutrition on root growth of crop plants. *Advances in Agronomy*, **138**: 63-96. <https://doi.org/10.1016/bs.agron.2016.05.001>
- FAO. (2019). The State of Food and Agriculture 2019. Moving forward on food loss and waste reduction. Rome. License: CC BY-NC-SA 3.0 IGO
- Farooq, M. S., Majeed, A., Ghazy, A. *et al.* (2024). Partial replacement of inorganic fertilizer with organic inputs for enhanced nitrogen use efficiency, grain yield, and decreased nitrogen losses under rice-based systems of mid-latitudes. *BMC Plant Biology*, **24**: 919. <https://doi.org/10.1186/s12870-024-05629-w>.
- Goyal, S. R. and Prasad, R. (2016). Role of organic amendments in improving soil fertility and crop productivity. *Soil Science Society of America Journal*, **80**(5): 1137-1150. <https://doi.org/10.2136/sssaj2016.05.0134>.
- Kebede, T., Diriba, D. and Boki, A. (2023). The Effect of Organic Solid Waste Compost on Soil Properties, Growth, and Yield of Swiss Chard Crop (*Beta vulgaris* L.). *The Scientific World Journal*. 6175746. <https://doi.org/10.1155/2023/6175746>.
- Kumar, M., Sharma, S. K., and Saini, S. K. (2017). Effects of nitrogen levels on growth and yield of okra (*Abelmoschus esculentus* L.). *Agronomy Journal*, **109**(3): 857-864. <https://doi.org/10.2134/agronj2016.09.0545>.
- Nyamangara, J., Piha, M. I. and Giller, K. E. (2015). Effectiveness of cattle manure and nitrogen fertilizer for maize production in semi-arid Zimbabwe. *Field Crops Research*, **174**: 1-10. <https://doi.org/10.1016/j.fcr.2014.11.012>.
- Oklahoma State University Extension. (2021). Okra Production. <https://extension.okstate.edu/fact-sheets/okra-production.html>
- Ojeniyi, S. O. and Adeniyi, O. N. (2020). Response of okra (*Abelmoschus esculentus* L. Moench) to different sources of organic and inorganic fertilizers. *Heliyon*, **6**(9): e04932. <https://doi.org/10.1016/j.heliyon.2020.e04932>.
- Palm, C. A., Smukler, S. M. and Sullivan, C. C. (2017). Agroecological intensification of maize-based cropping systems in sub-Saharan Africa. *Agricultural Systems*, **155**: 182-193. <https://doi.org/10.1016/j.agsy.2017.01.012>.
- Sande, T. J., Tindwa, H. J., Alovisi, A. M. T., Shitindi, M. J. and Semoka, J. M. (2024). Enhancing sustainable crop production through integrated nutrient management: a focus on vermicompost, bio-enriched rock phosphate, and inorganic fertilizers – A systematic review. *Frontiers in Agronomy*, **6**. <https://doi.org/10.3389/fagro.2024.1422876>.
- Sharma, S. P. and Saini, S. K. (2018). Nitrogen management for okra growth and yield. *Horticultural Science*, **45**(3):134-140. <https://doi.org/10.1016/j.hortscience.2018.05.006>.
- Shittu, E.A. (2024). Correlation and Regression Analysis of Cucumber (*Cucumis sativus* L) as Affected by Manure teas of Different Sources and Rates in the Sudano-Sahelian ecology of Nigeria. *World Scientific News*, WSN **198**: 182-193.
- Shittu, E.A., and Bassey, M.S. (2023). Sustainable Okra (*Abelmoschus esculentus* L.) Productivity as Influenced by Fortification of Goat Manure with Rice Husk Ash in Northern Guinea Savanna Ecology of Nigeria. *Journal of Plant Development*, **30**(2): 89-97. doi: 10.47743/jpd.2023.30.1.929.
- Shittu, E. A., Hussaini, M. A. and Garba, A., (2024). Physiological Growth Characters, Yield and Quality Response of Cucumber (*Cucumis sativus* L) as impacted by compost and horse manure teas”, Pp 153-157. In: A. E. Obayelu, O. M. Olosunde, P. B. Abdulsalam-Saghir, O. S. Sowande, E. O. Fakoya and J. J. Atungwu (Eds). Theme: Climate Change: Agricultural Innovations and Bio-entrepreneurship for Sustainable Development, Food Sufficiency and Economic Transformation. *Proceedings of the 8th Annual Conference and 67th AGM-ABEOKUTA of The Association of Deans of Agriculture in Nigeria Universities (ADAN), Held at The FUNAAB Red Senate chamber, Abeokuta, Ogun State, Nigeria, from July 7th to 11th, 312pp*.
- Singh, H. and Lal, M. (2017). Impact of integrated nutrient management on okra growth and yield. *Journal of Plant Nutrition*, **40**(9):1298-1310. <https://doi.org/10.1080/01904167.2017.1298492>.



- Stewart, Z. P., Pierzynski, G. M., Middendorf, B. J. and Prasad, P. V. V. (2020). Approaches to improve soil fertility in sub-Saharan Africa. *Journal of Experimental Botany*, **71**(2): 632-641.
<https://doi.org/10.1093/jxb/erz446>.
- Witt, C., and Dobermann, A. (2016). Integrated nutrient management for sustainable rice production. *Agronomy Journal*, **108**(4):1443-1454.
<https://doi.org/10.2134/agronj2016.01.0032>.
- Zewide, I. and Ademe, A. (2025). Unlocking faba bean (*Vicia faba* L.) potential: How cattle manure and fertilizer boost yields in Kaffa Zone, South-Western Ethiopia. *Heliyon*, **11**(2): e41771.
<https://doi.org/10.1016/j.heliyon.2025.e41771>.