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Assessing the Effect of NPK Fertilizer on the Growth and Yield of Nsukka Landrace Okra (*Abelmoschus esculentus* (L.) Moench)

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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Abstract

Okra (*Abelmoschus esculentus* (L.) Moench) is an important fruit vegetable in tropical Africa, but its productivity may be constrained by inadequate soil fertility and inappropriate fertiliser rates. This study evaluated the effects of four NPK 15:15:15 rates on the growth and yield of the Nsukka landrace. A field experiment was conducted at the Teaching and Research Farm, Department of Crop Science, University of Nigeria, Nsukka, using a randomised complete block design with four replications. Treatments comprised 0, 150, 300, and 450 kg ha^{-1} NPK 15:15:15. Data were collected at two-week intervals on plant height, number of leaves, stem girth, flowering, fruiting, fruit dimensions, number of fruits per plant, fruit weight per plant, and total fruit yield. The 450 kg ha^{-1} rate produced the greatest plant height and stem girth at most assessment periods, whereas 300 kg ha^{-1} produced the highest number of leaves at 6 weeks after planting. The 300 kg ha^{-1} treatment also resulted in the shortest time to flowering and fruiting and produced the highest fruit length, number of fruits per plant, fruit weight per plant, and total fruit yield. Total yield reached 6.55 t ha^{-1} at 300 kg ha^{-1}, compared with 5.29 t ha^{-1} at 450 kg ha^{-1} and 2.30 t ha^{-1} in the control. Under the conditions of this study, 300 kg ha^{-1} NPK 15:15:15 provided the most favourable overall yield response for Nsukka landrace okra.

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Keywords: Abelmoschus esculentus; Nsukka landrace; NPK 15:15:15; fertiliser rate; plant growth; fruit yield; inorganic fertiliser; randomised complete block design; soil fertility.

1. Introduction

Okra (*Abelmoschus esculentus* (L.) Moench), also called 'lady's finger', is a flowering plant belonging to the family Malvaceae. It originated in East Africa and is now widely distributed throughout tropical, subtropical, and warmer temperate regions, where it is used as a fruit vegetable, including in soups in tropical Africa (Benchasri, 2012). Okra occurs in two colour varieties, red and green. Both varieties have a similar flavour, and red okra turns green when cooked.

Okra plays a vital role in the human diet because it is rich in vitamin C, vitamin K_1, magnesium, folate, fibre, and antioxidants such as polyphenols (Elkhalifa et al., 2021; Jallow et al., 2021). It is also low in calories and contains more protein than many other fruits and vegetables. Okra may help lower the risk of heart disease by binding to cholesterol during digestion and may support healthy blood glucose levels in people with prediabetes and type 2 diabetes (Mokgalaboni et al., 2023). Folate in okra supports a healthy pregnancy by helping to reduce the risk of brain and spinal conditions in a developing foetus (Kushi et al., 2023). Okra contains a thick, gel-like substance called mucilage, which can bind to cholesterol during digestion, causing it to be excreted in the stool rather than absorbed into the bloodstream. The polyphenol content of okra may help prevent heart disease and stroke (Islam, 2019). Okra also contains a protein called lectin, which may inhibit the growth of human cancer cells (Monte et al., 2014). Research further suggests that okra may have beneficial effects on glycaemic control in people with prediabetes and type 2 diabetes (Bahari et al., 2024; Mokgalaboni et al., 2023). Young, immature okra pods are consumed as fresh produce and can be prepared in different forms (Elkhalifa et al., 2021). The fruit can be boiled, fried, or cooked (Elkhalifa et al., 2021). Okra is a common household vegetable crop cultivated primarily for its fresh pods and leaves. It is generally referred to as 'a perfect villager's vegetable' because it is a rich source of dietary fibre, minerals, and vitamins and is often recommended by nutritionists for cholesterol control and weight-reduction programmes (Islam, 2019; Mokgalaboni et al., 2023).

Furthermore, okra mucilage is suitable for medicinal and industrial applications (Adetuyi et al., 2011). In Thailand, okra is commonly boiled in water, producing slimy soups and sauces that are widely consumed. The fruits also serve as thickeners (Moekchantuk & Kumar, 2004), while the leaves are considered suitable cattle feed.

The inherently low fertility of tropical soils, characterised by low-activity clay, organic matter, nitrogen, phosphorus, and exchangeable bases, has increased the need for professionally sound soil-fertility improvement practices (Ngala et al., 2013). In recent years, these practices have included the adoption of appropriate and adequate fertiliser packages involving organic and/or inorganic fertilisers (Osundare & Fawole, 2018). The application of different organic amendments, wastes, and composts increases soil-nutrient availability, improves soil-structure stability, and helps maintain stable soil pH (Jiang et al., 2019).

Inorganic fertilisers, on the other hand, can improve crop yields, soil pH, total nutrient content, and nutrient availability more rapidly (Akande et al., 2010), particularly in the tropics, where soils are adversely affected by suboptimal fertility and erosion, resulting in nutrient depletion and changes in soil-organism populations. However, their use is constrained by soil acidity, scarcity, nutrient imbalance, and high cost, which may place them beyond the reach of resource-poor farmers. Excessive application may also depress yield by reducing the number of fruits, delaying fruit formation, and reducing fruit set (Amina et al., 2023). Recent studies have further shown that okra growth and yield responses depend on the balance and source of applied nutrients, including integrated nutrient management, organic amendments, and combined mineral-organic fertilisation (Acharya et al., 2024; Devi et al., 2025; Kesamreddy et al., 2025; Patel et al., 2024; Tan et al., 2023).

A major aspect of crop production and management that limits crop yield is the use of an inappropriate fertiliser type or application rate, together with, to some extent, erratic environmental factors (Jagadeeswaran et al., 2005). Plant requirements for the nutrient elements supplied by fertilisers may differ according to growth and developmental needs. Nitrogen, phosphorus, and potassium (NPK) fertilisers contain different concentrations of the elements required for plant growth and development. Consequently, different NPK concentrations can produce different growth and yield responses (Akande et al., 2010; Jallow et al., 2021). Although some research has examined okra growth, little is known about the effects of appropriate NPK fertiliser rates on the morphological growth and yield of okra in Nsukka, Nigeria (Amina et al., 2023; Jallow et al., 2021). Determining a suitable NPK fertiliser rate for the local soil may therefore support okra production in Nsukka and potentially in comparable areas of West Africa. Despite these advances, location-specific evidence remains limited regarding the response of the Nsukka landrace to graded NPK 15:15:15 rates under the soil and climatic conditions of Nsukka, particularly whether application above a moderate rate provides an additional yield benefit.

1.1 Objective

This study aimed to evaluate the effects of NPK 15:15:15 applied at 0, 150, 300, and 450 kg ha^{-1} on the morphological growth, flowering, fruiting, and yield of Nsukka landrace okra.

2. Materials and Methods

2.1 Experimental Site

The experiment was conducted at the Research Farm of the Department of Crop Science, University of Nigeria, Nsukka. The site is located in the derived savanna zone at latitude 06°52′N and longitude 07°24′E, at an altitude of 447.26 m above sea level (Uguru et al., 2011).

2.2 Soil Sample Analysis

Before planting, topsoil samples were collected from the field and taken to the Department of Soil Science Laboratory to determine soil pH, NPK status, and other soil nutrients.

2.3 Experimental Materials

The experimental materials used in the study included:

i. Nsukka okra landrace.
ii. NPK fertiliser (15:15:15), sourced from a licensed commercial fertiliser dealer in a local market in Nsukka.
iii. Measuring tape, used to measure plant height and leaf length.
iv. Vernier caliper, used to measure stem girth and pod girth.
v. Pegs, used to mark demarcations and boundaries for beds and pathways.
vi. Sensitive weighing balance, used to measure yield traits such as pod yield, fruit weight per plant, individual fruit weight, and 100-seed weight.
vii. Record book, used to record the data collected from the field.
viii. Hoe, used to prepare the beds.
ix. Cutlass, used to clear grasses and stumps from the demarcated experimental site.

Treatment

Four treatment rates of NPK 15:15:15 fertiliser were used:

i. 0 kg ha^{-1} (control)
ii. 150 kg ha^{-1}
iii. 300 kg ha^{-1}
iv. 450 kg ha^{-1}

2.4 Experimental Design

The experiment was arranged in a randomised complete block design (RCBD) with four replications. A site measuring 15 m × 6 m was demarcated, ploughed, and prepared as seedbed plots. Each seedbed plot represented one treatment. Four sample plants were established per plot. The seedbeds were divided into four blocks, each containing four plots, giving a total of 16 plots. Each plot measured 2.8 m × 1.6 m, with a spacing of 0.5 m between plots. Okra seeds were sown directly into the soil at a spacing of 60 cm × 5 cm. The seeds were presoaked for 24 h before sowing to soften them. Three seeds were planted per hole, and one seedling was subsequently thinned, resulting in a total of 64 experimental plants. The experimental site lies within the derived savanna of the south-eastern ecological zone of Nigeria. The climate is humid tropical and is characterised by two distinct seasons: a wet season from April to October and a dry season from November to March. The experiment was conducted during the wet season.

2.5 Fertilizer Application

NPK (15:15:15) fertiliser was applied to the plants using the ring method. Briefly, a shallow ring was made around each plant, and a matchbox was used to measure the quantity applied per plant. The ring was then covered with soil. Fertiliser was applied three times during the experiment.

2.6 Post Planting Operations

Weeding was performed manually at two-week intervals using a hoe to protect the okra plants from weed competition and disease attack.

2.7 Irrigation

Irrigation was carried out using a watering can as required, based on the prevailing climatic conditions and soil-moisture status.

2.8 Harvest

Immature fruits were harvested one week after flowering and fruit formation using a razor blade.

2.9 Data Collection and Analysis

Data were collected at two-week intervals for the following agronomic and yield parameters: number of leaves, plant height, stem girth, days to 50% flowering, days to 100% flowering, days to 50% fruiting, fruit length, fruit girth, number of fruits per plant, fruit weight per plant, and total fruit yield (t ha^{-1}). For all data presented in Tables 2-6, the mean values of four experimental measurements are reported because the experiment was replicated four times.

2.10 Mode of Data Collection

i. Number of leaves: The total number of leaves on each sample plant was counted and recorded.
ii. Plant height: The height of each plant was measured from the soil surface to the plant tip.
iii. Stem girth: Stem girth was measured at the broad portion of the stem near ground level.
iv. Days to 50% flowering: This was determined by counting the number of days from sowing until half of the plants had started flowering.
v. Days to 100% flowering: This was determined by counting the number of days from sowing until all plants had flowered.
vi. Days to 50% fruiting: This was determined by counting the number of days from sowing until half of the plants had started fruiting.
vii. Fruit length: The length of each fruit pod was measured using a measuring tape.
viii. Fruit girth: The circumference of each fruit pod was measured using a Vernier caliper.
ix. Number of fruits per plant: The fruit pods produced by each plant were counted.
x. Fruit weight per plant: A sensitive weighing balance was used to determine the weight of freshly harvested fruit pods from each plant.

Total pod yield: The fruits from the sample plants were weighed, and the fruit weight was converted to tonnes per hectare. The formula is expressed as follows:

$$\frac{\text{Average fruit weight per plant } (g) \text{ x number of plants per plot x number of plots per hectare}}{10{,}000} \quad \text{(Eq.1)}$$

2.11 Statistical Analysis

All collected data were subjected to analysis of variance (ANOVA) using GenStat Release 12.0 Discovery, 12th Edition, for the RCBD. Table 1 presents the analysis-of-variance structure used in this study. Treatment means were separated using Fisher's least significant difference (F-LSD) test at the 5% probability level (Obi, 2002).

Table 1. Analysis of Variance (ANOVA) Table for a 4x4 Randomized Complete Block Design (RCBD)

Sources of Variation	Degree of Freedom
Block (R-1)	4 -1 =3
Treatment (T-1)	4 -1=3
Error (T-1) (R-1)	(4 -1) (4 -1) =9
Total (TR -1)	(4 x4) -1 =15

3. Results

The physicochemical properties of the experimental soil before planting indicated a sandy-loam texture. The soil contained high proportions of fine and coarse sand, with values of 37.00% and 40.00%, respectively, together with measurable proportions of clay and silt. Regarding nutrient status, available phosphorus was 31.71 ppm, while moderate organic-matter content was recorded. The soil also contained a low nitrogen content (Table 2).

For the exchangeable cations, a cation-exchange capacity (CEC) of 24.8 cmol kg^{-1} was determined from the basic and acidic ions present. Furthermore, Ca^{2+} and Mg^{2+} values of 2.20 and 1.00 cmol kg^{-1}, respectively, were recorded. The experimental soil also contained low amounts of Na^+ and K^+.

Exchangeable Al^{3+} was 20.00, indicating that the experimental soil was mildly acidic. Base saturation was 13.78%, while the H^+ level was considerably lower (Table 2).

Table 2. Soil Physiochemical properties of the experimental site before planting

Parameters	Values obtained
Clay	12.00%
Silt	11.00%
Fine sand	37.00%
Coarse sand	40.00%
pH (H_2O)	6.50
pH (KCl)	6.20
Textural class	Sandy loam
Organic carbon (%)	4.918
Organic matter (%)	8.578
Nitrogen (%)	0.112
Available Phosphorus (ppm)	31.71
Exchangeable Cations (cmol/kg)	
Na^+	0.07
K^+	0.15
Ca^{2+}	2.20
Mg^{2+}	1.00
CEC (cmol/kg)	24.80
Exchangeable Acidity	
AI^{3+}	20.00
H^+	1.40
Base Saturation (%)	13.78%

The results in Table 3 show the effects of different NPK (15:15:15) fertiliser rates on the number of leaves per okra plant. The numbers of leaves were higher under the 450 and 300 kg ha^{-1} treatments than under the 150 kg ha^{-1} treatment and the control at 2, 4, 6, and 8 weeks after planting (WAP). The 450 kg ha^{-1} rate produced the highest numbers of leaves at 2, 4, and 8 WAP, with mean values of 7.22, 9.75, and 38.44 leaves, respectively, across four replicate measurements. These values were statistically similar to those obtained with the 300 kg ha^{-1} rate at the corresponding intervals. At 6 WAP, the 300 kg ha^{-1} treatment produced the highest number of leaves (20.21), followed by the 450 and 150 kg ha^{-1} treatments. The control (0 kg ha^{-1}) produced the lowest numbers of leaves at 2, 4, 6, and 8 WAP.

Table 3. Effects of different rates of NPK fertilizer on number of leaves at 2, 4, 6 and 8 weeks after planting (WAP)

	Number of Leaves			
Treatment	**Weeks after planting (WAP)**			
	2	**4**	**6**	**8**
0 kg ha^{-1}	4.75	7.24	15.77	27.38
150kg ha^{-1}	5.38	8.47	17.36	32.55
300kg ha^{-1}	6.25	8.91	20.21	37.63
450kg ha^{-1}	7.22	9.75	18.92	38.44
F-LSD $_{(0.05)}$	3.36	4.00	8.57	15.21

Where F-LSD$_{(0.05)}$ = Fisher's least significant difference at 5% level of probability

Table 4 shows the effects of different NPK fertiliser rates on stem girth at 2, 4, 6, and 8 WAP. The 450 kg ha^{-1} treatment produced the greatest stem girth at 2, 4, 6, and 8 WAP, with mean values of 1.94, 2.68, 4.45, and 5.67 cm, respectively. These values were similar to those obtained with 300 kg ha^{-1} at the corresponding intervals. The 150 kg ha^{-1} treatment produced a smaller stem girth, suggesting that this rate was insufficient to maximise stem growth. By contrast, the control (0 kg ha^{-1}) recorded the lowest stem-girth values at 2, 4, 6, and 8 WAP. These results indicate that NPK (15:15:15) application increased the stem girth of okra plants.

Table 4. Effects of different rates of NPK fertilizer on stem girth at 2, 4, 6 and 8 weeks after planting (WAP)

	Stem girth (cm)			
Treatment	**Weeks after planting (WAP**			
	2	**4**	**6**	**8**
0 kg ha^{-1}	0.38	1.36	3.05	4.12
150 kg ha^{-1}	0.91	2.11	3.66	4.87
300 kg ha^{-1}	1.46	2.48	4.20	5.43
450 kg ha^{-1}	1.94	2.68	4.45	5.67
F-LSD $_{(0.05)}$	**0.33**	**0.68**	**1.04**	**1.11**

Where F-LSD$_{(0.05)}$ = Fisher's least significant difference at 5% level of probability

Plant height approximately doubled between 4 and 6 WAP and was significantly greater than that of the control at 8 WAP (Table 5). The 450 kg ha^{-1} rate produced the highest plant heights at 4, 6, and 8 WAP, with mean values of 10.58, 20.91, and 48.59 cm, respectively. This treatment was followed by the 300 kg ha^{-1} rate at the same intervals, whereas the control (0 kg ha^{-1}) produced the lowest mean plant heights at 4, 6, and 8 WAP. At 2 WAP, the effects of 0, 150, 300, and 450 kg ha^{-1} NPK fertiliser on plant height were not significant ($p > 0.05$). Nevertheless, the 450 kg ha^{-1} rate produced a greater mean plant height than the control at 2 WAP (Table 5).

Table 5. Effects of different rates of NPK fertilizer on plant height at 2, 4, 6 and 8 weeks after planting (WAP)

	Plant height (cm)			
Treatment	**Weeks after planting (WAP)**			
	2	4	6	8
0 kg ha^{-1}	**2.55**	**7.38**	**15.72**	**27.37**
150 kg ha^{-1}	2.87	8.24	16.53	38.29
300 kg ha^{-1}	3.58	9.33	18.35	45.20
450 kg ha^{-1}	3.28	10.58	20.91	48.59
F-LSD $_{(0.05)}$	**NS**	**4.31**	**8.54**	**14.26**

Where F-LSD$_{(0.05)}$ = Fisher's least significant difference at 5% level of probability, NS = Non-significant

Table 6 shows that the different NPK fertiliser rates had significant effects ($p < 0.05$) on days to 50% flowering, days to 100% flowering, and days to 50% fruiting. The 300 kg ha^{-1} treatment produced the shortest times to 50% flowering (38.55 days), 100% flowering (39.27 days), and 50% fruiting (45.27 days). By contrast, plants in the control treatment (0 kg ha^{-1}) took the longest time to attain 50% flowering, 100% flowering, and 50% fruiting.

Table 6. Effects of different rates of NPK fertilizer days to 50% flowering, days to 100% flowering, and days to 50% fruiting

Treatments	D50%FL	D100%FL	D50%F
0 kg ha^{-1}	48.92	52.12	59.28
150 kg ha^{-1}	41.38	43.62	48.91
300 kg ha^{-1}	38.55	39.27	45.27
450 kg ha^{-1}	40.63	41.50	46.39
F-LSD $_{(0.05)}$	**5.628**	**6.112**	**6.082**

Where D50%FL = days to 50% flowering, D100%FL = 100% flowering, D50%F = days to 50% fruiting, F-LSD$_{(0.05)}$ = Fisher's least significant difference at 5% level of probability, NS = Non-significant

Table 7 shows that the application of different NPK (15:15:15) fertiliser rates improved most of the yield-related traits examined, except fruit girth (FG). The 300 kg ha^{-1} treatment produced greater fruit length, number of fruits per plant (NF/PL), fruit weight per plant (FW/PL), and total fruit yield (TFY) than the control (0 kg ha^{-1}), with mean values of 10.44 cm, 5.44 fruits, 9.29 g, and 6.55 t ha^{-1}, respectively. The results obtained with 450 kg ha^{-1} were generally similar to those obtained with 300 kg ha^{-1}, whereas 150 kg ha^{-1} was insufficient to produce comparable improvements in the measured yield traits. Fruit girth did not differ significantly among the 0, 150, 300, and 450 kg ha^{-1} treatments. However, the 300 kg ha^{-1} rate produced the highest mean fruit girth, while the control produced the lowest value (Table 7). Based on the calculated Fisher's least significant difference values, the 300 kg ha^{-1} rate produced the strongest overall improvement in the measured okra yield traits.

Table 7. Effects of different application rates of NPK fertilizer on yield traits of Okra

Treatments	FL(cm)	FG(cm)	NF/PL	FW/PL(g)	TFY(t/ha)
0kg ha^{-1}	8.65	10.22	2.15	6.28	2.30
150kg ha^{-1}	9.10	10.77	3.00	7.14	3.84
300kg ha^{-1}	10.44	11.68	5.44	9.29	6.55
450kg ha^{-1}	9.75	10.81	3.68	8.92	5.29
F-LSD $_{(0.05)}$	**1.114**	**NS**	**2.582**	**3.015**	**2.072**

Where FL = fruit length, FG = fruit girth, NF/PL = number of fruits per plant, FW/PL = fruit weight per plant, TFY = total fruit yield, F-LSD$_{(0.05)}$ = Fisher's Least significant difference at 5% level of probability, NS = Non-significant

4. Discussion

Crop production requires fertiliser application, particularly in areas with poor soils, to support adequate growth and yield. However, chemical fertilisers must be applied at rates appropriate for each crop (Amina et al., 2023). The application of inorganic fertilisers can contribute to increased agricultural food production (Akande et al., 2010).

Okra requires nutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sodium (Na), and sulphur (S) for soil-fertility maintenance and crop production (Khandaker et al., 2017). These nutrients perform specific functions and must be supplied to plants in appropriate quantities. Insufficient nutrient supply results in poor crop performance, restricted growth, and low yield (Adesida et al., 2019). In this study, okra plants treated with 450 kg ha^{-1} NPK fertiliser attained greater heights than plants under the other treatments, suggesting that an increase in the fertiliser-application rate was associated with increased plant height. One possible explanation is that high rates of NPK 15:15:15 promoted cell division and tissue formation, resulting in luxuriant vegetative growth and increased plant height (Miao et al., 2024). As expected, okra plants receiving NPK fertiliser produced greater yield-related traits than the control plants (0 kg ha^{-1}). The 300 kg ha^{-1} rate produced greater fruit length, number of fruits per plant, fruit weight per plant, and total fruit yield. Previous work showed that higher fertiliser-application rates significantly increased the growth and yield characteristics of okra but did not assess the sensitivity of these responses to the application rates (Jallow et al., 2021). The present study therefore examined which rate of NPK 15:15:15 was sufficient to maximise the yield of Nsukka landrace okra. Although the results suggest that 300 kg ha^{-1} NPK 15:15:15 was the most effective rate for okra yield in south-eastern Nigeria, this response may not apply to other regions, as indicated by a study conducted in northern Nigeria (Amina et al., 2023). Variations in soil properties and climate are therefore likely to influence crop responses to fertiliser application. Other limitations of this study include the absence of economic, nutrient-use-efficiency, and environmental assessments.

5. Conclusion

This study evaluated the response of Nsukka landrace okra to four rates of NPK 15:15:15 under field conditions in Nsukka, south-eastern Nigeria. Fertiliser application improved vegetative growth and yield-related traits compared with the unfertilised control. Although 450 kg ha^{-1} generally produced the greatest plant height and stem girth, it did not provide the highest fruit yield. The 300 kg ha^{-1} treatment resulted in the earliest flowering and fruiting and produced the greatest fruit length, number of fruits per plant, fruit weight per plant, and total fruit yield. Its total yield of 6.55 t ha^{-1} exceeded the yields obtained with 450 kg ha^{-1} and the control. These findings indicate that, under the soil and seasonal conditions of this experiment, 300 kg ha^{-1} NPK 15:15:15 gave the most favourable overall yield response. However, the result should be interpreted as location- and season-specific. Further studies should assess the response across seasons and locations and include organic nutrient sources, economic returns, nutrient-use efficiency, and potential environmental effects before broader recommendations are made.

6. Limitations

The experiment was conducted at a single location during one wet season and evaluated only one okra landrace and one NPK formulation. Consequently, the findings may not represent responses under different soils, climates, seasons, or genotypes. The study did not include an economic analysis, nutrient-use-efficiency assessment, or environmental evaluation.

Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation, and related scholarly work. The author(s) acknowledge the use of Grammarly and ChatGPT to assist with grammar checking, language refinement, reference formatting. These AI-assisted tools were not used as authors and did not replace the intellectual contributions or scholarly judgment of the author(s). All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the author(s). The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Author has declared that no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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