MORPHOLOGICAL AND REPRODUCTIVE ATTRIBUTES OF SELECTED CUCUMBER GENOTYPES UNDER HUMID TROPICAL CONDITION

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Abstract
Cucumber (*Cucumis sativus* L.) is an important vegetable crop that contributes to household nutrition, income generation, and food security, particularly in developing countries such as Nigeria where vegetables provide affordable sources of essential vitamins and minerals. This study evaluated the performance and genetic variability of selected cucumber genotypes under humid tropical conditions in Calabar (May to July, 2021), to identify high-yielding genotypes and key traits associated with fruit yield to support sustainable vegetable production. The experiment was conducted using a randomized complete block design with three replications, and data were collected on vegetative growth, flowering, yield components, and total fruit yield. Substantial variation was observed among the genotypes for most of the traits evaluated, indicating considerable genetic diversity and potential for improvement. Considering earliness in flowering and maturity, Kayin, Amarisa C16 and Nandini 732 performed better than others. Across other traits, Kayin, Amarisa C16, Oliveira C14, and Nandini 732 consistently showed superior performance, making them promising candidates for further breeding and wider cultivation.

Keywords: Adaptation, Environment, Phenology and Yield.

Introduction
Cucumber (*Cucumis sativus* L.) is a globally significant vegetable crop, cultivated for its edible fruits and valued in both fresh and processed markets. Global production of cucumbers and gherkins reached approximately 98 million metric tons, ranking as the third most produced vegetable worldwide reflecting strong market demand and wide consumer acceptance (FAOSTAT, 2024). Africa's share of world cucumber production is relatively modest, it has steadily increased, with continental output estimated at about 1.7 million tonnes in 2024 (IndexBox, 2024). In Nigeria, cucumber is widely cultivated across multiple agro-ecological zones, particularly where humidity and rainfall support year-round vegetable production (Umeh *et al.,* 2024). Although comprehensive national statistics are limited, field studies indicate meaningful variation in growth and yield traits among genotypes grown under local conditions (Umeh *et al.,* 2024). This localized production contributes to household nutrition and rural livelihoods, especially in urban and rural markets. Cucumber contributes significantly to both nutrition and economic livelihoods across diverse production systems. With its refreshing taste, high water content, and rich composition of vitamins and minerals, cucumber occupies an important

place in human diets and local food (Borecka & Karaś, 2025). Beyond fresh consumption, cucumbers are widely processed into pickles, juices and value-added products, supporting a range of market opportunities from small-scale enterprises to larger processing industries (Borecka & Karaś, 2025). Economically, cucumbers offer reliable income for farmers due to their short cropping cycle and year-round market demand. Irrespective of its importance, cucumber production in humid tropical environments faces persistent challenges. High humidity, heavy rains, and associated pest and disease pressures can limit crop performance and yield stability (Ma *et al.,* 2025). These conditions differ significantly from temperate or controlled environments. Consequently, there is a critical need to evaluate how cucumber genotypes perform to guide breeding and selection strategies tailored to tropical production systems. Some studies have reported significant differences among cucumber genotypes for vegetative traits such as vine length, number of branches, internode length, and flowering behavior, as well as for yield components including number of fruits per plant, fruit weight, and total yield (Odor *et al.,* 2017; Kumar et al., 2025). Shukla *et al.,* (2025) found substantial differences among genotypes for quantitative traits including fruit yield, primary branch number. Earlier studies conducted under diverse production systems showed that yield attributes, vine characteristics, and flowering traits often exhibit high phenotypic and genotypic variation, highlighting the genetic richness available for breeding (Tadkal *et al.,* 2024). Similar trends have been reported in studies involving segregating populations and hybrid evaluations, where superior progenies and crosses consistently expressed higher yield potential and better performance (Meena *et al.,* 2025). Studies conducted under protected cultivation systems, including net house conditions, further confirm that cucumber genotypes exhibit substantial variability for both yield and quality traits, reinforcing the adaptability of the crop to diverse growing conditions (Meena *et al.,* 2025). Despite notable progress in understanding cucumber genetic variability, most work has focused on environments that do not fully represent the complex stresses of humid tropical regions. This gap limits the practical application of selection criteria for local breeders and farmers who operate under variable climatic conditions. Therefore, characterizing the performance of cucumber genotypes in humid tropical environments is essential to identify traits that reliably enhance productivity and stability. Such insights can accelerate the development of improved, adaptable cucumber varieties capable of contributing to sustainable food security, particularly in regions where vegetable availability remains constrained by environmental and agronomic challenges. Although recent studies have clearly shown that cucumber possesses considerable genetic variability and that several yield related traits respond well to selection, much of this work has been carried out under controlled or location specific conditions (Gade *et al.,* 2025; Shukla *et al.,* 2025). In particular, information on how different cucumber genotypes perform in humid tropical environments is still limited. Such environments, like those found in southern

Nigeria, are characterized by high rainfall and humidity, conditions that can strongly influence plant growth, yield, and overall adaptability. This leaves uncertainty about which genotypes and traits are most suitable for selection in humid tropical regions. To address this gap, the present study evaluates the performance of selected cucumber genotypes under humid tropical conditions, with the aim of identifying reliable yield-related traits and adaptable, high performing genotypes that can support sustainable cucumber production and contribute to improved food security.

Materials and methods

The experiment was conducted at Crop Science Teaching and Research Farm, University of Calabar, Nigeria on 3rd May to July 2021. Calabar is located in Southern rainforest agro-ecological zone of Nigeria (4°58′ N 8° 19′ 30″ E) about 39 m above sea level and has annual rainfall of 2915 to 3500 mm and a temperature of 24 °C to 26 °C (Odor *et al.*, 2017). Prior to the commencement of the experiment, composite soil samples were collected at depths of 0 – 15 cm and 0 –30 cm. The samples were air-dried and passed through a 2 mm sieve for physico-chemical analysis. Organic carbon was determined using the Walkley–Black method as outlined by Nelson and Sommers (1982). Total nitrogen was analyzed following the Kjeldahl procedure described by Jackson (1962). Soil pH was measured in a 1:2 soil-to-water suspension with a digital pH meter. Exchangeable acidity was extracted in KCl and determined by titration. Micronutrient concentrations were assessed using the procedure of Udo *et al.* (2009). Particle size distribution was determined by the hydrometer method of Bouyoucos (1962). Seeds were collected from National Root Crop Research Institute Umudike and East West seeds company, Nigeria. The genotypes used were Nandini 732 F1, Market more, Kayin F1, Amarisa C16, 999, Oliveira C14 and Akpabuyo (land race). The experiment was laid out in randomized complete block design (RCBD) with three replications. Each plot size was 2 m^2, while the gross plot was 136 m^2. The blocks were separated by 1 m pathway while, the plots within each block were separated by 0.5 m pathway. Two seeds were planted per hole, which was later thinned to one, two weeks after planting. The plant spacing was 50 cm × 25 cm, giving a plant population of 80,000 plants ha^{-1}. The plots were weeded twice at 3 and 5 weeks after planting (WAP) and staking was done at 4 WAP. Data was collected from 4 plants in the net plot on the following: Number of days to 50 % emergence (within one week after planting), number of leaves, vine length (cm) at 3, 5 and 7 WAP, leaf area (cm^2) was calculated using the formula below:

$$\text{Leaf Area (LA)} = L \times W \times K$$

Where:

L = Length of leaf; W = Width (Widest portion of the leaf); K = Correction factor 0.85 (Blanco & Folegatti, 2003). Leaf area index (LAI) was calculated as the ratio of total leaf area to the ground area occupied by the plant (Taiz *et al.*, 2017). Other data collected include number of branches, number of nodes per vine, number of days to 50% flowering, number of days to first harvest, fruit length (inches), fruit diameter (inches), number of fruits, fruit weight (kg), and yield (t ha^{-1}). Data collected were subjected to analysis of variance (ANOVA) using Genstat (16th ed.; VSN International, 2013). Means were separated using Duncan new multiple range test (DNMRT) at 5 % probability level.

Results and discussion

Physical and chemical properties of the soil at the experimental site

The soil pH of 4.8 indicates a strongly acidic condition (Table 1). Most vegetable crops, including cucumber, generally prefer a slightly acidic to neutral pH range of about 6.0 to 7.0 for optimal nutrient availability and microbial activity (Brady & Weil, 2016). In strongly acidic soils, the availability of essential nutrients such as phosphorus, calcium, and magnesium can be reduced, while potentially toxic elements like aluminum become more soluble and can adversely affect root growth and nutrient uptake (Fageria *et al.*, 2015). The soil organic carbon (1.20 %) and organic matter (2.85 %) were moderate. Organic matter is crucial for maintaining soil structure, enhancing water-holding capacity, and providing slow-release nutrients through microbial decomposition (Lal, 2016). In tropical soils, moderate organic matter can help buffer acidity and support root development under humid conditions. Total nitrogen was low hence the reason we applied NPK fertilizer 20:10:10 (200 kg / ha) at two weeks after planting and NPK 15:15:15 (250 kg /ha) at four weeks after planting to increase the mineral content in the soil. Nitrogen is central to chlorophyll synthesis and leaf development, and low levels can restrict canopy expansion and overall biomass accumulation (Mengel & Kirkby, 2001). Available phosphorus was moderately high and favorable for crop growth. Phosphorus is critical for root development, early establishment, and energy transfer reactions in plants. Adequate phosphorus in soil may have contributed to effective early vine growth observed in some genotypes. The effective cation exchange capacity (ECEC) of 7.83 c mol kg^{-1} (Table 1) suggests a moderate capacity of the soil to retain and supply nutrient cations. In sandy loam soils as the one we used, moderate ECEC is typical, but it also means the soil has limited buffering against nutrient leaching, especially under humid tropical rainfall (Brady & Weil, 2016). Sandy loam soils are favorable for vegetable production because it promotes good aeration and root penetration (Brady & Weil, 2016). Sandy loam soils also warm up quickly, encouraging early plant development in humid tropical environments (Brady & Weil, 2016). Overall, the soil conditions at the experimental site present a combination of strengths and challenges. The moderate organic matter and favorable phosphorus levels support healthy root and shoot development. However, the strong acidity may have constrained maximum yield potential and influenced genotype performance variability.

Table 1: Physical and chemical properties of the soil from the experimental site

Properties	Values
Chemical Characteristics of the soil	
Soil pH	4.8
Organic carbon	1.20 %
Organic matter	2.85 %
Exchangeable Bases	
Total Nitrogen	0.08 %
Available Phosphorus	59.87 mg kg^{-1}
Calcium	5.4 cmol kg^{-1}
Magnesium	0.70 cmol kg^{-1}
Potassium	0.13 cmol kg^{-1}
Sodium	0.11 cmol kg^{-1}
Aluminum	0.67 cmol kg^{-1}
Hydrogen	0.98 cmol kg^{-1}
Effective cation exchange capacity	7.83
Base saturation	79.0 %
Physical composition of soil	
Clay	10.7 %
Silt	19.0 %
Sand	75.6 %
Textural Class	Sandy loam

Morphological attributes of the cucumber genotypes

The morphological attributes of the cucumber genotypes at 5 and 7 weeks after planting (WAP) clearly demonstrates the presence of substantial genetic variability in vegetative growth traits under the humid tropical conditions of Calabar (Table 2). This variability aligns with earlier reports that cucumber exhibits wide phenotypic expression when grown under contrasting environmental and soil conditions, particularly in the tropics (Odor *et al.,* 2017; Hossain *et al*., 2020; Kumar *et al*., 2021). Number of days to 50 % emergence did not differ significantly among the genotypes (Table 2), with emergence occurring within 4 to 5 days. This uniformity suggests that seed quality and early environmental conditions, particularly soil moisture and temperature, were favorable across treatments. Similar findings have been reported in cucumber studies where emergence is largely influenced by environmental conditions rather than genotype once optimal conditions are provided (Odor *et al.,* 2017; Singh *et al.,* 2019). Uniform emergence is desirable because it ensures synchronized early growth, allowing subsequent differences in plant performance to be attributed mainly to genetic variability rather than uneven stand establishment (Brady & Weil, 2016). The number of leaves showed highly significant variation at both 5 and 7 WAP (Table 2) (Figure 1), indicating differential canopy development among the genotypes. Kayin, Nandini, and Amarisa consistently produced more leaves compared to Market More and Akpabuyo. Leaf production is a critical growth parameter in cucumber, as leaves are the primary sites of photosynthesis and carbohydrate synthesis required for vine growth and fruit formation (Taiz *et al.*, 2017). Increased leaf number enhances light interception and assimilate availability, which has been positively associated with yield in cucumber and other cucurbits grown under tropical conditions (Hossain *et al*., 2020; Kumar *et al*., 2021). Significant differences were observed in number of branches at 5 WAP (Table 2). Kayin and Akpabuyo exhibited higher branching ability, while Market More recorded the lowest number of branches. Branching is an important architectural trait because cucumber fruits are borne on lateral branches, and increased branching provides more sites for flower initiation and fruit development (Pandey *et al*., 2018). High branching capacity has been reported as a desirable trait for yield improvement and adaptability in cucumber, especially under tropical conditions (Yadav *et al.*, 2021). This supports the selection of genotypes with strong branching potential for enhanced productivity. Vine length varied significantly among the genotypes at 7 WAP, with Kayin recording the longest vines at both 5 and 7 WAP followed by Nandini and Akpabuyo (Table 2). Longer vines often support more nodes and lateral branches, increasing opportunities for flowering and fruiting (Kumar *et al.*, 2021). The number of nodes differed significantly among genotypes at both sampling periods, with Kayin and Amarisa producing more nodes than the other genotypes (Table 2). Node number is a critical yield-related trait in cucumber because flowers and fruits develop at the nodes. Genotypes with higher node numbers have a greater potential for fruit production, provided that pollination and nutrient supply are adequate (Rahman *et al*., 2020). This observation agrees with earlier studies that identified node number as a reliable indicator of yield potential in cucumber (Hossain *et al.*, 2020).

Figure 1: Cucumber genotypes at vegetative stage

Table 2: Morphological attributes of the cucumber genotypes at 5 and 7 WAP

Genotype	D50	Number of Leaves		Number of Branches		Vine length (cm)		Number of nodes		LA (cm^2)	LAI
		5WAP	7WAP	5WAP	7WAP	5WAP	7WAP	5WAP	7WAP		
Nandini	5	34.94 c	30.75 b	3.26 ab	4.917	92	265 b	3.33 b	15.00 cd	119.0ab	952a
Market more	5	27.73 a	23.00 a	1.69 a	4.5	70.5	126 a	7.17 a	12.25 ab	97.6a	781ab
Kayin	5	42.41 c	38.08 b	3.92 c	5	66.67	367 c	11.33 b	16.67 e	157.3c	1258bc
Amarisa	4	31.94 bc	28.33 a	2.93 a	4.75	73.42	207 ab	11.08 b	16.08 de	145.6bc	1164c
999	5	28.43 ab	23.50 a	3.25 ab	4.917	68.25	228 b	7.92 a	13.58 bc	175.1cd	1401cd
Oliveira	5	29.04 ab	23.25 a	3.53 bc	4.417	75.17	195 ab	7.42 a	13.08 ab	162.4cd	1299cd
Akpabuyo	5	21.77 a	17.50c	3.64 bc	4.583	67.42	244 b	6.50 a	11.75 a	193.9d	1551d
Significance	NS	***	**	***	NS	NS	**	**	***	***	***
S.e.d	0.3	1.529	2.097	0.186	0.341	10.86	40.4	0.64	0.651	14.24	1113.9
CV (%)	7.2	6.1	9.8	7.2	8.8	18.1	21.2	8.9	5.7	11.6	11.6

D50 = Number of days to 50 % emergence; LA = Leaf area; LAI = leaf area index; NS - Non significant * $p \leq 0.05$ ** $p < 0.01$ *** $p < 0.001$; S.e.d = standard error of difference; CV = coefficient of variation; Means followed by the same letter in a column are not statistically different from each other using DNMRT.

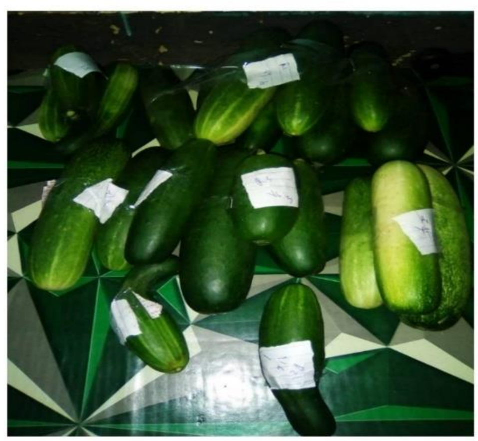
Leaf area showed significant differences at both sampling periods (Table 2). Akpabuyo and Kayin recorded larger leaf areas at 7 WAP, indicating enhanced canopy expansion. Larger leaf area improves photosynthetic efficiency and biomass accumulation, which are essential for sustaining fruit growth in cucumber (Taiz *et al.,* 2017). In humid tropical environments, adequate leaf area is particularly important for maximizing light capture under frequent cloud cover (Lal, 2016). However, excessive leaf area may also increase canopy humidity and disease pressure, highlighting the need for balanced vegetative growth. Leaf area index differed significantly among the genotypes, with Akpabuyo and Kayin showing higher LAI values (Table 2). LAI is an important indicator of canopy structure and light interception efficiency. Moderate to high LAI values are associated with improved photosynthesis and yield in vegetable crops, including cucumber (Hossain *et al.*, 2020). Thus, genotypes with optimal rather than excessive LAI are better suited for sustainable production. The observed differences in leaf production, branching, vine length, node number, and canopy development provide a strong biological basis for subsequent differences in yield attributes. Identifying genotypes with stable growth and efficient resource use under humid tropical conditions is essential for improving vegetable productivity, enhancing household nutrition, and supporting smallholder livelihoods this will help ameliorate problems of food security (FAO, 2017).

Reproductive attributes of the cucumber genotypes

The observed differences in number of days to 50 % flowering, ranging from 38 to 63 days, indicate variation in early flowering among the genotypes. Kayin and Market More flowered earlier than others, while Akpabuyo flowered late (Table 3). Early flowering is an important trait particularly in tropical environments where crops may be exposed to fluctuating rainfall patterns and disease pressure. Early flowering allows plants to initiate fruiting sooner, extending the harvesting window and improving yield stability. This agrees with the findings of Tadkal *et al*., 2024. The flowering patterns observed in this study therefore provide useful information for identifying genotypes suited for early or staggered production systems. The number of days to first harvest differed significantly among genotypes, with Kayin, Amarisa, and Nandini, reaching harvest earlier than Market More and Akpabuyo (Table 3). Early harvest is highly desirable in vegetable production systems because it enhances cropping intensity, improves income for farmers, and reduces exposure to late season biotic and abiotic stresses. According to FAO (2023), early-maturing vegetable varieties play a crucial role in improving food availability and income generation, particularly for smallholder farmers in developing regions. This highlights the importance of selecting genotypes with short reproductive cycles for sustainable cucumber production in humid tropical environments. Fruit diameter showed no significant variation among most genotypes, suggesting that this trait is relatively stable under uniform environmental and management conditions (Table 3). Similar observations have been reported in cucumber, where fruit diameter often exhibits lower variability compared to other yield components such as fruit length and weight (Kumar *et al.*, 2021; Tadkal *et al.*, 2024). This stability may be advantageous for market consistency, as uniform fruit girth is often preferred in both local and export markets. There was a significant difference in fruit length and fruit diameter (p < 0.001) (Table 3), with Kayin producing the longest fruits, followed by Amarisa and Nandini (Figure 2) while Market more had the shortest fruits. Fruit length is an important quality and market trait, influencing consumer preference and price. Most customers may prefer the longer fruits to the shorter ones. These longer fruits are associated with higher market value in many cucumber value chains (Rebollar-Rebollar *et al*., 2022). The observed variability in fruit length reflects genetic differences in fruit growth dynamics and assimilate partitioning during the reproductive stage. Fruit weight varied significantly among the genotypes (p

≤ 0.05), with Kayin and Amarisa recording the highest values, while Akpabuyo and Market more the lightest fruits (Table 3). Enhanced fruit weight also has nutritional implications, as larger fruits contribute more edible biomass per unit area. Cucumbers are known to be rich in water, dietary fiber, vitamins, and bioactive compounds, which contribute to hydration, digestion, and overall health (Borecka & Karaś, 2025). There was also a significant difference in number of fruits per plant with Kayin producing the highest number of fruits, followed by Amarisa, Nandini (Figure 2) while Akpabuyo had the lowest number (Table 3). Fruit number is a key yield component and often compensates for moderate fruit size in determining total yield. High fruit bearing capacity has been identified as a critical trait for improving cucumber productivity (Umeh *et al.*, 2024). Genotypes combining high fruit number with acceptable fruit size, such as Kayin and Amarisa in this study, are therefore particularly valuable for yield improvement. Yield highly differed significantly among the genotypes (p < 0.001), The value of yield ranged from 2.09 t ha^{-1} to 22.46 t ha^{-1}. Kayin recorded the highest yield, followed by Amarisa and Nandini, while Akpabuyo and Market More had the lowest yield (Table 3). The superior yield performance of Kayin can be attributed to its favorable combination of early flowering, early harvest, higher fruit number, longer fruits, and greater fruit weight. These yield levels are consistent with reports on cucumber productivity and highlight the potential for yield improvement through genotype selection (Umeh *et al.*, 2024). High-yielding genotypes can therefore contribute to narrowing yield gaps and strengthening regional vegetable supply chains.

Some harvested fruits of Kayin (High performing genotype)



Some harvested fruits of Amarisa and Nandini

Figure 2: Some harvested fruits of the best performing genotypes

Table 3: Reproductive attributes of the cucumber genotypes

Genotype	Number of days to 50 % flowering	Number of days to first harvest	Fruit diameter (cm)	Fruit length (cm)	Fruit weight (kg)	Number of fruits	Yield (t ha^{-1})
Nandini	41 a	43a	14.18b	16.20b	2.70b	9.00ab	13.50b
Market more	39 ab	56b	13.79bc	13.93d	1.90ab	7.00a	9.50ab
Kayin	38 a	43a	13.30c	18.00a	4.49c	13.00b	22.46c
Amarisa	41 b	43a	15.12a	16.34b	3.99c	10.00ab	19.92c
999	41b	46a	13.74bc	15.43c	1.43a	7.00a	7.12a
Oliveira	41b	44a	14.89a	14.48d	2.12b	9.00ab	10.59b
Akpabuyo	63c	59b	13.99b	14.72d	0.42	1	2.09
Significance	***	***	***	***	*	**	***
S.e.d	1.4	13	0.16	0.18	0.256	2.1	1.286
CV (%)	3.9	3.2	6.3	6.7	12.9	31.4	12.9

* $p \leq 0.05$ ** $p < 0.01$ *** $p < 0.001$; S.e.d = standard error of difference; CV = coefficient of variation; Means followed by the same letter in a column are not statistically different from each other using DNMRT.

CONCLUSION

The findings from this study showed substantial genetic variation among cucumber genotypes evaluated under the humid tropical conditions of Calabar. Significant differences were observed for important growth and yield traits, including leaf area at 5 WAP, leaf area index, number of nodes, number of leaves, vine length at 7 WAP, number of branches at 5 WAP, days to first harvest, and fruit weight. These variations reflect the strong influence of genetic factors on trait expression and provide opportunities for effective selection in cucumber improvement programs. Genotypes Kayin, Amarisa, and Nandini 732 consistently exhibited superior performance across growth and yield traits and are therefore recommended for further breeding and multi-location testing in similar humid tropical environments. Adoption of high-performing and genetically stable genotypes will enhance cucumber productivity, increase farmers' income, and improve the availability of nutritious vegetables, thereby contributing to sustainable food security in humid tropical regions.

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