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Assessment of Growth Parameters of Pigeon Pea (*Cajanus cajan* (L.) Millsp.) Cultivated in Two Different Ecological Zones in Cross River State

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Abstract

Background and Objective: Sustainable food security in Nigeria has become very important to curb malnutrition and protein deficiency. Changes in the observed climate are affecting the growth of food crops through phenological alterations among other stress factors. Pigeon pea (*Cajanus cajan* (L.) Millsp.) has been reported as one of those crops with significant potential to withstand these stressors as well as meet the demands for a source of protein and medicine for humans and livestock. This study assessed the growth parameters of fifty accessions of pigeon pea (*Cajanus cajan* (L.) Millsp.) cultivated in two ecological zones in Cross River State. **Materials and Methods:** A 50 × 2 factorial in a completely randomized block design with three replications was used. Three seeds per accession were sown per hole at a depth of 2 cm and thinned to two after emergence, on beds measuring 1 × 1 m. Each bed had six plants and growth parameters were measured on plant height, number of leaves, number of branches and leaf area. **Results:** It showed significant differences in growth parameters, including plant height, number of leaves, number of branches, leaf area, leaf area index and relative growth rate between the two locations, with the accessions planted in Calabar displaying higher mean values for all parameters except plant height and leaf area indices, 50.98 and 5.38 cm, respectively, which were higher in Obudu. **Conclusion:** The findings of this study showed that these fifty accessions of pigeon peas can be cultivated successfully in Calabar and Obudu. This information is crucial for farmers to optimize pigeon pea production to diversify the food base, ameliorate protein deficiency and enhance soil nutrition in Cross River State and Nigeria.

Key words: Pigeon pea, accessions, ecological zones, growth performance, germination, vegetative growth

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The interdependence of food production, food security and climate change is well-established. Alterations in climatic patterns over extended periods result in significant modifications to the climate system, thereby giving rise to multifaceted consequences such as increased temperatures, erratic precipitation, flooding and elevated sea levels¹. Climate change has region-specific repercussions and affects various crops differently¹. Based on available evidence, it can be inferred that climate change will have significant implications for crop growth, yield and quality. Changes in the observed climate will affect crop growth through many mechanisms, including but not limited to phenological alterations, heat stress, water stress, waterlogging and fluctuations in the incidence of pests and diseases^{2,3}. Interestingly, some crop plants have been identified to have the capacity to withstand the stressors orchestrated by climate change, especially the landraces of these crops⁴. Pigeon pea (*Cajanus cajan* (L.) Millsp.) has been reported to be drought tolerant and highly adaptable to varying nutritive profiles⁵. It has also been emphasized that for sustainable food security in Sub-Saharan African countries, Nigeria in particular, there is an urgent need to explore, exploit development and improve landraces of crops, especially legumes taking into consideration the ravaging and scourging wave of malnutrition across this continent due to protein deficiency. Pigeon pea has significant economic potential in many nations, serving as a major cash crop in Africa and Asia. It offers protein for humans and livestock, has medicinal value and can be processed in different ways for consumption. Pigeon peas are a popular crop among smallholder farmers in rural areas, especially in Nigeria, because they can be grown there and are a low-cost source of revenue that may also be used to feed livestock and provide food during times of scarcity⁶⁻⁸. In Nigeria, desertification threatens the Northern Region where 90% of legumes are cultivated, with an annual estimated increase of 30%. To achieve comprehensive food production, diversification of the food base is crucial. The aim of this work was to determine the germination rate and compare the growth parameters of fifty accessions of pigeon pea (*Cajanus cajan* (L.) Millsp.) cultivated in two ecological zones in Cross River State.

MATERIALS AND METHODS

Study area: The study was conducted at two locations in Cross River State, Nigeria in areas considered to have high annual rainfall, the Southern experimental plot behind the

biological sciences department of the University of Calabar and the Northern site in Ohong Village, Obudu Local Government Area. Calabar is situated in the Southern-Eastern humid tropical rainforest zone of Nigeria at 4°58'58.3428"N, 8°20'4.2108"E and has an altitude of 39 m, bimodal annual rainfall ranging from 3000 to 3500 mm, mean annual temperature between 27°C and 35°C and relative humidity of 78-85%. The soil is ultisol with high leaching and less than 35% base saturation. Obudu is located at latitude 6°40'2.53"N, 9°10'17.65"E, with an altitude of 144 m and estimated annual rainfall between 2000 to 3000 mm⁹. The temperature ranges from 18°C to 40°C, with an optimum of 29°C. The study was conducted during the 2016 cropping season.

Seed collection: Fifty accessions of pigeon pea seeds (*Cajanus cajan* L. Millsp.) were obtained from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Niger Republic, for this study.

Site preparation and experimental design: Prior to the experiment, the vegetation at the experimental sites was manually cleared and the plots were mapped out and tilled into beds based on the experimental design. The experiment was a 50×2 factorial design with a Completely Randomized Block Design (CRBD) and three replications. The plot size was 30×25 m (750 m²) for both locations, separated by a 1m alley. Beds measuring 1×1 m were created with a spacing of 30×30 cm. Each bed had 6 plants, with 3 seeds planted per hole at a depth of 2 cm. After emergence, the plants were thinned to 2 per stand.

Soil sampling: Soil samples were collected pre- and post-harvest at a depth of 0-25 cm from different points in the experimental site using a soil auger. Pre-planting soil samples were air-dried, bulked and sieved through a 2 mm mesh sieve before analysis for physical and chemical properties. Post-harvest soil analysis included determining silt, sand, pH, organic carbon (C), total nitrogen (N), available phosphorus (P), calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), exchangeable hydron (H⁺), exchangeable aluminum, adequate cation exchangeable capacity (CEC) and base saturation. Soil particle sizes were determined using the hydrometer method¹⁰.

Planting: Seeds were soaked in distilled water for 6 hrs before sowing. Each accession was sown with three seeds per hole in triplicate. Upon germination, the seedlings were thinned to two per hole.

Data collection: The following parameters were measured:

$$\text{Germination rate} = \frac{\text{Total number of plants germinated}}{\text{Total number of seeds sown}}$$

Plant height (cm): The height of the tagged plants was measured using a measuring tape from the base to the top of the main axis and the mean values were recorded.

Number of leaves: The number of leaves per plant was determined by counting the fully expanded leaves of the sampled plants.

Number of branches: The number of branches per plant was counted by counting the number of branches on the tagged plants.

Leaf area: The leaf area was determined at all sampling stages by measuring the leaf length and the maximum width and was calculated as follows:

$$LA = \text{Length} \times \text{Width} \times 0.821^{11}$$

Leaf area index per plant: The leaf area index (LAI) was determined by dividing the leaf area of the plant by the ground area covered by the plant using the formula:

$$LAI = \left(\frac{\text{Leaf area}}{\text{Ground area}} \right)^{11}$$

Relative growth rate (RGR): Relative growth was calculated according to Peng *et al.*¹² as:

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

Where:

W_1 = Total dry weight at first harvest

W_2 = Total plant dry weight at second harvest

$t_2 - t_1$ = Time interval between the first and second harvest

$\log_e$ = Natural logarithm

All data were collected from 2 weeks to 12 weeks after planting.

Statistical analysis: The data were subjected to a combined Analysis of Variance (ANOVA) using SPSS Version 20 and means were separated using the Duncan Multiple Range Test at a significance level of 5%.

RESULTS

The physicochemical properties of the soil before and after the experiment in the two locations were presented in Table 1. The results showed that the clay, sand and silt contents of the post-harvest soil in Obudu (60.02, 48.5 and 65.9%, respectively) and Calabar (9.0, 6.7 and 84.3%, respectively) were higher compared to the pre-planting stage with values of 50.3, 46.7 and 65.7% for Obudu and 9.0, 6.7 and 84.3% for Calabar.

Table 1: Pre-planting and post-harvest soil properties at the experimental locations

Soil properties	Location			
	Calabar		Obudu	
	Pre-planting	Post-harvest	Pre-planting	Post-harvest
Clay (%)	9.00	10.10	50.30	60.02
Silt (%)	6.70	6.90	46.70	48.50
Sand	84.30	84.00	65.70	65.90
pH	5.50	6.30	5.50	7.40
Organic C (%)	1.38	1.58	1.00	1.41
Total N (%)	1.38	1.99	35.10	36.00
Available P (mg kg ⁻¹)	46.50	76.10	45.50	47.50
Ca (cmol kg ⁻¹)	2.00	5.90	4.30	7.00
Mg (cmol kg ⁻¹)	2.00	6.70	3.50	5.40
K (cmol kg ⁻¹)	0.10	0.15	3.50	4.30
Na (cmol kg ⁻¹)	0.06	0.08	0.20	0.30
H ⁺ (cmol kg ⁻¹)	1.04	1.08	0.80	1.00
Al ⁺⁺⁺ (cmol kg ⁻¹)	0.00	0.01	0.01	0.02
ECEC (cmol kg ⁻¹)	7.20	7.30	5.20	5.40
Base saturation	85.00	90.20	53.50	80.50

Table 2: Percentage germination of fifty accessions of *Cajanus cajan* (L.) Millsp. at Calabar and Obudu in Cross River State, Nigeria

Accession	Germination percentage	
	Calabar	Obudu
ICEAP 0068	60.00 ^h	55.00 ^j
ICEAP 00790	70.00 ^c	71.67 ^c
ICEAP 540	75.00 ^{bc}	65.00 ^f
ICEAP 550	70.00 ^c	66.67 ^e
ICEAP 554	66.67 ^e	78.33 ^{bc}
ICEAP 850	46.67 ⁿ	51.67 ^l
ICEAP 902	60.00 ^h	60.00 ^h
ICP 1	58.33 ⁱ	75.00 ^{bc}
ICP 11277	60.00 ^h	60.00 ^h
ICP 11497	53.33 ^f	78.33 ^{bc}
ICP 11543	60.00 ^h	48.33 ^m
ICP 11737	80.00 ^b	80.00 ^b
ICP11957	80.00 ^b	78.33 ^{bc}
ICP12011	50.00 ^l	51.67 ^l
ICP12734	76.67 ^{bc}	73.33 ^c
ICP 13555	50.00 ^l	41.67 ^o
ICP 14231	70.00 ^c	51.67 ^l
ICP 14429	70.00 ^c	61.67 ^h
ICP 151	73.33 ^c	71.67 ^c
ICP 161	70.00 ^c	60.00 ^h
ICP 332	70.00 ^c	73.33 ^c
ICP 6	90.00 ^a	80.00 ^b
ICP 6443	63.33 ^g	63.33 ^g
ICP 6907	76.67 ^c	73.33 ^c
ICP 6927	63.33 ^g	75.00 ^{bc}
ICP 6974	63.33 ^g	71.67 ^c
ICP 7035	60.00 ^h	51.67 ^l
ICP 7118	76.67 ^c	65.00 ^e
ICP 7184	66.67 ^g	76.67 ^{bc}
ICP 7187	60.00 ^g	70.00 ^c
ICP 7222	80.00 ^b	65.00 ^f
ICP 7400	53.33 ^k	51.67 ^l
ICP 7613	63.33 ^g	51.67 ^l
ICP 8388	40.00 ^o	60.00 ^h
ICP 84023	66.67 ^e	61.67 ^h
ICP 87	58.33 ⁱ	78.33 ^{bc}
ICP 8719	45.00 ⁿ	71.67 ^c
ICP 8738	55.00 ^j	46.67 ⁿ
ICP 8739	60.00 ^h	66.67 ^e
ICP 8740	66.67 ^e	68.33 ^d
ICP 8741	70.00 ^c	70.00 ^c
ICP 8805	76.67 ^{bc}	61.67 ^h
ICP 8863	66.67 ^e	78.33 ^{bc}
ICPL 84031	60.00 ^h	66.67 ^e
ICPL 85063	50.00 ^l	51.67 ^l
ICPL 85095	63.33 ^g	51.67 ^l
ICPL 86012	50.00 ^l	55.00 ^j
ICPL 87119	63.33 ^g	61.67 ^l
MN 5	53.33 ^k	51.67 ^l
UPAS 120	50.00 ^l	41.67 ^o
Grand mean	63.00	63.83

Means with the same letter within rows are not significantly different and ($p = 0.05$)

The result showed highly significant differences ($p = 0.05$) amongst accessions. The ICP 6 and ICP 8388 recorded the highest and least germination percentages of 90.00 and 40.00 in Calabar, while ICP 11737 and ICP 13555 had the highest and

least percentages of 80.00 and 41.67 in Obudu (Table 2). Results on plant height, number of leaves, number of branches, leaf area, leaf area index and relative growth rate showed significant differences between locations 12

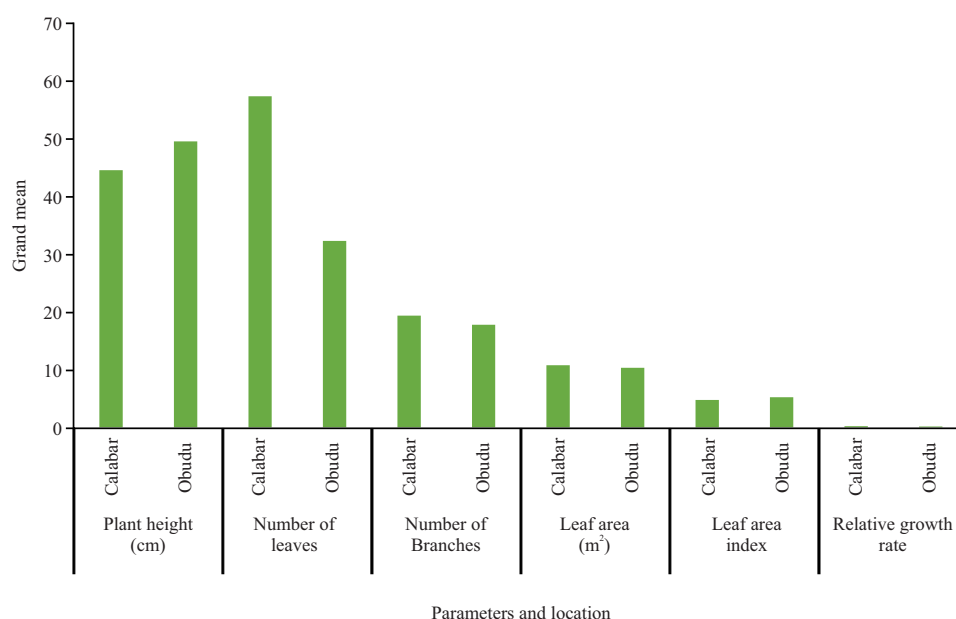


Fig. 1: Grand mean of growth parameters of fifty accessions of *Cajanus cajan* (L.) Millsp. cultivated at Calabar and Obudu, Cross River State

Table 3: Mean plant height (cm), number of leaves, number of branches, leaf area (m²), leaf area index and relative growth rate of fifty accessions of *Cajanus cajan* (Mill. sp.) 12 weeks after planting in Calabar and Obudu, Cross River State

Accession	Plant height		Number of leaves		Number of branches		Leaf area		Leaf area index		Relative growth rate	
	Calabar	Obudu	Calabar	Obudu	Calabar	Obudu	Calabar	Obudu	Calabar	Obudu	Calabar	Obudu
ICEAP 0068	42.70 ^p	107.33 ^d	26.00 ⁿ	45.33 ^j	20.00 ^e	10.33 ⁱ	17.567 ^e	15.100 ^g	8.77 ^e	6.80 ^j	0.211 ^f	0.127 ^g
ICEAP 00790	41.17 ^p	31.33 ^t	40.33 ^l	145.67 ^e	16.33 ^j	11.00 ^j	9.300 ^m	9.533 ^m	5.93 ^m	6.50 ^j	0.131 ^g	0.108 ^g
ICEAP 540	53.50 ⁿ	87.63 ^h	60.00 ^h	44.33 ^j	24.00 ^{de}	18.00 ^h	13.833 ⁱ	18.567 ^d	7.10 ^k	9.97 ^c	0.149 ^g	0.065 ^h
ICEAP 550	71.67 ^j	103.00 ^d	20.00 ^p	21.33 ^p	20.00 ^e	16.33 ⁱ	10.733 ^l	16.900 ^f	6.03 ^m	6.77 ^j	0.106 ^g	0.156 ^g
ICEAP 554	40.14 ^p	41.80 ^p	34.67 ^l	99.00 ^f	20.67 ^e	24.00 ^{de}	14.067 ^h	21.967 ^c	8.03 ^d	5.80 ^m	0.152 ^g	0.060 ^h
ICEAP 850	78.00 ^j	70.43 ^j	37.67 ^k	27.00 ⁿ	20.67 ^e	18.33 ^g	15.333 ^g	9.600 ^m	9.27 ^d	21.37 ^a	1.146 ^g	0.171 ^g
ICEAP 902	78.40 ^j	40.47 ^p	31.67 ^l	25.33 ⁿ	19.00 ^f	19.00 ^e	10.867 ^l	9.232 ^m	4.53 ^m	4.33 ⁿ	0.551 ^c	0.955 ^a
ICP 1	41.10 ^p	49.10 ^p	363.33 ^d	34.33 ^j	24.00 ^{de}	15.00 ^j	14.400 ^h	9.000 ^m	13.53 ^b	4.53 ^m	0.114 ^g	0.079 ^h
ICP 11277	139.67 ^a	48.43 ^p	16.67 ^q	20.00 ^p	22.33 ^e	8.33 ^m	14.400 ^h	9.433 ^m	2.83 ^p	4.80 ^m	0.216 ^f	0.105 ^g
ICP 11497	33.30 ^t	100.17 ^f	23.00 ^p	35.33 ^j	15.67 ^j	30.00 ^b	7.100 ^o	9.133 ^m	4.80 ⁿ	4.40 ^{no}	0.070 ^h	0.354 ^e
ICP 11543	32.00 ^t	72.57 ^j	22.00 ^p	52.67 ^j	16.00 ^j	24.00 ^{de}	20.600 ^{cd}	14.000 ^h	2.07 ^p	6.50 ^j	0.309 ^e	0.323 ^e
ICP 11737	31.07 ^t	22.53 ^v	27.00 ^o	24.67 ⁿ	12.67 ^k	10.33 ^l	7.333 ^o	7.333 ^o	3.57 ^o	3.50 ^o	0.115 ^g	0.043 ^h
ICP 11957	34.47 ^s	36.00 ^r	33.67 ^l	19.00 ^{mq}	13.67 ^k	16.67 ^h	6.100 ^p	5.100 ^q	2.63 ^p	2.50 ^p	0.046 ^h	0.026 ^h
ICP 12011	33.70 ^t	40.13 ^o	28.33 ^m	25.00 ⁿ	16.33 ^j	25.33 ^d	10.900 ^j	6.367 ^p	7.30 ^k	6.87 ^j	0.188 ^g	0.239 ^f
ICP 12734	41.87 ^p	38.27 ^q	9.33 ^s	29.67 ⁿ	16.33 ^j	30.67 ^b	10.233 ^l	24.833 ^b	2.80 ^o	8.30 ^f	0.160 ^g	0.072 ^h
ICP 13555	37.10 ^q	34.40 ^t	30.00 ^m	38.00 ^k	17.33 ^h	11.33 ^l	6.700 ^p	6.833 ^p	7.90 ^h	8.40 ^f	0.121 ^g	0.073 ^h
ICP 14231	40.93 ^p	34.40 ^t	20.00 ^p	29.33 ^j	28.33 ^c	18.33 ^g	11.700 ^k	8.467 ⁿ	5.73 ^m	5.50 ^m	0.130 ^g	0.118 ^g
ICP 14429	38.03 ^q	37.27 ^q	31.33 ^l	25.67 ⁿ	19.67 ^f	16.67 ^h	7.867 ^p	7.267 ^o	3.83 ^o	3.50 ^o	0.163 ^g	0.192 ^g
ICP 151	40.53 ^p	114.67 ^b	22.67 ^p	24.00 ^o	17.33 ^h	23.33 ^d	10.833 ^l	11.667 ^k	3.00 ^o	3.90 ^o	0.172 ^g	0.079 ^h
ICP 161	85.37 ^h	48.53 ^o	12.33 ^r	31.33 ^j	22.00 ^e	13.67 ^k	9.600 ^m	7.300 ^o	5.90 ^m	4.80 ^{mn}	0.269 ^f	0.138 ^g
ICP 332	36.03 ^r	38.23 ^q	408.00 ^c	34.33 ^j	24.00 ^d	20.00 ^e	10.300 ^l	8.567 ⁿ	2.27 ^p	4.10 ⁿ	0.214 ^f	0.054 ^h
ICP 6	39.67 ^q	30.10 ^t	19.00 ^o	32.00 ^l	16.67 ^h	15.00 ^h	10.500 ^l	9.700 ^m	5.80 ^m	5.00 ^{mn}	0.076 ^h	0.089 ^h
ICP 6443	31.70 ^t	39.33 ^q	22.67 ⁿ	25.00 ⁿ	21.67 ^e	32.67 ^{ab}	14.600 ^h	9.500 ^m	4.03 ⁿ	4.63 ⁿ	0.236 ^f	0.244 ^f
ICP 6907	31.83 ^t	48.20 ^o	30.67 ^l	30.00 ^m	14.67 ^h	24.00 ^{de}	9.400 ^m	6.467 ^p	4.43 ⁿ	4.50 ⁿ	0.080 ^h	0.129 ^g
ICP 6927	67.37 ^k	87.80 ^h	16.67 ^q	33.33 ^j	24.67 ^{de}	19.33 ^f	11.700 ^k	17.300 ^e	6.67 ^j	5.70 ^m	0.137 ^g	0.188 ^h
ICP 6974	53.03 ⁿ	37.27 ^r	12.67 ^r	10.33 ^s	25.67 ^d	13.00 ^k	10.733 ^l	5.900 ^q	3.03 ^o	2.80 ^p	0.398 ^e	0.217 ^f
ICP 7035	68.63 ^k	55.00 ⁿ	29.33 ^m	36.67 ^k	16.67 ^h	34.00 ^a	13.300 ^j	12.433 ^j	1.90 ^q	8.37 ^g	0.072 ^h	0.241 ^f
ICP 7118	40.13 ^p	110.10 ^e	26.00 ^o	33.67 ^k	17.67 ^h	29.33 ^b	13.267 ⁱ	15.800 ^g	4.27 ⁿ	4.00 ⁿ	0.136 ^g	0.144 ^g

Table 3: Continue

Accession	Plant height		Number of leaves		Number of branches		Leaf area		Leaf area index		Relative growth rate	
	Calabar	Obudu	Calabar	Obudu	Calabar	Obudu	Calabar	Obudu	Calabar	Obudu	Calabar	Obudu
ICP 7184	30.10 ^f	37.17 ^q	41.00 ^l	36.67 ^k	16.00 ^j	15.33 ^j	5.900 ^q	17.300 ^e	3.00 ^o	2.80 ^p	0.035 ^h	0.116 ^g
ICP 7187	30.17 ^t	37.33 ^q	19.00 ^p	26.00 ⁿ	15.67 ⁱ	21.00 ^e	7.200 ^o	5.833 ^q	4.83 ⁿ	4.07 ⁿ	0.147 ^g	0.078 ^h
ICP 7222	67.37 ^k	106.70 ^e	27.67 ⁿ	32.67 ^l	17.67 ^h	16.00 ^h	12.600 ^j	80.433 ^a	5.30 ^m	6.40 ^l	0.014 ^h	0.331 ^e
ICP 7400	38.67 ^q	47.07 ^o	446.33 ^b	22.67 ⁿ	26.00 ^d	13.33 ^k	4.400 ^r	7.867 ^o	1.23 ^q	2.70 ^p	0.193 ^g	0.455 ^d
ICP 7613	65.17 ^l	28.37 ^u	20.00 ^p	32.00 ^l	29.67 ^b	10.67 ^l	14.067 ^h	11.967 ^k	3.10 ^o	4.20 ⁿ	0.673 ^b	0.251 ^f
ICP 8388	36.77 ^r	36.00 ^r	36.67 ^k	31.67 ^l	16.33 ⁱ	25.67 ^{de}	9.767 ^m	8.733 ⁿ	4.77 ^m	4.37 ⁿ	0.138 ^g	0.326 ^e
ICP 84023	60.37 ^m	43.70 ^o	29.67 ⁿ	26.67 ^o	21.33 ^e	13.00 ^k	9.333 ^m	3.500 ^s	5.40 ^m	6.33 ^l	0.062 ^h	0.153 ^g
ICP 87	28.43 ^u	22.47 ^v	16.67 ^q	30.33 ^j	27.00 ^d	14.00 ^k	7.600 ^o	9.567 ^m	6.73 ^l	5.73 ^m	0.316 ^e	0.100 ^g
ICP 8719	50.70 ⁿ	31.60 ^t	45.33 ^j	46.00 ^j	19.33 ^f	12.67 ^k	19.133 ^d	5.667 ^q	4.90 ^m	2.0 ^p	0.190 ^g	0.145 ^g
ICP 8738	36.50 ^s	36.23 ^s	17.67 ^q	25.67 ⁿ	15.33 ^j	28.00 ^c	5.667 ^q	11.033 ^k	4.90 ^m	3.40 ^o	0.145 ^g	0.091 ^h
ICP 8739	40.50 ^p	40.60 ^o	84.67 ^g	30.67 ^l	13.00 ^k	15.67 ^j	7.600 ^o	6.533 ^p	4.83 ^m	3.43 ^o	0.400 ^d	0.024 ^h
ICP 8740	22.17 ^v	32.30 ^t	26.67 ⁿ	28.00 ^m	21.33 ^e	20.67 ^e	16.000 ^f	16.033 ^f	5.20 ^m	4.10 ⁿ	0.120 ^g	0.062 ^h
ICP 8741	26.07 ^u	35.03 ^t	33.33 ⁱ	24.67 ⁿ	16.33 ⁱ	16.67 ^h	7.133 ^o	9.767 ^m	4.30 ^m	3.90 ^o	0.116 ^g	0.105 ^g
ICP 8805	36.37 ^r	52.13 ⁿ	30.00 ^m	48.00 ^{ji}	26.67 ^d	20.33 ^e	19.200 ^d	16.267 ^f	1.80 ^q	4.50 ⁿ	0.189 ^g	0.131 ^g
ICP 8863	25.87 ^{uv}	37.83 ^q	13.33 ^r	24.00 ⁿ	22.33 ^e	16.00 ⁱ	10.600 ^j	8.000 ⁿ	4.80 ^m	6.37 ^l	0.145 ^g	0.106 ^g
ICPL 84031	38.27 ^q	94.27 ^g	13.33 ^r	27.00 ^{mn}	22.00 ^e	9.00 ^j	13.933 ⁱ	9.733 ^m	3.33 ^o	3.60 ^o	0.370 ^e	0.082 ^h
ICPL 85063	65.43 ^l	31.37 ^t	20.00 ^p	24.00 ⁿ	15.33 ^j	15.33 ^j	9.333 ^m	6.433 ^p	3.30 ^o	7.50 ^{ji}	0.114 ^g	0.105 ^g
ICPL 85095	36.33 ^r	35.80 ^s	25.00 ^{no}	26.67 ⁿ	30.67 ^b	22.67 ^e	10.667 ^l	13.400 ^j	1.93 ^q	6.43 ^l	0.039 ^h	0.107 ^g
ICPL 86012	40.53 ^p	45.93 ^{op}	484.00 ^a	25.33 ⁿ	21.00 ^e	20.33 ^e	16.100 ^f	13.533 ⁱ	7.80 ⁱ	7.57 ^l	0.213 ^f	0.146 ^g
ICPL 87119	47.87 ^o	47.33 ^o	28.67 ⁿ	28.00 ^m	15.33 ^j	20.33 ^e	6.100 ^p	8.667 ⁿ	9.80 ^c	4.50 ⁿ	0.148 ^g	0.103 ^g
MN 5	46.17 ^o	37.17 ^q	13.00 ^r	15.00 ^q	31.33 ^b	10.33 ^j	9.500 ^m	13.367 ⁱ	1.80 ^q	3.03 ^o	0.349 ^e	0.044 ^h
UPAS 120	20.03 ^w	22.53 ^v	24.33 ⁿ	18.00 ^o	12.67 ^k	10.00 ^j	7.200 ^o	5.600 ^q	3.90 ^o	2.80 ^p	0.146 ^g	0.059 ^h

Means with the same letter within rows are not significantly different and (p = 0.05)

weeks after planting. The plant height at Calabar ranged from 20.03 cm in UPAS 120 to 139.67 cm in ICP 11277 with a mean of 45.86 cm. At the same time, ICP 151 and ICP 87 had the highest and least plant height of 114.67 and 22.47 cm, respectively, with a total mean of 50.98 cm at Obudu (Fig. 1). The number of leaves ranged from 9.33 in ICP 12734 to 484.00 in ICPL 86012 with a mean of 59.03 at Calabar, while Obudu had a range of 10.33 in ICPL 6974 to 145.67 in ICEAP 00790 with a mean of 33.24. The number of branches in Calabar ranged from 12.67 in ICP 11737 and UPAS 120 to 31.33 in MN5 with a mean of 19.93, while the range was from 8.33 in ICP 11277 to 34.00 in ICP 7035 with a mean of 18.29 at Obudu. Leaf area at Calabar ranged from 4.40 to 20.60 in ICP 7400 and ICP 11543, respectively with a mean of 11.06, while at Obudu, the mean leaf area was 10.61 with a range of 3.50 to 80.43 in ICP 84023 and ICP 7222, respectively. The leaf area index ranged from 1.23 in ICP 7400 to 13.53 in ICP 1 with a mean of 4.90 at Calabar, while in Obudu, the leaf area index ranged from 2.00 in ICP 8719 to 21.37 in ICEAP 850 with a mean of 5.38. Relative growth rate ranged from 0.01 in ICP 7222 to 0.67 in ICP 7613 with a mean of 0.20 at Calabar, while the range was from 0.02 to 0.96 in ICP 8739 and ICEAP 902, respectively with a mean of 0.13 at Obudu (Table 3).

DISCUSSION

The study found that the clay, sand and silt contents in the soil were higher after harvest than before planting in both

locations. The high proportion of sand in all soil samples indicated that the soils in both places were sandy in nature. The size differences between the various soil textural classes, including sand, silt, loam and clay, are important as they impact the soil's pore size and cation exchange capacity, which are vital for water, gas and nutrient storage and transport in the soil. The study also revealed that the post-harvest soil in Obudu had a higher pH than that of Calabar, increasing from 5.5 to 7.4 in Obudu and 5.5 to 6.3 in Calabar (Table 1). This suggested that pigeon pea has the potential to reduce soil acidity and increase nutrient availability to crops. Furthermore, the post-harvest soil in Obudu had higher levels of organic carbon, total nitrogen, calcium, magnesium and base saturation compared to the pre-harvest soil in both locations. These results were consistent with the findings of Mapfumo *et al.*¹³, who reported that pigeon peas enhanced the soil fertility in smallholder pigeon pea farms in Zimbabwe. This finding was also consistent with the reports by Adjei-Nsiah¹⁴, which revealed that incorporating pigeon peas in rotation farming, can contribute to nitrogen fixation and enhance the levels of other nutrients in the soil.

Significant variations in percentage germination were observed among the different accessions, with ICP6 having the highest percentage of 90.00 and 80.00 in both locations, followed by ICP11737 with 80.00 and 80.00 in both places, ICP12743 with 76.67 and 73.33 in both places and ICP 151 with 73.33 and 71.67. Overall, the percentage of germination was above 60 % in both places, indicating favorable germination

conditions. Several authors have reported the significant impact of water pre-treatment of seeds on the rate and consistency of seedling germination, possibly due to the triggering of pre-germination metabolic changes^{15,16}. The rainfall rate was higher in Calabar (2,448.3 mm) than in Obudu (1,772.1 mm) and germination rates were above 60% in both locations. The results of the study showed that the mean height of pigeon pea plants grown in Obudu was greater than Calabar. This difference in plant height may be due to microenvironmental conditions, temperature differences that may have influenced the crop in Obudu as well as inherent qualities in the accessions in relation to maturation times in certain environments¹⁷⁻¹⁹. The mean number of leaves observed in Calabar, 59.03 was higher than that in Obudu, 33.24. This difference may be attributed to variations in latitude and altitude between the two locations²⁰. Time of planting is also implicated as a possible factor for the differences observed in the number of leaves between Calabar and Obudu²¹. The number of branches of pigeon peas was higher in Calabar than in Obudu. This could be due to differences in genetic traits or ecological factors such as rainfall and temperature^{22,23}. The leaf area and leaf area index of the pigeon pea accessions were found to be significantly different between the two locations, respectively, with higher mean values observed in Calabar and Obudu, respectively. Differences in leaf indices may have been due to the increased functional leaf area and delayed leaf senescence by the production of phytohormones that enhanced cell division and elongation²⁴. Other factors such as radiation quality, sunlight interception and day length may be responsible for the variation observed in leaf area and leaf area index between the two locations²⁵. Pigeon pea accessions grown in Calabar showed a higher mean relative growth rate than those in Obudu which may be attributed to the duration to maturity of the accessions and the overall supply of light, water, temperature and nutrient availability²⁶.

This study has provided valuable information on the growth performance of pigeon peas in Calabar and Obudu as well as the potential of the crop to serve as a viable source of food and income for farmers in both regions. However, the study focused on only two locations in Cross River State, Nigeria which may not be representative of the growth and performance evaluation of pigeon peas in the entire region. Also, the study did not investigate the contributions of genetic factors to the differences observed in the growth parameters of the different accessions. Based on these limitations, further studies could investigate the growth and performance of some or all of these pigeon pea accessions in more locations

as well as the specific genetic characteristics that influence their growth. This could provide more insight into the traits that influence their adaptability across different locations.

CONCLUSION

The study investigated the growth parameters of pigeon peas in two different ecological zones, Calabar and Obudu, in Nigeria. The results showed significant differences in growth parameters, including plant height, number of leaves, number of branches, leaf area, leaf area index and relative growth rate between the two locations, with the accessions planted in Calabar displaying higher mean values for all parameters except plant height and leaf area indices which were higher in Obudu. These differences may be attributed to environmental factors such as rainfall, temperature, relative humidity, photosynthetic rates, soil type and possibly a myriad of other factors. The findings of this study show that these fifty accessions of pigeon peas can be cultivated successfully in Calabar and Obudu. This information is crucial for farmers to optimize pigeon pea production to diversify the food base, ameliorate protein deficiency and enhance soil nutrition in Cross River State and Nigeria.

SIGNIFICANCE STATEMENT

This study discovers the growth performance of pigeon peas in Calabar and Obudu and provides important insights into the influence of environmental factors on crop growth. This study is significant because it helps to identify the factors that contribute to better crop growth and yield, which can inform crop management practices to improve productivity. Furthermore, the findings of this study add to the body of knowledge on the growth performance of pigeon peas in different ecological zones and can serve as a basis for further research in this area. Ultimately, the results of this study can help to improve food security and contribute to sustainable agricultural practices.

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