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RESPONSE OF SOME SPRING WHEAT (*Triticum aestivum* L.) CULTIVARS TO TWO N-FERTILIZER RATES IN SOILS DERIVED FROM COASTAL PLAIN SANDS

[1]Otie V.O., [1]Udo I.I., [2]Unagwu B.O., [3]Unuigbe B.O.,
[2]Ozo-Ogueji A.N., [2]Nwandu G.C., [*4]Elemi E.D. and [1]Eneji A.E.

[1]Department of Soil Science, Faculty of Agriculture, University of Calabar, PMB 1115, Calabar, Nigeria
[2]Department of Soil Science, Faculty of Agriculture, University of Nigeria, Nsukka, Enugu State, Nigeria
[3]Department of Soil Science Technology, Federal College of Land Resources Technology, Kuru-Jos, Nigeria
[4]Department of Crop Science, Faculty of Agriculture, University of Calabar, PMB 1115, Calabar, Nigeria

*Corresponding author's email: ekinyaekama1@yahoo.com

ABSTRACT

This study evaluated the effects of three levels of nitrogen (N): 0, 150, and 200 kg N ha^{-1} on four wheat cultivars (Imam, Sc. Sahai, Norman and WZ 272-2015) in soils derived from coastal plain sands. The experiment was laid out in a 4 × 3 factorial in a completely randomised design, with three replications. The results revealed that organic carbon (OC), total nitrogen (TN), available phosphorus (AvP), exchangeable bases, effective cation exchange capacity (ECEC) and base saturation (BS) improved significantly ($p \le 0.05$) following N applications, while the exchangeable acidity (EA) was reduced ($p \le 0.05$), especially at the 150 kg N ha^{-1} rate. The highest ($p \le 0.05$) nutrients were recorded in plots treated with 150 kg N ha^{-1} relative to other N rates. Overall, Sc. Sahai plots were highest ($p \le 0.05$) in nutrients and significantly took fewer (48 days) number of days to heading relative to other cultivars. The cultivar Sc. Sahai exhibited superior growth, dry matter, biological yield, yield attributes, grain yield (20.17 g plant^{-1}) and had higher photosynthetically active radiation (54.95 µmol m^{-2} s^{-1}) under the 150 kg N ha^{-1} compared to the control. The results obtained demonstrate that integrating suitable wheat lines with balanced fertilization is critical for sustainable wheat production.

Key words: acid sands, inorganic fertilizers, nutrient management, poultry manure, wheat

INTRODUCTION

Wheat (*Triticum aestivum* L.) is an important global staple food after rice that meets the carbohydrate, protein and fiber requirements of billions of people (Ahmad *et al*., 2021). In 2017/2018, wheat output exceeded 761.7 million tonnes while global wheat demand was projected to reach 762.4 million tonnes (FAO, 2020). Wheat is commonly used for crumpets, cookies, flakes, chapatis, bread, biscuits, noodles, flour, and grain to livestock, roasted grain, and so forth. As population increases, there is need to increase wheat production so as to meet consumption needs (Pandey *et al*., 2020). Wheat crops decline in productivity due to losses in soil fertility and low soil organic matter content (SOM) (Liu *et al.,* 2020; Srinivasarao *et al.,* 2021). In addition, fertilizer applications often result in either suboptimal or excessive use which leads to distresses in soil fertility and human health (Seenivasagan and Babalola, 2021). Assessing soil fertility status before cultivation can help draw sound nutrient management options. Balanced fertilization facilitates crop nutrient uptake. The nutrient found in inorganic fertilizers, including NPK have improved wheat quality and yield (Ejigu *et al.,* 2024). Fertilizer application at recommended rates can promote good, strong and steady growth and higher yields of cereals including wheat.

Nitrogen (N) is considered the most yield-limiting nutrient in wheat production and other crops in general (Belete *et al.,* 2018). Despite the positive effect of N fertilizers on crops, there are indirect negative effects on soil health, especially when improperly used (Sharma and Bali, 2018). Both excessive and under-use of nitrogen fertilizers pose serious problems globally. However, resource-poor countries, for instance, African countries, have been using under-recommended rates (Feyisa *et al.,* 2024), while resource-rich countries, including most developed countries and China, have been applying above the recommended rates leading to environmental pollution (Ai *et al.,* 2024). Misuse of any type of fertilizer (organic or inorganic) pollutes the environment and affects the health system. Hence, adequate N supply is crucial to increasing yields (Seleiman *et al.,* 2019). Studies show that N fertilizer rates for wheat yield could vary by environment, while integrated approaches combining N with other chemical fertilizers could increase use efficiency and yield (Otie *et al.,* 2016; Bhandari *et al.,* 2020). Application of NPK fertilizer to plants in a timely manner may increase production substantially (Nwite *et al*., 2012; Umeugokwe *et al.,* 2021). Also, optimal combination of organic amendments and mineral fertilizers can increase crop yield, and water

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use efficiency (Nnadi *et al*., 2020; Zhang *et al*., 2025). Application of recommended rates of fertilizers can improve the growth, physiological and yield attributes of wheat such as plant height, relative growth rate, leaf area index, net assimilation rate, chlorophyll content, spike length, number of tillers, spikelets/spike, grains/spike, dry matter yield, harvest index and grain yield (Pandey *et al*., 2020).

Coastal plain sands of the South-Eastern Nigeria are coarse-textured, fragile, acidic, low fertility due to high level of leaching of nutrients by high amount of rainfall. The friable and coarse texture of the soil may cause nutrient loss and affect the growth and yield of crops (Adesemuyi and Adekayode, 2019; Otie *et al.,* 2025b). Cations and other soluble nutrient elements are leached beyond plants' root zone (Araki *et al.,* 2012). Due to the poor agricultural productivity of these soils, they are not intensively cultivated by farmers, who have inadequate knowledge and appropriate technology to manage such marginal lands for optimum productivity. Wheat being grass needs a high quantity of nitrogen (N) for its physiological processes (Saddiq *et al.,* 2025) and cultivating the plant in this zone may not be productive with inadequate N supply. Elsewhere in Ethiopia and China, application rates of 69 and 225 kg ha^{-1} of N were reported to give the highest grain yield of wheat (Feyisa *et al.,* 2024; Muhammad *et al.,* 2025), whereas in Sudan and Guinea Savanna agroecologies of Nigeria, extensive research work aimed at evaluating optimum N-rates for wheat grain yield recommended 160 kg ha^{-1} as optimum for wheat production (Akaangee *et al.,* 2023; Saddiq *et al.,* 2025; Rabiu *et al.,* 2025). Despite extensive studies on wheat across the globe, several gaps remain as most research is conducted on winter wheat. There is not much information on N rates and spring wheat in Nigeria. In Calabar, Cross River State of Nigeria, little or no work is done on N-rates and spring wheat growth. We hypothesise that the different spring wheat cultivars differ in their performance, and the different N rates will have the same effects on the growth and yield of wheat. Also, all other cultivars will respond to the different rates of N equally. This study aimed at investigating the response of different spring wheat cultivars to different N fertilizer rates in soils derived from Coastal Plain Sands. The objectives were to determine (i) the performance of spring wheat cultivars, (ii) effects of different N rates on growth and yield of wheat, and (iii) differential response of the cultivars and different nitrogen rates.

MATERIALS AND METHODS

Study Area

The experiment was conducted at the Department of Soil Science, University of Calabar Screenhouse Facility (04º 57' N, 08º 20' E, 39 m asl). The mean annual temperature in Calabar ranges between 27 and 28 ºC while relative humidity is 70-80%. Calabar rainy season normally starts from March to late October while the dry season begins from November to late February. The soil has a pH range of 4.0-6.0 and derived from Coastal Plain Sands (Akpanidiok and Ukwang, 2012).

Collection and Preparation of Materials for the Study and Laboratory Analyses

Wheat cultivars

The wheat cultivars, *Imam, Sc. Sahai, Norman and WZ 272 2015* were obtained from Lake Chad Research Institute (LCRI), Maiduguri, Borno State. The LCRI was created in 1962 with the mandate to improve the productivity of the farming system of Wheat (*Triticum aestivum* L.) and other closely related crops like barley, sorghum and millet.

NPK and urea fertilizers

Two mineral fertilizers were used in this study namely NPK 20:10:10 and Urea (46%).

Poultry manure

Cured poultry manure was sourced from the University of Calabar Livestock Farm, shade-dried, crushed and analysed for nutrient contents as described in Udo *et al.* (2009). Five days before wheat seeding, 60 g of the manure was weighed and thoroughly mixed into the soil per pot (12 kg soil), corresponding to the recommended 10 t ha^{-1} for wheat production in Nigeria (Ali and Wabekwa, 2024). This served as basal application.

Soil sample collection and preparation

Soil samples were collected from a previously cultivated plot at the Faculty of Agriculture Practical Year Research Farm, University of Calabar. The farm was fallowed for a year, after the removal of previous crops (okra, cucumber and fluted pumpkin). The soil was amended with poultry manure to boost the fertility status of the soil. Soil samples (0-30 cm) were collected from five different spots in the fallowed land, using a soil auger and bulked to form a composite sample. A portion of about 150 g was taken for routine physicochemical analysis using standard laboratory procedures as outlined in Udo *et al.* (2009) and Otie *et al.* (2025a). The surface soil (0-20 cm), where organic matter is mostly concentrated, was air-dried and screened with a 4-mm sieve and weighed (12.0 kg) into 32 plastic pots (measuring 50 cm in height and 40 cm in diameter), which were perforated at the base to drain excess water. Wheat is a shallow fibrous root feeder mainly because of its genetic makeup, and soil exploration tendency on nutrient-rich topsoil (Akma, 2020).

Treatments and Experimental Design

There were two factors denoted as wheat variety (V) and nitrogen (N) in the form of urea. Four spring wheat varieties (*Imam* = V_1, *Sc. Sahai* = V_2, *Norman*

= *V_3 and WZ 272 2015 = V_4*) were factorially combined with three rates of N (0, 150 and 200 kg N ha^{-1}) following the standard recommended N rate for wheat crop (Yokamo *et al.,* 2023), and were denoted as N_0, N_1 and N_2, respectively. These gave 12 treatment combinations: V_1N_0, V_1N_1, V_1N_2, V_2N_0, V_2N_1, V_2N_2, V_3N_0, V_3N_1, V_3N_2, V_4N_0, V_4N_1 and V_4N_2. The 12 treatment combinations were replicated 3 times (36 experimental units) and laid out in a 4 × 3 factorial experiment in completely randomised design. For the N rates, combination of NPK 20:10:10 and urea fertilizers were used. The 0 kg N ha^{-1} was the control pots with no fertilizer application. Because split application of N fertilizers is promising in coarse-textured soils of the humid tropics (Umezinwa *et al*., 2020), the other two rates of N were achieved by split application as 70% basal and 30% top dressed prior to tillering (4 weeks after planting). For the 150 kg ha^{-1} N, 525 kg ha^{-1} NPK 20:10:10 was applied basally, which is equivalent to 3.15 g per 12 kg soil supplying 105 kg N ha^{-1}. The balance of 45 kg N ha^{-1} was achieved via topdressing of Urea at 97.83 kg ha^{-1}, which is equivalent to 0.58 g per 12 kg soil. For the 200 kg ha^{-1} N, basal application of 700 kg ha^{-1} NPK (20:10:10) gave equivalent of 4.20 g per 12 kg soil supplying 140 kg N ha^{-1}. The balance of 60 kg N ha^{-1} was achieved through topdressing of Urea at 130.43 kg ha^{-1}, equivalent to 0.78 g per 12 kg soil.

Planting and Maintenance of Experimental Units

Fifteen wheat seeds were planted 2 cm deep in 3 rows of five seeds per row per pot at 10 cm apart and later thinned to nine vigorous seedlings at 14 days after planting (DAP). The fertilizer treatments described above were applied. Irrigation was carried out twice daily at 500 mL per pot using a graduated water scoop based on the plant population and weather condition during the time the experiment was conducted (early February through the end of May). There was no frequent rain, but rather a very high evapotranspiration was experienced. During flowering and grain filling stages, the water was increased to 1.2 litres (600 mL twice daily) while at grain maturity, irrigation was returned to 1 litre per day. The pots were weeded manually as the need arose. Insect pests attack was also monitored. Harvesting was done at physiological maturity and dried for one week in an open field until properly dried and then threshed manually with sticks.

Plant Data Collection

Growth and morphological traits of wheat

The height measurement was done at 8 weeks after sowing (WAS) with the help of a meter rule from the ground level to the growing point (terminal bud) following the standard traditional procedure in Yuan *et al.* (2018). Flag leaf area (cm^2) was calculated at 6 WAS, using the formula (Aldesuquy *et al*., 2014):

$$Leaf\ area = Length \times breadth\ \times 0.75;$$

where 0.75 is the correction factor.

The tiller count per plant was obtained from each plant at 6 WAS. The functional tiller count per plant was obtained from each plant at 8 WAS. The number of days from sowing to heading was recorded through visual observation at 6 WAS.

Plant physiological measurement

The photosynthetically active radiation (PAR, µmol m^{-2} s^{-1}) was determined as spot measurement on the flag leaves at 4, 6, and 8 WAS on sunny days, using the MQ-100: Quantum Integral Sensor Meter (Apogee Instruments INC. USA).

Yield components and dry matter yield

The length of spike and numbers of spikes per plant, spikelets per main spike and spikelets per main plant were measured at 10 WAS. Also, the weights of spikes and plant dry matter were measured at harvest after oven drying at 75 °C for 72 h.

Harvest index and grain yield

Harvest index (%) was estimated as:

$$\text{Harvest index} = \frac{Seed\ dry\ matter}{Plant\ dry\ matter} \times \frac{100}{1}.$$

The grain yield per plant was measured at harvest using a sensitive weighing balance (g).

Laboratory Analysis

Analysis of physical properties of the soil

Particle size distribution was determined by Bouyoucous hydrometer method (Udo *et al.,* 2009). The soil textural classes were determined from percent sand, silt and clay using USDA textural triangle.

Analysis of chemical properties of the soil

The soil pH was determined with a pH meter in a 1:2.5 soil: water suspension using a glass-electrode. Total nitrogen was determined by micro-Kjeldahl method as described in Bremner (1996). Available phosphorus was extracted by Bray-2 method and the color was developed in soil extract using ascorbic acid blue method (Kuo, 1996). Exchangeable bases (Ca^+, Mg^+, K^+, and Na^+) were extracted by leaching the soil with neutral 1M NH_4OAc (John *et al.,* 2020) and read with an atomic absorption spectrophotometer (AAS). Potassium and sodium in the filtrate were determined by flame photometer, while calcium and magnesium were determined with an atomic absorption spectrophotometer (Model 6405 UV/visible spectrophotometer, Jenway, UK). The effective cation exchange capacity (CEC) was calculated by summation of exchangeable bases and exchangeable acidity (Juo, 1981). Exchangeable acidity was determined by successive leaching of the soil with neutral un-buffered IN KCl using a 1:10 soil liquid ratio. The amount of acidity (H and Al) in the leachate was estimated by titration with 0.05 NaOH to a permanent pink end point using phenolpthalein indicator (Maclean, 1982). The sum of the exchangeable bases and exchangeable acidity was taken as the effective CEC (ECEC). Organic carbon was determined by the dichromate wet oxidation method of Walkley and Black as outlined in Nelson and Sommers (1996). The result was multiplied by van Bemmelen factor of 1.724 (Page *et al.,* 1982) to estimate the soil organic matter content.

Statistical Analysis

The data were subjected to analysis of variance using GenStat software 15.1, 8th edition (VSN International, 2008) to partition the effects of the 2-factor experiment and their interactions. Treatment means were compared using Duncan's new multiple-range test at a 5% level of probability.

RESULTS AND DISCUSSION

The soil physicochemical properties and poultry manure nutrient composition of the experiment are presented in Table 1. Results showed that the soil was predominantly sand 78.30%, silt 12.50% and clay 16.00%. The soil was sandy loam in texture with a pH of 5.4 (strongly acid). Soil organic matter (SOM) content was within a low value of 1.04 % (Chude *et al.,* 2011), and contained 0.09% total N (TN), and 4.50 mg kg^{-1} available phosphorus. The exchangeable cations were 3.36 cmol kg^{-1} for Ca^{2+}, 1.60 cmol k^{-1} for Mg^{2+}, 0.08 cmol kg^{-1} for Na^{+}, and 0.10 cmol kg^{-1} for K^{+}. The exchangeable acidity was 2.52 cmol kg^{-1} for Al^{3+} and 0.76 cmol kg^{-1} for H^{+}. The soil ECEC was also low (< 10 cmol kg^{-1}) with the value of 8.42 cmol kg^{-1}. The base saturation (61%) was within the sufficiency limit of 60-80%.

Table 2 shows the main and interaction effects of wheat varieties and N fertilizer on soil chemical properties after sowing. There was a significant difference in the N application rate on soil pH, where a higher pH value of 6.28 was in the 150 kg^{-1} N treatment relative to the control (pH = 5.53). This result is consistent with the findings of Tana and Woldesenbet (2017) that fertilizers, including N, could improve soil pH compared with other treatment combinations. There was a significant ($p \leq 0.05$) increase in SOM in plots sown to *WZ 272-2015* and *Sc. Sahai* relative to other wheat varieties. Application of N significantly ($p \leq 0.05$) increased SOM, especially at the 150 kg N ha^{-1} rate relative to the control. Their interaction effects indicated that SOM was highest (3.67%) in soil sown to *WZ 272-2015* when treated with 150 kg N ha^{-1} compared to the control (0.00 kg N ha^{-1} = 0.80%). This indicates that N fertilization, especially at the150 kg ha^{-1} rate, could be promising for improving soil health to boost fertility in agricultural systems in support of wheat production (Agegnehu *et al.,* 2014). There were significant ($p \leq 0.05$) N and varietal effects on TN content of the soil. *Sc. Sahai* plots had higher TN under moderate N fertilization (150 kg N ha^{-1}), whereas their interactions showed that *WZ 272-2015* plots had more ($p \leq 0.05$) TN content under same N rate. This increase could be attributed to varietal superiority and the role of mineral fertilizer in boosting nutrient cycling in the soil (Agegnehu and Amede, 2016). Nitrogen fertilizers supply N in inorganic forms and are readily available for plant use for increased soil N levels. This suggests that N inputs at moderate levels may boost soil N level for wheat crop (Agegnehu *et al.,* 2014).

Across wheat varieties, soil content of available phosphorus (AvP) was highest ($p \leq 0.05$) in *Sc. Sahai* plots (Table 2), while the highest Av. P was recorded in plots treated with 150 kg N ha^{-1} (21.99 mg kg^{-1}) compared with the 0 kg N ha^{-1} (control, 12.38 mg kg^{-1}) and 200 kg N ha^{-1} (18.82 mg kg^{-1}) rates. The varieties and N rates interaction effects on AvP was highest (29.56 mg kg^{-1}; $p \leq 0.05$) for *Sc. Sahai* at the 150 kg N ha^{-1} rate. The results suggest varietal differences in phosphorus acquisition ability, which is often associated with root morphological traits and activities of phosphatase soil enzyme (Shen *et al.,* 2018). Treatment effects significantly ($p \leq 0.05$) enhanced the exchangeable bases (Mg, K and Na) across the wheat varieties in the order *Sc. Sahai > WZ 272-2015) > Norman > Imam*. Nitrogen application increased the soil exchangeable bases (Ca^{2+}, Mg^{2+} and K^{+}) which were highest ($p \leq 0.05$) in plots treated with 150 kg N ha^{-1} (4.85, 0.85 and 0.11 cmol kg^{-1}, respectively) relative to the control (0 kg N ha^{-1}). This signifies that an adequate supply of N can retain and exchange essential soil nutrients for optimal wheat development (Hao and Zhang, 2019). The exchangeable acidity (Al^{3+} and H^{+}) was reduced ($p \leq 0.05$) in soils planted with *Sc. Sahai* when N was applied relative to other varieties (Table 2). The application of N at 150 kg N ha^{-1} reduced the concentration of the exchangeable acidity (Al^{3+} and H^{+}) in soil (0.70 and 0.90 cmol kg^{-1}) compared with the control (1.13 and 1.41 cmol kg^{-1}). This could possibly be due to improvement in the overall soil chemical balance following a sustained nutrient availability (Zingore *et al*., 2023). Furthermore, the ECEC and base saturation (BS) were highest in *Sc. Sahai* and *WZ 272-2015* plots. Application of N fertilizer boosted soil ECEC and BS substantially

Table 1: Soil physicochemical properties and nutrient composition of poultry manure of the study

	Soil property	Value	Soil property	Value
Particle sizes	% Clay	16.00	pH-H_2O	5.4
	% Silt	12.50	% Org. matter	1.04
	% Sand	78.30		
	Soil texture	Sandy loam		
			Poultry manure	
Exch. bases & acidity (cmol kg^{-1})	% Total N	0.09	% Nitrogen	2.36
	Available P (mg kg^{-1})	4.50	% Phosphorus	0.54
	Calcium, Ca	3.36	% Calcium	4.83
	Magnesium, Mg	1.60	% Magnesium	2.64
	Potassium, K	0.10	% Potassium	2.11
	Sodium, Na	0.08		
	ECEC	8.42		
	Aluminum, Al^{3+}	2.52		
	Hydrogen, H^{+}	0.76		
	% Base saturation	61.0		

Table 2: Effects of wheat varieties and nitrogen fertilizer on chemical properties of soil after sowing

Treat-ment	pH-H_2O	% OM	% TN	AvP ($mg\ kg^{-1}$)	Ca^{2+} (cmol kg^{-1})	Mg^{2+}	K^{+}	Na^{+}	Al^{3+}	H^{+}	ECEC	% BS
Wheat variety (V)												
V_1	5.50a	2.24b	0.08d	17.75b	3.74a	0.47d	0.06d	0.08d	1.04a	1.28b	5.69c	52.70d
V_2	5.57a	2.40ab	0.14a	26.19a	4.00a	0.80a	0.13a	0.15a	0.59d	1.03d	8.99a	88.30a
V_3	5.60a	2.24b	0.11c	16.48b	4.27a	0.53c	0.09c	0.11c	0.88b	1.39a	7.24bc	68.00c
V_4	5.63a	2.48a	0.12b	6.50c	4.00a	0.60b	0.10b	0.13b	0.78c	1.15c	7.83b	79.70b
Nitrogen (N)												
N_0	5.53bc	2.05c	0.10c	12.38c	3.30c	0.45c	0.09b	0.09a	1.13a	1.41a	4.38c	51.50c
N_1	6.28a	2.59a	0.13a	21.99a	4.85a	0.85a	0.11a	0.12a	0.70c	0.90c	7.96a	82.25a
N_2	5.92b	2.38b	0.12b	18.82b	3.86b	0.50b	0.10ab	0.11a	1.01b	1.32b	6.78b	70.50b
N × V												
$N_0 V_1$	5.80a	1.91hij	0.10ef	9.00e	3.80bc	0.20ef	0.08de	0.09a	0.76e	1.36c	7.12a	55.00f
$N_0 V_2$	5.00a	2.14ghi	0.11def	5.00f	2.80c	0.20ef	0.08de	0.10a	0.92d	1.52b	7.68a	57.00ef
$N_0 V_3$	5.90a	1.72j	0.11def	3.00g	3.00c	0.30e	0.07e	0.09a	0.68e	1.52b	8.00a	62.00e
$N_0 V_4$	5.90a	1.38ij	0.09f	2.50gh	3.60bc	0.30e	0.09cd	0.08a	0.44f	1.24cd	7.65a	60.00e
$N_1 V_1$	5.70a	2.65bc	0.13cd	27.75b	4.20abc	0.40d	0.09cd	0.08a	1.16c	1.28cd	6.09a	59.00ef
$N_1 V_2$	5.00a	2.83b	0.14b	29.56a	5.00ab	1.80a	0.12a	0.27a	0.44f	0.96e	5.82a	85.00a
$N_1 V_3$	5.00a	2.28ef	0.09f	18.75c	5.00ab	0.40d	0.11b	0.06a	1.52b	1.68a	6.78a	62.00e
$N_1 V_4$	5.40a	3.67a	0.16a	2.50gh	5.20a	0.60c	0.11b	0.08a	1.40d	1.24cd	6.89a	78.00b
$N_2 V_1$	5.00a	2.12ghi	0.10ef	6.50ef	3.23c	0.40d	0.11b	0.21a	1.92a	1.20d	6.86a	65.00de
$N_2 V_2$	6.00a	2.21fgh	0.11def	27.00b	4.20abc	0.80b	0.10c	0.08a	0.64e	0.48f	7.30a	68.00c
$N_2 V_3$	5.90a	2.74b	0.14b	27.69b	4.80ab	0.60c	0.11b	0.09a	0.44f	0.96e	7.00a	61.00e
$N_2 V_4$	5.60a	2.45cd	0.12cde	14.50cd	3.20c	0.60c	0.09cd	0.07a	1.04d	1.08c	5.96a	66.00d

V_1 - *Imam*, V_2 - *Sc. Sahai*, V_3 - *Norman*, V_4 - *WZ 272-2015*; N_0 - 0 kg N ha^{-1} (control), N_1 - 150 kg N ha^{-1}, N_2 -200 kg N ha^{-1}; OM - Organic matter; TN - Total nitrogen, AvP - Available phosphorus, Ca^{2+} - Exchangeable calcium, Mg^{2+} - Exchangeable magnesium, Exchangeable K^{+} - Potassium, Exchangeable Na^{+} - Sodium, Al^{3+} - Exchangeable aluminium, H^{+} - Exchangeable hydrogen, ECEC - Effective cation exchange capacity, BS - Base saturation. Means within a column with the same letter(s) are not significantly different at 5% probability level according to Duncan's multiple range test.

and were highest ($p \leq 0.05$) at the 150 kg N ha^{-1} rate. The varietal differences observed in this study highlight the need for selection of potential wheat variety that could be more tolerant to acidic soil conditions. The study results suggest that cultivating wheat with sustainable N fertilization regime could potentially improve fertility status in humid tropical soils in support of long-term productivity.

Plant Growth Variables

Table 3 shows the response of wheat varieties, N fertilizer and their interactions on plant height, flag leaf area, number of tillers, number of functional tillers and number of days to heading. Significant ($p \leq 0.05$) varietal differences were observed across wheat agronomic attributes. *Sc. Sahai* had the tallest plants (49.96 cm) and a higher number of tillers (11.92) compared with other varieties. This suggests *Sc. Sahai's* capacity for vegetative vigour and adaptability. *Imam* maintained good performance in number of functional tillers (9.60) and flag leaf area (14.43 cm²), which thus, reflects its potential for growth and strong canopy development. In contrast, *Norman* recorded the longest interval to heading (82 days) and had low values for plant growth (31.40 cm). This indicates that while *Norman* variety may be late maturing, its productivity potential could be limited to inherent genetic variation. Similarly, *WZ 272-2015* had low growth rate and functional tillers, which may reduce its competitiveness under intensive cultivation. These varietal differences show that the genetic make-up of crops could influence their vegetative growth traits (Oraegbunam *et al*., 2016). This has been reported to be specifically true for wheat under different environmental conditions (Din *et al.,* 2020).

Application of N significantly enhanced wheat growth attributes compared to the control. At 150 kg N ha^{-1}, the highest plant height (57.63 cm), flag leaf area (18.73 cm²) and number of tillers/functional tillers (14.75, 11.18) were recorded relative to the control. This confirms that wheat growth is strongly dependent on adequate nutrient supply, particularly N, which influences enzyme activity, nutrient uptake, chlorophyll formation and tiller initiation in this crop (Guo *et al.,* 2019), and indeed leaf expansion in vegetable crops (Ebido *et al.,* 2024).

However, higher N applications at 200 kg N ha^{-1} did not further increase growth traits, suggesting possible nutrient imbalance or reduced efficiency in nutrient uptake at higher rates, a similar trend also reported in wheat crop (Khan *et al.*, 2025).

Photosynthetically Active Radiation

The effect of wheat varieties and N on photosynthetically active radiation (PAR) at 4, 6 and 8 WAS is shown in Table 4. Across the varieties, *Sc. Sahai* and *Norman* consistently had significantly ($p \leq 0.05$) higher light interception than *Imam* and *WZ 272-2015*, especially at 6 and 8 WAS. *Sc. Sahai* recorded the highest ($p \leq 0.05$) PAR (54.95 µmol $m^{-2}\ s^{-1}$) whereas *WZ 272-2015* had the least (31.65 µmol $m^{-2}\ s^{-1}$).

Table 3: Effect of wheat varieties and N on growth and morphological traits

Treatment		Plant height (cm) 8 WAS	Flag leaf area (cm^2) 6 WAS	Number of tillers 6 WAS	Number of functional tillers 8 WAS	Number of days to heading 6 WAS
Wheat variety (V)	V_1	45.11^b	14.43^a	9.33^b	9.60^a	60^c
	V_2	49.96^a	12.90^b	11.92^a	7.35^{ab}	48^d
	V_3	31.40^d	5.46^b	4.94^c	3.77^b	82^a
	V_4	36.37^c	4.70^{bc}	3.32^d	3.07^b	68^b
Nitrogen (N)	N_0	37.46^c	10.33^c	6.94^c	5.30^c	71^a
	N_1	57.63^a	18.73^a	14.75^a	11.18^a	49^c
	N_2	41.29^b	14.81^{ab}	9.45^b	7.10^b	60^b
N × V	$N_0 V_1$	50.60^a	4.99^a	5.67^a	1.72^a	74^a
	$N_0 V_2$	46.21^a	3.32^a	2.67^a	1.35^a	55^a
	$N_0 V_3$	47.30^a	12.77^a	3.67^a	0.81^a	81^a
	$N_0 V_4$	46.33^a	4.24^a	3.78^a	1.35^a	77^a
	$N_1 V_1$	51.60^a	6.65^a	6.22^a	1.74^a	79^a
	$N_1 V_2$	47.22^a	8.39^a	4.00^a	1.46^a	61^a
	$N_1 V_3$	45.01^a	14.78^a	5.72^a	0.81^a	82^a
	$N_1 V_4$	32.52^a	5.10^a	3.07^a	0.71^a	52^a
	$N_2 V_1$	33.11^a	4.74^a	5.89^a	1.35^a	51^a
	$N_2 V_2$	46.82^a	5.98^a	3.33^a	1.24^a	58^a
	$N_2 V_3$	47.01^a	15.74^a	5.44^a	0.71^a	83^a
	$N_2 V_4$	31.22^a	4.76^a	3.13^a	1.14^a	50^a

V_1 - *Imam*, V_2 - *Sc. Sahai*, V_3 - *Norman*, V_4 - *WZ 272-2015*; N_0 - 0 kg N ha^{-1} (control), N_1 - 150 kg N ha^{-1}, N_2 -200 kg N ha^{-1};
Means within a column with the same letter(s) are not significantly different at 5% probability level after Duncan's multiple range test.

Table 4: Effect of wheat varieties and N on photosynthetically active radiation (PAR, µmol m^{-2} s^{-1})

Treatment		PAR 4 WAS	PAR 6 WAS	PAR 8 WAS
Wheat variety (V)	V_1	22.17^b	28.52^c	36.79^c
	V_2	27.65^a	36.68^a	54.95^a
	V_3	27.13^a	34.48^b	47.26^b
	V_4	21.40^b	25.77^d	31.65^d
Nitrogen (N)	N_0	21.93^b	26.79^c	33.04^c
	N_1	29.43^a	37.32^a	56.30^a
	N_2	22.39^b	29.22^b	38.65^b
N × V	$N_0 V_1$	21.22^f	23.12^g	24.10^h
	$N_0 V_2$	17.02^h	19.40^{hi}	23.11^h
	$N_0 V_3$	14.44^i	16.28^j	20.07^i
	$N_0 V_4$	18.16^h	21.00^h	24.06^h
	$N_1 V_1$	24.12^e	33.31^e	50.22^d
	$N_1 V_2$	32.16^b	59.13^a	88.48^a
	$N_1 V_3$	48.10^a	47.89^b	79.60^b
	$N_1 V_4$	30.24^{cd}	40.04^c	61.18^c
	$N_2 V_1$	21.16^f	28.04^f	27.14^g
	$N_2 V_2$	18.98^{gh}	19.11^i	33.02^f
	$N_2 V_3$	20.40^{fg}	29.12^f	33.22^f
	$N_2 V_4$	29.03^d	36.91^d	47.73^e

V_1 - *Imam*, V_2 - *Sc. Sahai*, V_3 - *Norman*, V_4 - *WZ 272-2015*;
N_0 - 0 kg N ha^{-1} (control), N_1 - 150 kg N ha^{-1}, N_2 -200 kg N ha^{-1}.
Means within a column with the same letter(s) are not significantly different at 5% probability level after Duncan's multiple range test.

Source-sink structure is an intrinsic factor that affects crop photosynthesis and is also one of the main quality characteristics of high photosynthetic efficiency in crop populations (Fernie *et al.,* 2020). The significant differences in PAR among the wheat varieties could be attributed to source-sink relationships. Large-tillers/spike cultivars with high sink strength usually have higher photosynthetic traits such as larger flag leaf areas, longer leaf area durations, and stronger photosynthetic performance than small-tiller/spike counterparts (Fernie *et al.,* 2020; Zhang *et al.,* 2024). Application of N significantly improved PAR of wheat varieties across the sampling periods. The highest PAR was recorded at 8 WAS under the 150 kg N ha^{-1} rate (56.30 µmol m^{-2} s^{-1}) relative to the control (33.04 µmol m^{-2} s^{-1}). This may be attributed to denser canopies under fertilized conditions, that intercepted more radiation and translated into higher biomass (Ahmed *et al.,* 2025). Excessive or imbala-nced fertilization could reduce canopy efficiency and increase self-shading (Kubar *et al.,* 2022).

The N × variety interaction (N×V) showed that *Norman* under 150 kg N ha^{-1} application rate had the highest PAR at 4 WAS (48.10 µmol m^{-2} s^{-1}), while *Sc. Sahai* under same treatment was highest ($p \leq 0.05$) at 6 and 8 WAS (59.13 µmol m^{-2} s^{-1}; 88.48 µmol m^{-2} s^{-1}), respectively. Such contrasting responses suggest that variety × environment × nutrient interactions strongly influence light interception dynamics. Over 90% of dry matter accumulation in wheat cultivars is based on their photosynthetic efficiencies (Gaju *et al.,* 2016). Overall, the results suggest that wheat varietal choice could significantly affect PAR utilisation, where a higher N rate may not necessarily guarantee better light interception. Optimal fertilizer management must therefore balance canopy growth and efficient radiation use (Kubar *et al.,* 2022).

Yield Attributes

Table 5 shows the effect of wheat varieties and N on number of spikes per plant, number of spikelets per main spike, spike length and number of spikelets per main stem. Across the varieties, *Sc. Sahai* and *Imam* performed better in yield attributes compared to *Norman* and *WZ 272-2015*. However, *Sc. Sahai* was most ($p \leq 0.05$) superior in number of spikes/plant, number of spikelets/main spike and stem, and spike length suggesting its better adaption to the prevailing environmental conditions in the study location. The effect of N fertilizer showed varying significant responses. Application of N at the rates of 150 and 200 kg N ha^{-1} influenced ($p \leq 0.05$) wheat performance, but 150 kg N ha^{-1} produced relatively higher values across the traits, especially in *Sc. Sahai* relative to other varieties. Nitrogen fertilization is essential for successful wheat cultivation due to its significance in plant nutrition and overall seed quality (Duan *et al.,* 2019). Excessive N application reduces its use efficiency and increases environmental risks (Rossini *et al.,* 2018). Litke *et al.* (2018) demonstrated that wheat agronomic components and grain yield could increase significantly, even at the N fertilizer rates of 150 to 180 kg ha^{-1}.

The interaction of N × V for the number of spikes/plant and number of spikelets/main stem was highest ($p \leq 0.05$) in *Sc. Sahai* at the 150 kg N ha^{-1}. This confirmed the importance of N supply for maximising wheat yield (Noor *et al.,* 2023), as both deficiency and excess can limit productivity. The higher effective branch counts in *Sc. Sahai* may be attributed to its better capacity to utilise the applied N more efficiently for greater net assimilation rate and spike development (Mansour *et al.,* 2017). Thus, spike numbers can be used as a distinctive parameter for screening wheat varieties for N-use efficiency.

Table 5: Effect of wheat varieties and N on yield attributes of wheat at 10 weeks after sowing (WAS)

Treatment		No. of spike/plant	No. of spikelet/main spike	Spike length (cm)	No. of spikelet/main stem
Wheat variety (V)	V_1	5.95^b	11.65^b	3.59^b	23.10^b
	V_2	7.80^a	13.07^a	5.54^a	29.30^a
	V_3	3.07^{cd}	8.54^c	2.46^c	13.20^d
	V_4	4.38^c	11.44^b	2.71^c	16.50^c
Nitrogen (N)	N_0	2.89^c	5.54^c	1.92^c	12.10^c
	N_1	9.50^a	15.22^a	4.89^a	18.70^a
	N_2	7.56^b	11.51^b	2.58^b	16.60^b
N × V	$N_0 V_1$	1.90^{cd}	12.44^a	0.63^a	11.10^g
	$N_0 V_2$	1.78^{cd}	12.78^a	0.49^a	12.80^{fg}
	$N_0 V_3$	1.00^d	13.28^a	0.58^a	11.20^g
	$N_0 V_4$	0.90^e	11.67^a	0.74^a	11.30^g
	$N_1 V_1$	2.56^c	14.00^a	0.69^a	22.80^b
	$N_1 V_2$	6.22^a	15.11^a	0.65^a	29.90^a
	$N_1 V_3$	4.11^b	10.22^a	0.53^a	18.30^d
	$N_1 V_4$	4.67^b	9.57^a	0.55^a	19.60^c
	$N_2 V_1$	2.00^c	10.90^a	0.44^a	16.20^e
	$N_2 V_2$	2.00^c	14.34^a	0.48^a	15.20^{ef}
	$N_2 V_3$	1.11^d	11.11^a	0.27^a	13.20^f
	$N_2 V_4$	1.57^{cd}	13.68^a	0.83^a	14.60^{ef}

V_1 - *Imam*, V_2 - *Sc. Sahai*, V_3 - *Norman*, V_4 - *WZ 272-2015*; N_0 - 0 kg N ha^{-1} (control), N_1 - 150 kg N ha^{-1}, N_2 -200 kg N ha^{-1}. Means within a column with the same letter(s) are not significantly different at 5% probability level according to Duncan's multiple range test.

Harvest Index, Spike Weight/Plant, Plant Dry Weight and Grain Weight/Plant

The effects of wheat varieties and N on harvest index (HI), spike weight/plant (SWP), plant dry weight (PDW) and grain weight/plant (GWP) are shown in Table 6. Across the varieties, *Sc. Sahai* consistently showed better performance. It recorded the highest ($p \leq 0.05$) harvest index (63.10%), spike weight (19.54 g), plant dry weight (31.88 g) and grain weight (20.17 g), indicating superior partitioning of assimilates into biological and grain yield. Its relatively higher harvest index may suggest efficient conversion of biomass into grains. This suggests *Sc. Sahai's* potential for efficient uptake and utilisation of N under moderate N environment (Gheith *et al.,* 2021). Increasing N applications reduced ($p \leq 0.05$) yield traits among the varieties. However, the highest ($p \leq 0.05$) traits were recorded at the 150 kg ha^{-1} N, confirming that wheat varieties could perform differently under diverse N environments (Guttieri, 2017). Each variety displayed a diversified performance to N applications due to their different uptake ability, physiological, genetic and agronomic features (Kubar *et al.,* 2022). *Sc. Sahai* showed superiority in these tendencies and was higher in biomass accumulation and grain yields. The interaction (N × V) revealed distinct varietal response to N where *Sc. Sahai* and *Norman* responded positively to N fertilizer and significantly produced the highest HI (41.19%; 36.13%), SWP (29.65 g; 25.13 g) and GWP (19.88 g; 16.51 g) relative to their counterparts.

Table 6: Effect of wheat varieties and N on harvest index, weight of spikes, plant dry weight and grain weight at harvest of wheat crop

Treatment		% HI	Spike weight (g plant^{-1})	Plant dry weight (g plant^{-1})	Grain weight (g plant^{-1})
Wheat variety (V)	V_1	50.14^b	13.59^b	21.96^b	13.24^{ab}
	V_2	63.10^a	19.54^a	31.88^a	20.17^a
	V_3	36.29^c	11.46^c	14.26^d	8.31^b
	V_4	37.40^c	13.11^b	15.95^c	8.47^b
Nitrogen (N)	N_0	29.22^c	13.61^c	14.64^c	10.24^c
	N_1	58.17^a	21.61^a	29.04^a	24.30^a
	N_2	40.32^b	19.51^b	21.60^b	18.35^b
N × V	$N_0 V_1$	1.21^f	10.63^g	11.80^a	7.28^{ef}
	$N_0 V_2$	17.34^g	14.49^e	12.24^a	8.16^e
	$N_0 V_3$	12.10^h	10.58^g	13.23^a	7.18^{ef}
	$N_0 V_4$	17.44^g	11.74^f	12.29^a	6.40^f
	$N_1 V_1$	30.21^d	18.69^d	22.22^a	13.21^c
	$N_1 V_2$	41.19^a	29.65^a	31.89^a	19.88^a
	$N_1 V_3$	36.13^b	25.13^b	31.64^a	16.51^b
	$N_1 V_4$	32.77^c	20.55^c	32.42^a	13.51^c
	$N_2 V_1$	25.12^{ef}	18.44^d	31.87^a	11.22^d
	$N_2 V_2$	30.19^d	14.48^e	22.50^a	13.18^c
	$N_2 V_3$	28.56^e	22.27^{bc}	29.90^a	11.51^d
	$N_2 V_4$	32.71^c	20.83^c	21.13^a	8.51^e

V_1 - *Imam*, V_2 - *Sc. Sahai*, V_3 - *Norman*, V_4 - *WZ 272-2015*; N_0 - 0 kg N ha^{-1} (control), N_1 - 150 kg N ha^{-1}, N_2 -200 kg N ha$^{-1,}$ HI - Harvest index. Means within a column with the same letter(s) are not significantly different at 5% probability level according to Duncan's multiple range test.

CONCLUSION

This study investigated the effect of wheat varieties and nitrogen (N) rates on soil chemical properties, growth, physiological, yield and yield components in soils derived from coastal plain sands. The results showed that wheat varieties differed in their responses to the different N rates. Generally, N application enhanced both growth and yield of wheat significantly compared to the control (0 kg N ha^{-1}). *Sc. Sahai*, *Imam* and *Norman* consistently performed better in growth rates, canopy development, light interception, yield and yield attributes than *WZ 272-2015*. However, the 200 kg N ha^{-1} decreaseed yield attributes and prolonged number of days to heading. The 150 kg N ha^{-1} enhanced growth, physiological and yield attributes, with *Sc. Sahai* being the best in response and efficient use of N. From this research, *Sc. Sahai* can be grown at 150 kg N ha^{-1} rate for optimum yield in Calabar. Further field trials can be conducted to validate these findings.

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