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Synergistic effects of poultry manure and 2,4-epibrassinolide on soil properties and performance of groundnut in the rainforest of Nigeria.

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Abstract

The growth and yield response of groundnut (*Arachis hypogaea* L.) to fertilizer and other crop management inputs on Nigerian soils derived from coastal plain sands has been little studied. This greenhouse evaluation was aimed to determine the impact of chicken manure (CM) and 2,4-epibrassinolide (BR) on the growth and yield of groundnut. Four levels of CM: 0, 5, 10 and 15 tons/ha denoted as CM_0, CM_3, CM_2 and CM_1, respectively were factorially applied with two levels of foliar-sprayed BR [with: BR_1= 100 and 150 mL, and without: BR_0= 0 mL (control)], and arranged into a completely randomized design with three replications. The growth and yield attributes of groundnut were significantly improved across CM + BR combination, irrespective of CM levels. Plants grown in 15 tons/ha CM amended soil and sprayed with BR flowered earlier [29 days after sowing (DAS)] than the control (CM_0BR_0) (46 DAS). Light interception was significantly higher in treatment CM_1BR_1 relative to the other treatment combinations across the sampling periods. The combined 15 tons/ha CM and 250 mL BR treatment significantly produced the highest number of branches (8), pods (19), mean pod weight (36.20 g/plant), shoot dry weight (43.59 g/plant), 100-seed weight (26.10 g) and seed yield (9.84 g/plant). This treatment combination has potential to maximize groundnut yield in Calabar environs, but this is subject to field validation in subsequent trials.

Keywords: Organic manure; plant growth hormone; groundnut; acid sands; South-east Nigeria.

1. Introduction

Persistent decline in soil fertility is a major constraint to agricultural production, especially in Sub-saharan Africa (Agegnehu *et al.,* 2016). Like many other tropical countries, South-eastern Nigeria is dominated by soil resources in the *Ultisol* order, and characterized by fragile thin-layered, coarsetextured topsoils with multiple nutrients deficiency problems (Igwe and Obalum, 2023). The sustainability of agriculture on this soil is constrained by these anomalies with adverse effects on crop yield (Agbede *et al.,* 2017). Soil improvement based on the application of fertilizers is often unaffordable for poor farmers; even the blanket use of inorganic fertilizer has not been sustainable as there is leaching of nutrient elements down the profile due to the fragile nature of the soil (Agegnehu *et al.,* 2016). Resource-poor farmers often depend on organic manures, including chicken manure (CM) as a nutrient source (Adewole *et al.,* 2016). Although the use of organic inputs has frequently been shown to increase soil fertility, the benefits are generally short-lived in tropical soils because of the rapid decomposition of soil organic matter under high temperature and aeration (Mekuria and Noble, 2013). Since frequent applications are required, it becomes expensive, and thus not common (Masulili *et al.,* 2010). For this reason, organic amendments have to be consistently applied yearly to sustain crop productivity. 2,4-epibrassinolide (BR) is known to increase yield by boosting the growth of plants. It is useful for germination, flower and root development, seed maturation, storage, and other physiological processes in plants (Sun *et al.,* 2016; Otie *et al.,* 2018, 2019a, 2021, 2022). They sustainably promote root and shoot growth (Otie *et al.,* 2016, Kim *et al.,* 2018), enhance water use efficiency (Giri *et al.,* 2018; Otie *et al.,* 2019a), promote flowering and pod setting (Nagel *et al.,* 2001; Otie *et al.,* 2021), chlorophyll content (Sun *et al.,* 2016; Otie *et al.,* 2022) improve photosynthetic rate (Qi *et al.,* 2013; Otie *et al.,* 2019b, 2019c, 2025), enhance the translocation of photoassimilates (Sun *et al.,* 2016; Liu *et al.,* 2019), increase biomass accumulation (Liu *et al.,* 2019; Mohamed and Latif, 2017; Otie *et al.,* 2018, 2019a, 2019b, 2019c, 2022) and induce tolerance to several abiotic stresses (Hamayun *et al.,* 2010; Otie *et al.,* 2018, 2019a, 2021, 2024), resulting in enhanced growth and yield of plants.

Organic fertilizers, in the form of manures are essential determinants of plant growth and development. They are good sources of macro and other micronutrients for the improvement of soil fertility. They contribute to plant growth significantly through their favorable effects on the physicochemical and biological properties of the soil (Effa *et al.,* 2022). Although they are considered very bulky, they are not only safer sources of plant nutrients, but are also environmentally friendly (Eifediyi and Remison, 2010). Chicken manure has historically been used as a source of soil nutrients and its benefits have been fully realized because it is environmentally friendly (Akpan *et al.,* 2023). The manure is quite high in organic matter, nitrogen, phosphorus, magnesium, calcium and pH (Uko *et al.,* 2009).

The use of plant growth regulators, in the form of BR could compliment CM and help overcome soil fertility-related constraints to crop growth and yield. Groundnut (*Arachis hypogaea* L.) is a leguminous crop of the *Fabaceae* family and is cultivated in the semi-arid and subtropical regions of the world. It is a self-pollinated, annual herbaceous plant and very rich in essential nutrients with potential health benefits (Janila and Mula, 2015). World production of groundnut in 2019 was 48.8 million tonnes from 29.6 million hectares with average production of 1,647 kg ha^{-1} (FAO, 2021). The production of groundnut is concentrated in Asia and Africa where the crop is grown mostly by smallholder farmers under rain-fed conditions with limited inputs. Nigeria was the third largest producer of groundnut in 2019 with annual production of 4.4 million tonnes after China (17.1 million tonnes), and India (6.7 million tonnes) (FAO, 2021). It was estimated that 3.9 million hectares of groundnut were planted in Nigeria in 2019 (FAO, 2021). The main agroecological zones for groundnut production in Nigeria are the Sahel, Sudan, Northern Guinea and most of the Southern Guinea and Derived Savannah (Vabi *et al.,* 2019). The problems limiting the production of groundnut include low soil nutrients, inappropriate crop management practices, high labor demand and market constraints (Ahmed *et al.,* 2010). These constraints have contributed immensely to the low yield of the crop which discourages farmers from its cultivation in preference to other crops like maize, especially in Nigeria where production particularly in the rain forest agroecological zone is very low. Therefore, it is important to evolve an integrated approach involving a combination of some soil and crop management inputs to boost the production of groundnut. In Nigeria today, farmers use little or no exogenous plant hormones such as 2,4-epibrassinolide whether singly or in combination with other inputs like chicken manure to increase crop yields. In this study, we evaluated the agronomic performances of groundnut under the complementary application of chicken manure and BR in the rain forest agroecological zone of Nigeria.

2. Materials and methods

2.1 Study area

The experiment was conducted in the Department of Soil Science, University of Calabar Screen House facility (04º 57' - 13º N, 08º 20' E, 39 m above sea level). The mean annual temperature in Calabar ranges between 27 and 28 ºC while the relative humidity is 70-80 %. The rainy season normally starts from March to late October following the dry season from November to late February. The soil had a pH of 4.0-6.0 and high buffering capacity of about 2.0-10.0 cmol kg^{-1} soil, low base saturation, high exchangeable Aluminum, low organic matter and severely leached (Akpanidiok and Ukwang 2012).

2.1.1 Collection and preparation of research materials/laboratory analysis

The Samnut-24 groundnut variety was sourced from Cross River State Agricultural Development Programme, IBB Way, Calabar. The Samnut groundnut genotypes are known to be early maturing and rosette resistant, with high oil content and yield (Moji *et al.,* 2020).
2,4-epibrassinolide is a plant growth regulator, and that used for this study was manufactured in China and distributed worldwide by Zhejiang Laiyi Biology Technique Company Ltd, Shengzhou, China.
Cured chicken manure was sourced from Cross River State Ministry of Agriculture, Barracks Road, Calabar, shade-dried, crushed and analyzed for nutrient contents as described in Estefan *et al.* (2013). The CM contained (g/100g) 2.57 N, 1.02 P, 2.33 K, 3.34 Ca, 2.54 Mg and 27.44 organic carbon, with a pH of 7.2.
The soil for this study was collected from a previously cultivated plot at the Faculty of Agriculture Practical Year Research Farm latitude 4.50° - 5.20° N and longitude 8.0° - 8.30° E, University of Calabar. The research farm was left fallow for a year, and previously cropped to okra, cucumber and fluted pumpkin; the soil was amended with chicken manure to boost the fertility status of the soil. Soil samples (0-15 and 15-30 cm) were collected from five (5) different spots in a fallow land, using a soil auger and bulked to form a composite sample. A portion of about 200 g was used for routine physicochemical analysis using standard laboratory procedures as outlined in Udo *et al.* (2009) and Otie *et al.* (2025).
The surface soil (0-15) was air-dried and screened via a 4mm sieve, and fourteen kilogram (14.0 kg) of the soil was weighed with a weighing balance to fill each of the 32 plastic buckets (height, 30cm; diameter, 25cm) perforated at the base for drainage, and for seeding the groundnut.

2.1.2 Experimental design and treatments allocation

The experiment comprised of four levels of chicken manure: 0 ton/ha (control), 15 tons ha^{-1}, 10 tons ha^{-1} and 5 tons ha^{-1} and two rates of 2,4-epibrassinolide [without, BR_0 (0 mL) and with, BR_1 (250 mL/plant, in two splits of 100 mL and 150 mL). The treatments were laid into a 4×2 factorial, arranged in a completely randomized design (CRD). The total number of treatment combinations was 4×2 = 8 (Table 1) and replicated four (4) times to give a total of thirty-two (32) experimental units.

2.1.3 Planting and maintenance of experimental units

The different rates of chicken manure (CM) were incorporated into the soil and left for two weeks before seeding. Each pot was amended with CM, following the recommended rates for groundnut (Effa *et al.,* 2022) at 35, 70 and 105 g equivalent to 5, 10 and 15 tons ha^{-1}, respectively. The zero pots served as the control. Three seeds of groundnut were sown per pot at depth of 5 cm and later thinned to one vigorous seedling 14 days after sowing (DAS). The BR was used following the manufacturer's recommended rate of 1 mL of BR to 1 litre (L) of deionized water (Otie *et al.,* 2023) and 100 mL of the BR solution was the foliar-applied at active vegetative growth stage (21 DAS), while 150 mL was applied similarly during the onset of flowering (35 DAS). Plants that received no BR (0 mL) served as the control. Weeding was done bi-weekly after sowing.

Table 1: Treatment combinations and designation

Treatment	Description
CM_0 BR_0	0 ton ha^{-1} CM, no BR (Control)
CM_1 BR_0	15 tons ha^{-1} CM, no BR
CM_2 BR_0	10 tons ha^{-1} CM, no BR
CM_3 BR_0	5 tons ha^{-1} CM, no BR
CM_0 BR_1	0 ton ha^{-1} CM + BR
CM_1 BR_1	15 tons ha^{-1} CM + BR
CM_2 BR_1	10 tons ha^{-1} CM + BR
CM_3 BR_1	5 tons ha^{-1} CM + BR

CM= chicken manure; CM_0= 0 ton ha^{-1} chicken manure (control); CM_1=15 tons ha^{-1} chicken manure; CM_2= 10 tons ha^{-1} chicken manure; CM_3= 5 tons ha^{-1} chicken manure; BR= 2,4-epibrassinolide; BR_0 = 0 mL (control); BR_1= 250 mL BR application

2.1.4 Plant data collection

The height measurements and counting of leaf number were done at 4, 6 and 8 weeks after sowing (WAS). The plant height was measured with the help of a meter rule from the ground level to the growing point (terminal bud). The leaf area was also computed as length x breadth x 0.821 (correction factor) of the youngest matured leaf, then multiplied by the total number of leaves per plant (Kathirvelan and Kalaiselvan, 2007). The Photosynthetically active radiation (PAR) (μmol m^{-2}s^{-1}) was determined as spot measurement on the youngest matured leaves periodically (4, 6, and 8 WAS) on sunny days, using the MQ-100: Quantum Integral Sensor with Handheld Meter (Apogee Instruments INC. USA). The number of days to 50 % flowering was determined at 25 DAS, while the number of branches per plant was determined at 35 DAS. The number of pods per plant was determined at 90 DAS. The pod weight per plant was obtained by harvesting all the pods, washed, air-dried and weighed with electronic weighing balance. Shoot dry weight per plant was also determined at harvest after oven-drying at 65 ºC for 72 hours and then weighing. The 100-seed weight was determined by counting 100 seeds from the bulk of each treatment combination and weighing with an electronic weighing balance. For seed yield analysis, each plant per pot was harvested, washed, and left to sun-dry for 7 days to reduce moisture content to 14 %. Pods were threshed and the seeds were weighed to obtain the seed yield.

2.2 Statistical analysis

The experimental data were subjected to analysis of variance using the GenStat software 16.1 (GenStat Sixteenth Edition, Rothamsted Experimental Station, Harpenden, UK) to partition the effects of the 2-factor experiment and their interactions. Means were compared using Duncan's new multiple-range test at the 5 % level of probability.

3. Results and discussion

Initial physical and chemical properties of experimental soil

The physical properties of the soil before planting had particle size dominated by sand with 783.0 g kg^{-1}, followed by clay (165.0 g kg^{-1}) and silt (157.0 g kg^{-1}). The soil was classified as sandy loam. Such soil drains excessively and cannot retain significant amounts of water or nutrients (Akpanidiok and Ukwang, 2012). With respect to chemical properties (Table 2), the soil reaction (5.4) was strongly acidic (Brady and Weil, 2002), a condition attributed to high rainfall (>3500 mm per annum) which favors leaching of exchangeable basis in the study location. The soil organic carbon (OC) content was within a moderate value of 12.80 g kg^{-1} following the tropical soil fertility rating of Chude *et al.* (2011). This was indicative that the soil may be able to sustain intensive production only with careful fertilizer and crop management practices (Adekayode, 2010). Total nitrogen content was rather low (1.10 gkg^{-1}). This low level may not sustain crop production, being below the 4.5 g kg^{-1} established for productive soils (Dong *et al.,* 2012). The initial available P (10.12 mg kg^{-1}) is usually fixed and low for strongly acid soils. There may be need for some external P fertilizer application, which is attributable with tropical acid soils (Akpanidiok and Ukwang, 2012).

Physicochemical properties of the experimental soil after crop harvest

The effects of chicken manure (CM) and 2,4-epibrassinolide (BR) on soil pH, organic carbon (OC), total nitrogen (TN), available P (Av. P), calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) are shown in Table 2. The initial soil nutrients were lower than the post-cropped stage and treatments with CM had higher nutrient values across the rates relative to the control. However, the highest ($p \leq 0.05$) soil nutrient values were observed in plots that received full rates of CM (CM_1 = 15 tons ha^{-1}), with the BR spray. The observed soil acidity, which is a major constraint to soil nutrient availability in the humid tropical region could be corrected by applying CM (Azu, 2017). The 2,4-epibrassnolide, an active by-product of brassinolide biosynthesis is one of the stress ameliorative agents known to release carbohydrates as exudates to their surrounding media and contributing to the decline in soil abiotic stresses, including acidity (Pandey *et al.,* 2017; Otie *et al.,* 2018, 2022).

Table 2: Effects of treatments on soil chemical properties

Treatment	pH (H_2O)	OC ($g\ kg^{-1}$)	TN ($g\ kg^{-1}$)	Av. P ($mg\ kg^{-1}$)	Ca	Mg cmol kg^{-1}	K	Na
Pre-cropping	5.4	12.80	1.10	10.12	6.11	1.14	0.09	0.13
CM x BR								
CM_0BR_0	4.52 e	3.50 h	0.27 g	27.65 f	2.48 f	0.27 gh	0.11 f	0.07 e
CM_0BR_1	5.87 c	10.60 d	0.76 cd	35.59 c	4.01 cd	0.88 d	0.39 cd	0.14 c
CM_1BR_0	5.33 d	8.90 e	0.63 de	33.56 d	3.74 d	0.61 e	0.42 c	0.14 c
CM_1BR_1	7.54 a	29.20 a	1.89 a	49.93 a	7.21 a	2.10 a	0.79 a	0.29 a
CM_2BR_0	5.14 d	8.20 f	0.55 ef	32.83 d	3.70 d	0.44 f	0.31 d	0.11 d
CM_2BR_1	6.52 b	12.10 b	1.07 b	38.83 b	5.91 b	1.80 b	0.60 b	0.19 b
CM_3BR_0	5.20 d	6,60 g	0.410 fg	29.633 e	3.12 e	0.32 g	0.23 e	0.09 de
CM_3BR_1	6.013 c	11.40 c	0.847 c	35.947 c	4.59 c	1.02 c	0.45 c	0.14 c

Mean pairs with different letters were significantly different at the 5% probability level according to Duncan's new multiple range test. Chicken manure (CM); CM_0= control- 0 ton ha^{-1}; CM_1= 15 tons ha^{-1}; CM_2= 10 tons ha^{-1}; CM_3= 5 tons ha^{-1}; 2,4-epibrassinolide (BR); BR_0= without BR (control= 0 mL); BR_1= with BR (250 mL); Av. P = available phosphorus

3.1 Growth variables

Plant growth and light interception

The effect of chicken manure and BR on plant height, number of leaves and photosynthetically active radiation (PAR) of groundnut is presented in Table 3. As expected, these growth attributes were much lower in control treatment (CM_0), but the application of BR significantly increased their values across the sampling periods. The best growth performance was observed in pots treated with 15 tons ha^{-1}, with or without BR spray. The poultry manure analysis showed that it had an ample amount of plant nutrient which may have been released during mineralization to enhance growth attributes for the plants (Uko et al., 2009). Nwoku (2011) reported that its application did increase the growth rate of groundnut. The exogenous spraying of BR improved groundnut growth under acidity stress. This positive effect was ascribed to its ability to regulate a wide range of processes, including source–sink relationships through its ability to limit nutrient toxicity, by modulating cell division and elongation, as well as the differentiation of stem cells in root meristem, and promoting root growth under stress conditions (Otie *et al.,* 2018; Canales *et al.,* 2023).

There was a marked ($p \leq 0.05$) effect of the CM treatments on PAR across the sampling periods. The highest PAR (50.97 µmol $m^{-2}s^{-1}$) was recorded at 8 WAS in CM_1 plots (15 tons ha^{-1}) with BR. Adequacy in supply of organic manure is critical for the development of photosynthetic structures in plants, relevant for efficient light interception for improved yield (Zhang *et al.,* 2020). Photosynthesis controls gas exchange between plants and the atmosphere. The photosynthetic rate of the groundnut leaves was significantly increased following treatment with BR, which was reported to play extensive roles in plant growth and development, response to biological and abiotic stresses and optimization of plant photosynthetic tendencies (Ali, 2019).

Table 3: Effects of treatments on growth parameters and photosynthetic active radiation (PAR)

	Plant height (cm)			No. of leaves			Leaf area (cm^2)			PAR ($\mu mol\ m^{-2}s^{-1}$)		
Chicken manure (CM)	4 WAS	6 WAS	8 WAS	4 WAS	6 WAS	8 WAS	4 WAS	6 WAS	8 WAS	4 WAS	6 WAS	8 WAS
CM_0 (0 ton ha^{-1})	16.39 b	23.76 c	25.49 c	58.00 b	67.00 c	77.00 c	124.20 d	568.52 d	387.12 d	11.35 d	15.26 d	21.93 d
CM_1 (15 tons ha^{-1})	19.53 a	33.26 a	34.35 a	90.00 a	99.00 a	103.00 a	510.10 a	1924.22 a	1711.35 a	18.58 a	25.65 a	38.02 a
CM_2 (10 tons ha^{-1})	18.33 ab	27.48 b	29.16 b	80.00 a	90.00 ab	94.00 b	311.30 b	1010.10 b	1001.04 b	15.83 b	21.31 b	31.57 b
CM_3 (5 tons ha^{-1})	17.91 ab	27.04 bc	28.83 b	77.00 a	87.00 b	90.00 b	209.90 c	902.14 c	804.24 c	13.97 c	18.44 c	24.11 c
2,4-epibrassinoloide (BR)												
BR_0 (0 mL $plant^{-1}$)	16.46 b	24.81 b	26.53 b	66.00 b	75.00 b	82.00 b	279.50 b	647.10 b	586.92 b	11.14 b	14.79 b	19.65 b
BR_1 (250 mL $plant^{-1}$)	19.61 a	30.96 a	32.39 a	87.00 a	96.00 a	100.00 a	504.12 a	1141.33 a	1011.04 a	18.73 a	25.55 a	38.17 a
CM x BR												
CM_0BR_0	14.65 c	19.80 c	21.50 c	36.00 c	45.00 c	63.00 c	317.30 d	894.71 h	759.55 h	6.87 g	11.41 f	15.53 h
CM_0BR_1	18.13 abc	27.73 b	29.48 b	81.00 ab	88.00 b	91.00 b	482.82 c	1179.21 f	1099.21 f	15.83 d	19.12 d	28.33 d
CM_1BR_0	17.25 bc	27.35 b	28.70 b	80.00 ab	87.00 b	90.00 b	520.61 b	1432.10 c	1320.20 c	14.85 d	18.17 d	25.07 e
CM_1BR_1	21.80 a	39.175 a	40.00 a	101.00 a	111.00 a	116.00 a	731.90 a	2219.38 a	1889.12 a	22.32 a	33.14 a	50.97 a
CM_2BR_0	17.18 bc	26.25 b	28.05 b	76.00 b	87.00 b	90.00 b	480.00 c	1251.33 e	1162.34 e	12.30 e	15.03 e	20.83 f
CM_2BR_1	19.48 ab	28.70 b	30.28 b	84.00 ab	94.00 b	97.00 b	544.70 b	1624.20 b	1478.94 b	19.36 b	27.60 b	42.32 b
CM_3BR_0	16.78 bc	25.83 b	27.85 b	71.00 b	83.00 b	84.00 b	415.31 cd	1094.70 g	1008.11 g	10.53 f	14.55 e	17.18 g
CM_3BR_1	19.05 ab	28.25 b	29.80 b	84.00 ab	91.00 b	91.00 b	498.50 c	1376.42 d	1202.13 d	17.42 c	22.34 c	31.05 c

Mean pairs with different letters were significantly different at the 5% probability level according to Duncan's new multiple range test. Chicken manure (CM); CM_0= control- 0 ton ha^{-1}; CM_1= 15 tons ha^{-1}; CM_2= 10 tons ha^{-1}; CM_3= 5 tons ha^{-1}; 2,4-epibrassinolide (BR); BR_0= without BR (control= 0 mL); BR_1= with BR (250 mL); WAS= weeks after sowing

3.2 Growth and yield component analysis

Growth analysis

The effects of treatments on the growth and yield components of groundnut are presented in Table 4. Improved crop management practices, including proper fertilizer management determine the productivity and yield of groundnuts (Kabir *et al.,* 2013). The number of branches and pod per plant and pod weight per plant increased ($p \leq 0.05$) successively with increases in CM rates. A previous report (Uguru *et al.,* 2011) showed that an appropriate fertilizer management of groundnut with needed nutrients at the right time had a significant effect on seed yield and quality. These observed increases following CM application only confirmed that organic fertilizers have the potential of influencing crop productivity positively. Plant growth regulators, including BR are essential for promoting flowering, pod setting and the overall shoot growth of plants (Otie *et al.,* 2021). In this study, the BR considerably increased the agronomic traits of groundnut possibly through its ability to increase the production and transportation of photosynthates from source to sink (Khan and Mazid, 2018). The number of days to 50 % flowering was significantly ($p \leq 0.05$) reduced following the application of CM. The plants began flowering at only 29.00 average days after sowing in the fully treated pots (CM_1 + BR_1), compared with 46.00 average days in control pots (CM_0 + BR_0) (Table 4). This could have been facilitated by the synergistic effect of the CM and BR (Amanullah *et al.,* 2010; Gruszka *et al.,* 2023). Successive increase in rates of CM and BR application led to a remarkable increase in shoot dry weight, 100 seed weight and seed yield, especially at the 15 tons ha^{-1} rate (Table 4). Chicken manures play important roles in soil nutrient supply and have been shown to enhance the productivity of groundnut on acid soils (Hepperly *et al.,* 2009). Several plant traits, also known as yield indices cumulatively determine the overall yield performance. For groundnut, indices such as number of pods, seed weight, number of seeds and dry matter yield contribute to the overall yield, and an increase in these indices may significantly influence the yield. Maximizing these attributes and subsequently, the overall yield would benefit from the adoption of suitable agronomic practices such as the combined use of CM and BR. Studies have shown the influence of BR on these indices and its overall effect on the yield of groundnut (Meena *et al.,* 2019; Menpadi *et al.,* 2022).

Table 4: Effects of treatments on the growth and yield components of groundnut

Treatment NPK rate	No. of BRH/plant (35 DAS)	No. of days to 50 % flowering	No. of pod plant^{-1}	PWt/plant (g plant^{-1})	Shoot dry weight (g plant^{-1})	100-Seed weight (g plant^{-1})	Seed yield (g plant^{-1})
CM_0 (0 ton ha^{-1})	3.00 b	42.00 a	8.00 b	18.13 c	16.47 d	7.22d	4.59 c
CM_1 (15 tons ha^{-1})	6.00 a	34.00 c	16.00 a	31.75 a	32.77 a	23.93 a	8.34 a
CM_2 (10 tons ha^{-1})	4.00 b	38.00 b	13.00 ab	25.00 b	24.46 b	14.09 b	6.80 b
CM_3 (5 tons ha^{-1})	4.00 b	38.00 b	10.00 b	19.88 bc	20.25 c	11.29 c	5.98 b
2,4-epibrassinolide (BR)							
BR_0 (0 mL plant^{-1})	3.00 b	43.00 a	8.00 b	17.13 b	16.64 b	8.03 b	4.71 b
BR_1 (250 mL plant^{-1})	5.00 a	33.00 b	15.00 a	30.25 a	30.34 a	21.51 a	8.15 a
CM x BR							
CM_0BR_0	2.00 c	46.00 a	5.00 b	9.75 c	10.44 f	7.11 e	2.34 e
CM_0BR_1	4.00 b	38.00 cd	12.00 ab	26.50 b	22.50 c	13.44 c	6.84 bc
CM_1BR_0	4.00 b	40.00 bc	12.00 ab	27.25 b	21.96 cd	15.75 bc	6.84 bc
CM_1BR_1	8.00 a	29.00 f	19.00 a	36.20 a	43.59 a	26.10 a	9.84 a
CM_2BR_0	4.00 b	42.00 bc	11.00 ab	20.75 b	18.45 de	12.90 cd	5.77 c
CM_2BR_1	4.00 b	34.00 e	16.00 a	29.25 ab	30.47 b	17.29 b	7.83 b
CM_3BR_0	3.00 bc	43.00 ab	7.00 b	10.75 c	15.71 e	9.43 d	3.89 d
CM_3BR_1	4.00 b	34.00 de	13.00 ab	29.00 ab	24.80 c	13.13 c	8.06 b

Mean pairs with different letters were significantly different at the 5% probability level according to Duncan's new multiple range test. Chicken manure level (CM); CM_0= control- 0 ton ha^{-1}; CM_1= 15 tons ha^{-1}; CM_2= 10 tons ha^{-1}; CM_3= 5 tons ha^{-1}; 2,4-epibrassinolide (BR); BR_0= without BR (control= 0 mL); BR_1= with BR (250 mL); BRH/plant = branch per plant; PWt/plant = pod weight per plant; WAS= weeks after sowing

The data from this study showed that the combined application of chicken manure and 2,4-epibrassinolide (BR) significantly improved soil nutrient properties and groundnut growth. The growth improvement was reflected in the reduced number of days to 50 % flowering and the yield indices of ground nut. We suggest that a combined application of 15 ton ha^{-1} of chicken manure plus 250 mL per plant of 2,4-epibrassinolide would optimize groundnut production in the study area. However, further studies are needed to validate this suggestion in the field.

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5. Declarations of interest

None

6. Submission declaration and verification

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