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ORIGINAL RESEARCH ARTICLE

Growth and yield response of groundnut cultivars to selected rates of phosphorous and soil amendments in the Southern Guinea Savanna of The Gambia

S.A.F. Jallow[1*], F. J. Manneh[1], A. Bah[2] and Michael Rotimi Olojugba[3]

[1]School of Agriculture and Environmental Sciences, University of Gambia, Faraba, The Gambia
[2]Associate Researcher, CIFOR-ICRAF, Banjul, Gambia
[3]Department of Crop, Soil and Pest Management, Olusegun Agagu University of Science and Technology, Okitipupa Ondo State, Nigeria
[*]Corresponding author's E-mail: sagarr.jallow@utg.edu.gm

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ABSTRACT

A field experiment was conducted at The Gambia College Research Farm in the wet season from June to November, 2022. The aim was to determine the growth and yield response of groundnut cultivars to selected rates of phosphorous and soil amendments in The Gambia. A split-plot design was used with two groundnut cultivars assigned to the the main plots and sixteen rates of phosphorous fertilizer and organic soil amendments allocated to the subplots. The treatments were replicated three times. The treatments were applied and incorporated into the soil two weeks before planting. Sowing was done at a depth of 5 cm and the plants were spaced at 50cm between rows and 12cm between stands within the row with one seed per stand. The application of phosphorus (P) at 30 $kgha^{-1}$ + Farm Yard Manure (FYM) at 5,000 $kgha^{-1}$ recorded the highest number of branches (18.67) and largest canopy (57.93cm), highest pod weight (1088.70 kg ha^{-1}) and kernel yield (1025.50 kg ha^{-1}), followed by P at 30 $kgha^{-1}$ + Biochar at 2500 $kgha^{-1}$ and P at 60 $kgha^{-1}$. The study concluded that application of P at 30 $kgha^{-1}$ + FYM at 5,000 $kgha^{-1}$ significantly increased the production of pod and kernel yields than rest of the treatments tested on groundnut. Therefore, this treatment is recommended for adoption by small-scale farmers to increase groundnut production and P availability in Gambian soils.

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INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important cash crop and occupying 40-50% of the total arable land area in The Gambia (Jallow *et al*., 2019). Despite this higher cultivation, Gambian farmers get relatively low yields from groundnut, mainly because of poor soils. Poor soil fertility threatens food security in the country, and increases poverty levels. According to Verde & Matusso (2014), smallholder farmers are faced with low crop yields, income and food scarcity due to low soil available P in most of Sub-Sahara African (SSA) soils. The low available P has been identified as one of the contributing factors to the decline of groundnut production over the years in the Gambia (GNAIP, 2019-2026). Phosphorus is an important organic compound in the soil that plays a significant role in the physiological development of plants such as cell division, increased root hairs, flower and pollen tube development, pollen germination and fruit and pod setting. The amount of phosphorus adsorbed by soils is highly correlated with exchangeable aluminum, total iron, organic matter, and low pH. Though groundnut is cultivated in many parts of The Gambia, very little research work has been done so far on the improvement of phosphorus levels and appropriate rates in different agroecological zones of the country. The field experiment results obtained elsewhere showed that application of FYM at 10 to 15 t ha^{-1} significantly increased pod and haulm yields, shelling percentage and 1000-seed weight in groundnut (Subrahmaniyan *et al*., 2000). Also, biochar has been identified as a good option for soil amendment due to its large surface area and ability to enhancing soil porosity, nutrients and water retention and improvement of microbial activities in the soil (Khan *et al*., 2018). The application of these soil amendments could help to improve the soil organic matter content and create conditions for slow release of the major nutrients such as Nitrogen (N), Phosphorus (P) and Potassium (K)); and enhance the buffering and cation exchange capacities of the soil (Liang *et al*., 2011). Furthermore, the use of organic soil amendments such as FYM and biochar will enhance phosphorus availability and improve the growth and yield of groundnut (Vyshnavi *et al*., 2021). Surya *et al*. (2022) reported that, biochar application to soil improves crop productivity through increased nutrient use efficiency, increased water holding capacity and decreased bulk density of the soil. The appropriate use of different rates of farmyard manure and biochar increases growth (canopy height, number of branches etc) and yield of groundnut (Surya *et al*., 2022). The aim of this study is to determine the growth and yield response of groundnut cultivars to selected rates of phosphorous and soil amendments in southern guinea savanna of the Gambia.

MATERIALS AND METHODS

Description of the experimental site

The experiment was conducted during the wet growing season from June to November, 2022. The experiment was located at the Gambia College Research farm which lies between 13.2867° N and 16.6571° W (Figure 1). The site was characterized by two seasons, wet season (June to November) and dry season (December to May). The mean annual rainfall was 1568.5 mm.

Experimental design and treatments used

The experimental design was split-plot with 32 treatments replicated three times. The treatments consisted of two factors: groundnut cultivars (Fleur 11 and Philippine pink) and 16 rates of phosphorous and soil amendments and their combinations. The P and soil organic amendment treatment comprised the following: 0 kgha^{-1}, FYM at 5000 kgha^{-1}, biochar at 5000 gha^{-1}, FYM at 10,000 kgha^{-1}, phosphorous at 30 kgha^{-1}, phosphorous at 15 kgha^{-1} + FYM at 2500 kgha^{-1}, phosphorous at 15 kgha^{-1} + biochar at 2500 kgha$^{-1,}$ phosphorous at 15 kgha^{-1} + FYM at 5,000 kgha^{-1}, phosphorous at 40 kgha^{-1}, phosphorous at 20 kgha^{-1} + FYM at 2500 kgha^{-1}, phosphorous at 20 kgha^{-1} + biochar at 2500 kgha^{-1}, phosphorous at 20 kgha^{-1} + FYM at 5,000 kgha^{-1}, phosphorous at 60 kgha$^{-1,}$ phosphorous at 30 kgha^{-1} + FYM at 2500 kgha^{-1}, phosphorous at 30 kgha^{-1} + biochar at 2500 kgh^{-1}and phosphorous at 30 kgha^{-1}+ FYM at 5,000 kgha^{-1}. Groundnut cultivars were assigned to the main plots, while rates of phosphorous and organic soil amendments and their Combination were allocated to the sub plots. Gross and net-plots sizes were 4.32 m^2 and 2.16 m^2, respectively. The groundnut seeds were sown at a depth of 5 cm using hand hoe. The plants were spaced at 50 cm between rows and 12 cm within rows with one seed sown per stand (Desmae *et al*., 2022). Soil samples were randomly collected at the depth of 0-30 cm using dutch auger prior to sowing and after harvest. The soil samples were air dried, grounded and sieved using 2mm sieve size before laboratory analysis. Samples were analyzed at the Centre for Dryland Agriculture (CDA) Soil Laboratory, Bayero University Kano, Nigeria. The samples were subjected to the following analytical methods: Soil Textural Class; percentage of sand, silt and clay using Hydrometer Method of Soil Mechanical Analysis (Bouyoucos, 1951), Soil pH using Glass- electrode pH meter Method (Bates, 1954), Total Nitrogen using Macro-Kjeldahl Method (Honda, 1962), Available Phosphorus for all the plots using Bray No.1 Method (Bray and Khurtz, 1945), Organic Carbon using Walkley-Black Method (Walkley & Black, 1934), CEC using Extraction Method as described by Anderson and Ingram (1993), Exchangeable bases: K, Na, Mg, Ca using Extraction Method as described by Anderson & Ingram (1993).
Farmyard manure and biochar were characterized before application. The bulk density, porosity and moisture content of the farmyard manure and biochar were determined by the methods of McLaughlin *et al*. (2009). The bulk density in all materials were determined by gravimetric method; N by micro-Kjheldal technique (Anderson & Ingram, 1993). Total P content, $Ca^{2+}$and Mg^{2+} of the farmyard manure and biochar were determined using Atomic Absorption Spectrophotometer (AAS) (Buck Scientific Model 210 VGP), while Na^+ and K^+ were read using flame photometer as described by Dawaki *et al*. (2019).

Biochar production

Biochar was produced in a fabricated metallic biochar kiln fitted with an inner cylindrical, airtight combustion chamber and an outer heater. Groundnut shells were used and filled in the biochar kiln and heated to 400 °C for three and a half hours as stated by Lado *et al*. (2021).

Data collected

Data collected included number of branches at harvest, canopy height at harvest, number of nodules at 3 and 6 weeks after sowing, pod yield, kernel yield were collected from the five tagged plants from the net plots and Agronomic Efficiency of Phosphorous (AEP) according to Fageria *et al*. (1997).

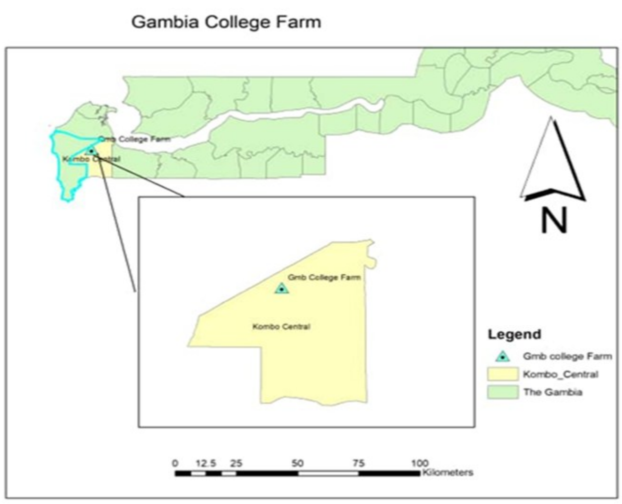

Figure 1. *Map of the study site.*

Data analysis

The data collected were analysed with Analysis of variance (ANOVA) using GenStat version 17th Edition. The difference between the means was compared using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

The Physical and chemical properties of farmyard manure and the biochar analysis were carried out. Soil amendment results of both materials revealed that the physical properties such as bulk density, porosity and moisture content were relatively optimum for crop production according to FAO (2023). The farmyard manure contained a bulk density of 0.513 g/cm^3, porosity of 54.399% and moisture of 17.166% while the biochar contained a bulk density of 0.410 g/cm^3, porosity of 57.095% and moisture of 8.191%. These results of the physical properties were considered optimum in improving good soil structure (FAO, 2023). The total Nitrogen of the farmyard manure was 1.610%, and total phosphorus, potassium, magnesium, exchangeable calcium, magnesium and sodium were 0.480%, 0.040%, 0.670%,0.240% and 0.110%, respectively. However, the biochar contained total nitrogen of 1.740%, total phosphorous of 0.370%, total potassium of 0.030%, exchangeable calcium of 0.240%, magnesium of 0.190% and sodium of 0.040%. Table 1 shows the physico-chemical properties of the soil before sowing during the 2022 rainy season. Soil analysis results of the study area revealed that the soil was sandy loam. The total N (0.05 %) and organic matter (1.0 %) were rated low according to the critical limits stated by Ethiosis Team Analysis (2014). The low nitrogen content of the soil in the experimental site could be attributed to the history of continuous cultivation with little or no application of organic matter. The pH was classified as moderately acidic (pH 6.0) which is considered ideal for groundnut production. Rusmayadi (2024) reported that soil pH is a critical factor that significantly influences nutrient availability in groundnut crops. A very low available P (10 ppm) before sowing at the experimental site indicated that P was a major limiting factor for groundnut production. Phosphorous is an important nutrient next to nitrogen for plants, it has a beneficial effect on nodule stimulation in groundnut, root development, growth and yield. A research work conducted by (Asante *et al*., 2020) revealed that phosphorus is considered a limiting factor in groundnut nutrition due to the deficiency of available soluble phosphate in the soil. Exchangeable cations like Ca, Mg and k were rated as marginal before the trial according to Ethiosis Team Analysis (2014). The CEC at 2.9 meq/100 g indicated soil infertility according to Ethiosis Team Analysis (2014). The micronutrients such as Fe and Mn were rated as extremely high, while Zn and B were rated low (Ethiosis Team Analysis, 2014). Table 2 shows the soil physico-chemical analysis of the various treatments during the 2022 rainy Season. The results of the soil physico-chemical analysis under the various treatments after the trial revealed that the application of phosphorous at 60 kgha^{-1} and 40 kgha^{-1} recorded 130 ppm of P and 100 ppm of P, respectively. According to the critical limit for soil nutrients stated by Ethiosis Team Analysis (2014) and Muhr *et al*. (1963), such a level of P is classified as being high. The application of Phosphorous at 30 kgha^{-1}+ FYM at 5,000 kgha^{-1}(TRT 16) recorded the third-highest amount of available P. However, the available P was low in the rest of the treatments. Due to the significant role played by P in plant growth and development, its addition to P-deficient soils lead to an increase in the yield of groundnut (Yaro *et al*., 2021). Application of biochar at 5000 kgha^{-1} (Trt 3) recorded exchangeable Ca and Mg of 800 ppm and 120 ppm, respectively and these were high according to Ethiosis Team Analysis (2014) and Muhr *et al*. (1963). The rest of the treatments recorded a marginal limit of exchangeable Ca and Mg. The exchangeable K was low for all the treatments evaluated. The selected rates of phosphorous and soil amendments significantly (*P=0.001*) increased both the number of branches plant^{-1} and canopy height at harvest (Table 3).

Table 1. Soil physico-chemical characteristics before sowing at Gambia College Research Farm during 2022 rainy season.

Properties	Result	Unit	Remark*
A. Physical			
Sand	53.1	%	
Clay	5.24	%	
Silt	41.6	%	
Textural Class	Sandy loam		
B. Chemical			
pH in H_2O	6.0		Moderately acidic
Total Nitrogen	0.05	%	Very low
Organic matter	1.0	%	Very low
Available P	10	Ppm	Very low
Exchangeable bases			
Calcium	400	Ppm	Medium
Magnesium	60	Ppm	Marginal
Potassium	40	Ppm	Low
CEC (meq/100g)	2.9	meq/100g	Indicate soil Infertility
Micronutrients			
Iron	70	Ppm	Extremely High
Manganese	60	Ppm	Extremely High
Copper	1.0	Ppm	Low
Zinc	1.0	Ppm	Low
Boron	0.5		Low

Table 2. Soil physico-chemical characteristics of various treatments at Gambia College Research Farm during 2022 rainy season.

TRT	Results																
	Physical				Chemical												
									Exchangeable bases (ppm)				Micronutrients (ppm)				
	Sand %	Clay %	Silt %	Textural Class	pH in H_2O	OM %	Total N (%)	Available P (ppm)	Ca	Mg	K	CEC meq/ 100g	Zn	Cu	B	Mn	Fe
TRT 1	53.1	5.24	41.6	Sandy loam	5.1	0.1	0.02	10	400	60	40	1.4	1.0	1.0	0.5	40	60
TRT2	53.1	5.24	41.6	Sandy loam	5.9	0.9	0.04	10	400	60	40	3.2	1.1	1.0	0.5	40	60
TRT3	53.1	5.24	41.6	Sandy loam	6.5	1.8	0.07	30	800	120	40	6.0	1.1	1.7	0.5	80	110
TRT4	53.1	5.24	41.6	Sandy loam	6.2	1.0	0.05	10	500	60	40	3.5	1.1	1.0	0.5	50	50
TRT5	53.1	5.24	41.6	Sandy loam	6.2	1.3	0.05	30	500	60	40	3.7	1.1	1.0	0.5	60	80
TRT6	53.1	5.24	41.6	Sandy loam	6.0	1.0	0.04	10	400	60	40	3.2	1.1	1.0	0.5	50	60
TRT7	53.1	5.24	41.6	Sandy loam	6.0	1.3	0.06	30	500	60	40	3.8	1.9	1.5	0.5	60	70
TRT8	53.1	5.24	41.6	Sandy loam	6.3	1.5	0.06	10	700	90	40	5.0	1.1	1.1	0.5	70	90
TRT9	53.1	5.24	41.6	Sandy loam	5.9	1.1	0.05	90	400	60	40	3.6	1.2	1.0	0.5	60	60
TRT10	53.1	5.24	41.6	Sandy loam	6.6	1.3	0.05	30	600	80	40	4.3	1.1	1.0	0.5	80	80
TRT11	53.1	5.24	41.6	Sandy loam	6.4	1.2	0.05	10	500	60	40	3.6	1.1	1.0	0.5	60	70
TRT12	53.1	5.24	41.6	Sandy loam	5.8	1.1	0.05	10	400	60	40	3.6	1.1	1.0	0.5	60	70
TRT13	53.1	5.24	41.6	Sandy loam	6.1	1.0	0.04	139	400	60	40	3.3	1.1	1.0	0.5	60	60
TRT14	53.1	5.24	41.6	Sandy loam	6.2	1.1	0.05	10	600	60	40	4.0	1.1	1.0	0.5	60	70
TRT15	53.1	5.24	41.6	Sandy loam	6.3	1.2	0.05	30	500	60	40	3.6	1.1	1.0	0.5	70	70
TRT16	53.1	5.24	41.6	Sandy loam	6.3	1.1	0.25	35	400	60	40	7.3	1.1	1.0	0.5	50	60

TRT=Treatment,TRT1=0 Phosphorous at Kgha^{-1} , TRT2=FYM at 5000Kgha^{-1} , TRT3= Biochar at 5000Kgha^{-1} ,TRT 4=FYM at 10,000Kgha^{1},TRT5=Phosphorous at 30 Kgha^{-1}, TRT6=Phosphorous at 15 Kgha^{-1} + FYM at 2500Kgha^{-1},TRT7=Phosphorous at 15 Kgha^{-1} + Biochar at 2500Kgha^{-1},TRT 8=Phosphorous at 15Kgha^{-1} + FYM at 5,000Kgha^{-1},TRT9= Phosphorous at 40 Kgha^{-1},TRT 10=Phosphorous at 20 Kgha^{-1} + FYM at 2500Kgha^{-1},TRT 11=Phosphorous at 20 Kgha^{-1} + Biochar at 2500Kgha^{-1},TRT12 =Phosphorous at 20Kgha^{-1} + FYM at 5,000Kgha^{-1}, TRT 13=Phosphorous at 60 Kgha^{-1},TRT 14= Phosphorous at 30 Kgha^{-1} + FYM at 2500Kgha^{-1},TRT 15=Phosphorous at 30 Kgha^{-1} + Biochar at 2500Kgh^{-1},TRT16=Phosphorous at 30 Kgha^{-1}+ FYM at 5,000Kgha^{-1}, OM= Organic matter, ppm=Parts per million *Soil physio-chemical Analysis was done at Centre for Dryland Agriculture Soil Lab, Bayero University Kano, Nigeria.

Table 3. Effect of selected rates of phosphorous and soil amendments and groundnut cultivars on number of branches at harvest and canopy height at harvest of groundnut.

Location: Gambia College Research Farm		
Treatments	2022 Rainy season	
	Number of Branches at Harvest	Canopy height (cm) at Harvest
Rates of Phosphorous and Soil Amendments		
P at 0Kgha^{-1} (control)	4.85f	23.30d
FYM at 5000 Kgha^{-1}	13.70cd	43.93c
Biochar at 5000 Kgha^{-1}	14.03cd	51.97abc
FYM at 10,000 Kgha^{-1}	13.72cd	47.30c
P at 30 Kgha^{-1}	7.58e	27.15d
P at 15 Kgha^{-1} + FYM at 2500 Kgha^{-1}	13.87cd	41.93c
P at 15 Kgha^{-1} + Biochar at 2500 Kgha^{-1}	13.50cd	44.97c
P at 15 Kgha^{-1} + FYM at 5,000 Kgha^{-1}	14.47c	43.37c
P at 40 Kgha^{-1}	13.23d	44.97c
P at 20 Kgha^{-1} + FYM at 2500 Kgha^{-1}	13.33cd	48.67bc
P at 20 Kgha^{-1} + Biochar at 2500 Kgha^{-1}	13.20d	43.83c
P at 20 Kgha^{-1} + FYM at 5,000 Kgha^{-1}	16.07b	43.57c
P at 60 Kgha^{-1}	13.17d	43.00c
P at 30 Kgha^{-1} + FYM at 2500 Kgha^{-1}	16.03b	43.50c
P at 30 Kgha^{-1} + Biochar at 2500 Kgha^{-1}	17.15b	55.53ab
P at 30 Kgha^{-1} + FYM at 5,000 Kgha^{-1}	18.67a	57.93a
Level of significance	0.001	0.001
SE±	0.41	2.19
Cultivar		
Fleur 11	14.99a	44.92
Philippine pink	12.08b	43.19
Level of significance	0.001	0.166
SE±	0.05	0.57
Interaction (RPSA*C)	0.001	0.216

Means followed by the same letter(s) in a column are not significantly different at 5% level of probability using Duncan's Multiple Range Test. FYM= Farmyard manure, RPSA= Rates of Phosphorous and Soil Amendments, C= cultivar, P= Phosphorous, NARI= National Agriculture Research Institution.

Application of P at 30 kgha^{-1} + FYM at 5,000 kgha^{-1} consistently recorded the highest number of branches and longest canopy of all the other treatments. This result conforms with the finding of Vyshnavi *et al.* (2021) who reported that combined application of a higher dose of P with farmyard manure (FYM) at a rate of 5 tones per hectare increased growth parameters like canopy height and number of branches in groundnut crop. However, the control recorded the lowest number of branches and smallest canopy. The cultivars were significantly different (P=0.001) in the number of branches, while no significant difference was observed in canopy size. Fleur 11 recorded a higher number of branches (14.99) than Philippine pink. This could be attributed to the higher branching traits possessed by Fleur 11, while in the other cultivar the branches grow in upright position (Jallow, 2019). The application of P at 30 kgha^{-1} + FYM at 5,000 kgha^{-1} significantly increased the number of branches plant^{-1} than all the other treatments. The control (no application) recorded the least number of branches (Table 3). This meant that the application of phosphorous and soil amendments are key in increasing crop growth. Surya *et al.* (2022) reported that had reported that the appropriate use of different rates of farmyard manure and biochar increases the growth and yield of groundnut. This could be attributed to the binding effect of the FYM which may reduce the leaching of the phosphorous. The selected rates of phosphorous and soil amendments significantly (P=0.001) influenced the number of nodules plant^{-1} at 3 and 6 weeks after sowing (Table 4). A significant increase in the number of nodules was observed at both 3 and 6 weeks after sowing in P at 30 kgha^{-1} + FYM at 5,000 kgha^{-1} and P at 30 kgha^{-1} + Biochar at 2500 kgha^{-1} while the peak was observed in the application of P at 60 kgha^{-1}. The higher number of nodulations recorded by P at 60 kgha^{-1} could be due to the optimum availability of P to the plants at the highest rate of the phosphorus fertilizer applied.

Table 4. Effect of selected rates of phosphorous and soil amendments and groundnut cultivars on days to number of nodules plant^{-1} at 3 and 6 week after sowing of groundnut.

Location: Gambia College Research Farm		
Treatments	**2022 Rainy season**	
	Number of Nodules plant^{-1} at 3WAS	**Number of Nodules plant^{-1} at 6WAS**
Rates of Phosphorous and Soil Amendments		
P at 0 Kgha^{-1} (control)	16.00c	22.17e
FYM at 5000 Kgha^{-1}	51.50b	75.50cd
Biochar at 5000Kgha^{-1}	45.33b	63.33d
FYM at 10,000 Kgha^{-1}	50.67b	68.33cd
P at 30 Kgha^{-1}	53.50b	67.50cd
P at 15 Kgha^{-1} + FYM at 2500 Kgha^{-1}	51.67b	69.67cd
P at 15 Kgha^{-1} + Biochar at 2500 Kgha^{-1}	47.83b	64.83d
P at 15 Kgha^{-1} + FYM at 5,000Kgha^{-1}	47.17b	60.00d
P at 40 Kgha^{-1}	72.00b	98.50c
P at 20 Kgha^{-1} + FYM at 2500 Kgha^{-1}	57.33b	72.17cd
P at 20 Kgha^{-1} + Biochar at 2500 Kgha^{-1}	56.50b	75.00cd
P at 20 Kgha^{-1} + FYM at 5,000 Kgha^{-1}	52.17b	64.50d
P at 60 Kgha^{-1}	124.33a	180.67a
P at 30 Kgha^{-1} + FYM at 2500 Kgha^{-1}	59.67b	79.33cd
P at 30 Kgha^{-1} + Biochar at 2500 Kgha^{-1}	52.33b	73.17cd
P at 30 Kgha^{-1} + FYM at 5,000 Kgha^{-1}	119.50a	155.50b
Level of significance	0.001	0.001
SE±	7.10	7.03
Cultivar		
Fleur 11	58.90	81.20
Philippine pink	60.80	80.10
Level of significance	0.134	0.806
SE±	0.56	2.79
Interaction (RPSA*C)	0.485	0.236

Means followed by the same letter(s) in a column are not significantly different at 5% level of probability using Duncan's Multiple Range Test. FYM= Farmyard manure, RPSA= Rates of Phosphorous and Soil Amendments, C= cultivar, P= Phosphorous, NARI= National Agriculture Research Institution, WAS= Week After Sowing.

This result agreed with the findings of Vyshnavi *et al.* (2021) who reported that the application of P at higher dose plays a major role in nodulation in groundnuts, biological nitrogen fixation and increases the availability of the residual nutrients. The rest of the treatments were statistically similar except the control, which recorded the lowest number of nodules at both 3 and 6 weeks after sowing. The selected rates of phosphorous and soil amendments significantly (P=0.001) affected the pod and kernel yield (kg ha^{-1}) (Table 5). The combination of soil amendments (FYM and biochar) and phosphorous had resulted in higher growth and yield of groundnut. The application of P at 30 kgha^{-1} + FYM at 5,000 kgha^{-1} recorded the highest pod and kernel yields. However, no significant difference existed between the application of P at 30 kgha^{-1} + FYM at 5,000 kgha^{-1} and P at 30 kgha^{-1} + Biochar at 2500 kgh^{-1} at p≤0.05. This could be attributed to the high amount of available P and Mg in the fertilizer and FYM and the ability of FYM to serve as a binding agent to reduce the loss of P through leaching. This is in accordance with the findings of Vyshnavi *et al.* (2021) who reported that combined application of a higher dose of phosphorus fertilizer along with soil amendments resulted in increasing growth and yield characters of groundnut. The rest of the treatments were statistically similar except for the control which recorded the lowest pod and kernel yield (Table 5). The effect of groundnut cultivars on pod and kernel yield was not significant. Similarly, the interaction between selected rates of phosphorous and soil amendments and groundnut cultivars on pod and kernel yield was not significant. The treatments responded significantly to the Agronomic Efficiency of Phosphorous (AEP) (Figure 2). Application of FYM at 5000 kgha^{-1} and Biochar at 5000 kgha^{-1}, recorded higher AEP and the rest of the treatments were statistically similar except for the control which recorded zero AEP. Research work conducted by Vasanthi (2021) revealed that the AEP is higher with a lower application rate of P and increased with the incremental rate of P.

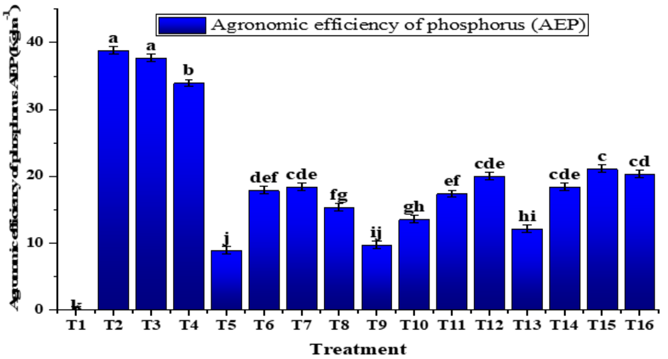

Figure 2. *Agronomic Efficiency of Phosphorous(AEP) in different treatments tested on groundnut cultivars; P ≤0.01, Error bar= SE±, T1=0Kgha^{-1}, T2=FYM at 5000Kgha^{-1},T 3=Biochar at 5000Kgha^{-1}, T4= FYM at 10,000Kgha^{-1}, T5= Phosphorous at 30 Kgha^{-1}, T6= Phosphorous at 15 Kgha^{-1} + FYM at 2500Kgha^{-1},T7=Phosphorous at 15 Kgha^{-1} + Biochar at 2500Kgha^{-1}, T8= Phosphorous at 15Kgha^{-1} + FYM at 5,000Kgha^{-1}, T9=Phosphorous at 40 Kgha^{-1}, T10= Phosphorous at 20 Kgha^{-1} + FYM at 2500Kgha^{-1}, T11=Phosphorous at 20 Kgha^{-1} + Biochar at 2500Kgha^{-1}, T 12= Phosphorous at 20Kgha^{-1} + FYM at 5,000Kgha^{-1}, T13= Phosphorous at 60 Kgha^{-1},T14= Phosphorous at 30 Kgha^{-1} + FYM at 2500Kgha^{-1}, T15=Phosphorous at 30 Kgha^{-1} + Biochar at 2500Kgh^{-1}, T16= Phosphorous at 30 Kgha^{-1} + FYM at 5,000Kgha^{-1}.*

Table 5. Effect of selected rates of phosphorous and soil amendments and groundnut cultivars on pod yield and kernel yield (kg ha^{-1}) of groundnut.

Location: Gambia College Research Farm		
Treatments	**2022 Rainy season**	
	Pod yield (kg ha^{-1})	**Kernel yield (kg ha^{-1})**
Rates of Phosphorous and Soil Amendments		
P at 0 Kgha^{-1} (control)	295.10k	243.40l
FYM at 5000 Kgha^{-1}	582.20i	547.10i
Biochar at 5000 Kgha^{-1}	572.50i	520.80j
FYM at 10,000 Kgha^{-1}	627.30h	517.00j
P at 30 Kgha^{-1}	518.50j	479.90k
P at 15 Kgha^{-1} + FYM at 2500 Kgha^{-1}	717.60e	611.10g
P at 15 Kgha^{-1} + Biochar at 2500 Kgha^{-1}	686.00f	611.10g
P at 15Kgha^{-1} + FYM at 5,000 Kgha^{-1}	650.90gh	608.00g
P at 40 Kgha^{-1}	642.70efg	581.80h
P at 20 Kgha^{-1} + FYM at 2500 Kgha^{-1}	672.80fg	619.60g
P at 20 Kgha^{-1} + Biochar at 2500 Kgha^{-1}	747.70d	657.40f
P at 20 Kgha^{-1} + FYM at 5,000 Kgha^{-1}	875.00c	786.30e
P at 60 Kgha^{-1}	980.70b	903.50d
P at 30 Kgha^{-1} + FYM at 2500 Kgha^{-1}	1007.70b	924.40c
P at 30 Kgha^{-1} + Biochar at 2500 Kgh^{-1}	1064.8a	956.40b
P at 30 Kgha^{-1} + FYM at 5,000 Kgha^{-1}	1088.70a	1025.50a
Level of significance	0.001	0.001
SE±	9.75	5.44
Cultivar		
Fleur 11	733.37	661.30
Philippine pink	732.93	662.90
Level of significance	0.779	0.687
SE±	0.98	2.53
Interaction (RPSA*C)	0.804	0.422

Means followed by the same letter(s) in a column are not significantly different at 5% level of probability using Duncan's Multiple Range Test. FYM= Farmyard manure, RPSA= Rates of Phosphorous and Soil Amendments, C= cultivar, P= Phosphorous, NARI= National Agriculture Research Institution.

Conclusion and recommendation

The current study results showed a positive response of groundnut cultivars to different rates of soil amendments and phosphoric fertilizers. From the outcome of the results, it could be concluded that the application of P at 30 $kgha^{-1}$ + FYM at 5,000 $kgha^{-1}$ had led to the highest production of pod and kernel yields of groundnut. The current results contribute to our understanding of the potential of enhancing groundnut fertilization through optimum P use efficiency as an organic amendment. The application of P at 30 $kgha^{-1}$ +FYM at 5,000 $kgha^{-1}$ before planting is recommended for adoption by smallholder farmers to enhance growth, pod and kernel yields of groundnut.

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DECLARATIONS

Author contribution statement

Conceptualization: S.A.F. J . and F. J. M .; Methodology: S.A.F. J ; Software and validation: S.A.F. J, F. J. M . A.Band M R O .; Formal analysis and investigation: S.A.F. J .; Resources: M. R. O; Data curation: A.B ; Writing—original draft preparation: S.A.F. J ; Writing—review and editing: F. J. M ; Visualization: A.B .; Supervision: F. J. M ; Project administration: S.A.F. J .; Funding acquisition: S.A.F. J . All authors have read and agreed to the published version of the manuscript.

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