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Growth and Yield Attributes of Groundnut (*Arachis hypogea*) as Influenced by Population Density and Phosphorous Fertilizer Rates on the Jos Plateau

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ABSTRACT

The experiment was conducted at the Federal College of Forestry demonstration farm Jos, Plateau State, Nigeria. The experimental design used was a Randomized Complete Block Design (RCBD) consisting of twelve treatments combination arranged in 3 x 4 factorial (plant population density; 133,333 at 50 x15 cm, 100,000 at 50 x 20 cm and 80,000 plant/ha at 50 x 25 cm spacing and phosphorous; 0, 20, 40 and 60kgP_2O_5/ha) replicated four times. Data were collected on plant height, leaf count, canopy spread, stem girth, leaf area, leaf area index, number of pods/plant, 100 seeds weight, shelling percentage, pod yield, total biomass and harvest index. Data collected were subjected to analysis of variance (ANOVA) at a 5% level of significance. Duncan Multiple Range Test (DMRT) was used to compare the means. The result obtained reveals that a plant population density of 100,000 plants/ha and the application of 40 kg P_2O_5/ha produced the highest growth and yield characters of groundnut respectively. No significant influence of interaction was recorded on the growth and yield characters but significantly influence the yield of the groundnut plant. The interaction between population density of 100,000/ha and phosphorous fertilizer at 40 kg P_2O_5/ha gave the highest pod yield/ha (2.50 t/ha). It is therefore recommended that a plant population of 100,000 plants/ha and the application of 40 kg P_2O_5/ha be encouraged for farmers of groundnut in the study area for optimum production.

INTRODUCTION

Generally speaking, plant density is defined as the number of main stems present in a given area of ground [1]. When the number of plants per unit area rose, the competition for growth resources such as nutrients, water, and the light increased as well, according and crop yield is defined by the efficiency with which a plant population utilizes available environmental resources for growth throughout the growing season [2–6]. When it comes to grain crops, plant density is an essential component of production. It is vital to discover the optimal plant densities for different locations and varieties since they each have a distinct potential for crop development and output [7]. Adjusting planting density is an essential technique for optimising crop growth and the amount of time necessary for canopy closure, as well as for achieving maximum biomass and grain production [8]. Because of variations in growth behaviour, certain crop cultivars respond differently to high plant density than others [7]. When cultivated at high densities, the majority of cultivars provide a high yield of grain per acre. Because of the reduction in-row spacing and the rise in plant density, increased light interception, dry matter, and yield components (pods and seeds) are increased [9].

The fact that groundnuts fix nitrogen does not negate the need for a starting dosage of 10-20 kg N ha–1 at planting time, particularly if the overall amount of nitrogen in the soil is less than 0.1 per cent [3]. Because the nodules can fix N_2 after 15-20 days of development, there is no need to apply a top dressing to the crop [10]. Soil phosphorus shortage has been a major constraint on crop productivity around the world [11].

phosphorus is one of the most essential elements for crop development, and its shortage is one of the most restricting plant nutrients for leguminous crop production in most tropical soils, particularly in the tropics [12]. It has been observed that reducing the availability of phosphorus below the essential level of 10 mg P kg–1 soil can lower legume grain yield by as much as 50%. The growth of roots and nodules [8] and the production of maximum yields of groundnuts require 15-40 kg P ha^{-1} depending on the soil type [11].

It is widely recognized that groundnut (*Arachis hypogaea* L.) is one of the most important leguminous crops grown all over the world, particularly in areas where annual precipitation is between 1000 and 1200 mm, which is ideal for the crop's optimum growth. China, India, Nigeria, the United States of America, Sudan, Senegal, and Argentina are among the countries that are the world's largest producers of crop [13–19]. Groundnut is a nutritious meal in Nigeria, as well as other poor nations where the crop is produced. It contains around 60% highly digestible protein, 22% carbs, 4% minerals, and approximately 8% fat, making it a great source of protein and carbohydrates [20].

A valuable cash crop for peasants in impoverished tropical nations, such as Nigeria, it has a high economic and nutritional potential and is a vital source of income [21]. Groundnuts are the second most important source of vegetable oils, after soybeans, which are the first. Among the goods used by people are groundnut flour, which is a cheap source of protein, as well as milk and other vital products [12]. Cooking, salads, margarine, soap, and lubricants are all made possible by oil, which is also a good source of fatty acids. The residue that remains after oil extraction is utilised as animal feed, while the green leaves are used as fodder [22–27].

Today, commercial groundnut production in Nigeria is concentrated in the northern sections of the nation, notably between the Northern Guinea and Sudan Savannah ecological zones, and in the southern parts of the country [28–30]. However, as a result of its high commercial value and consequent demand, the crop is currently becoming more popular as a cash crop for peasant households in the United States. However, due to a scarcity of knowledge on precise recommendations for plant densities and phosphorus fertilization to ensure stable and optimal yields of groundnut, the crop is seeing a drop in output levels.

This study effort was carried out in an attempt to close a gap in our current knowledge by developing a package for the optimization of groundnut production in the Jos Plateau via the use of appropriate planting density and phosphorus fertilizer rates. For the Jos Plateau, the goal of this study was to estimate the plant population density as well as the phosphorus fertilizer requirements for groundnut development and production.

MATERIALS AND METHOD

Study Area

This experiment took place on the Jos, the Plateau State Demonstration Farm at the Federal College in Nigeria, at a latitude of 9,94 and 8,89 in Guinea Savannah with an average annual rainfall of 1460mm, with temperatures between 19° and 32° C. The experiment was carried out at the Federal Forestry Farm [12].

Materials

Certified groundnut seed (SAMNUT 27) supplied from ICRISAT Kano, and Single Super Phosphate (SSP) obtained from Plateau Agricultural Development Programme were employed in this experimental study (PADP). Crop Production Technology Department, Federal College of Forestry, Jos departmental store provided measuring tape, metre rule, rope, Cutlass, Auger bit, Shovel, Rake, and Hoe [12].

Soil Analysis

Soil samples were collected at random from the field at two different depths (0-15 and 15-30cm) using an auger bit, hand trowel, and polythene bag to store the samples, which were then bucked and dried at room temperature before being taken to the Agricultural Service and Training Centre (ASTC) for analysis to determine the physical and chemical properties of the soil in the study area. Standard protocols were used to determine the physical and chemical parameters of the soil [12].

Experimental Design

The experimental design used for this study was a Randomized Complete Block Design (RCBD) consisting of twelve (12) treatments combination arranged in 3 x 4 factorial (plant population density; 133,333 at 50 x15cm, 100,000at 50 x 20cm and 80,000plant/ha at 50 x 25cm spacing and phosphorous; 0, 20, 40 and 60kgP_2O_5/ha) which were replicated four (4) times making a total of 48 plots each measuring 3 x $3m^2$ [12].

Agronomic Practices

a.Land Preparation: On June 10th, 2018, land preparation was completed. A cutlass and a hoe were used to manually clear the field. For the convenience of sowing, the soil was thoroughly dogged and the clumps were broken into finely tilted dirt particles [12]. Phosphorous fertiliser was put into the soil and beds were built on a 3 × 3m plot size.

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b. Planting: Groundnut seeds were planted at 2 - 4cm depth with 2 – 3 seeds per hole. The seedlings were thinned to 2 seeds per stand after two weeks of sowing.
c. Weeding: Weeding was carried out twice manually at three (3) weeks intervals.
d. Harvesting: This was done manually when the pods mature (30^{th} September, 2019).

Data Collection

Groundnut (10) plants were randomly selected and tagged for ease of identification and data collection. Data from the tagged plants were collected at 2 weeks interval on;

a. Plant height**:** The plant height was measured from the base to the tip of the last leaf of the plant with the aid of meter rule in centimetre (cm).
b. Leaf count**:** Number of leaves was counted per plant that was tagged.
c. Leaf Area: The leaf length and breadth were measured and leaf area calculated using
d.

$$\text{Leaf Area } (cm^2) = \text{Length} \times \text{Breadth} \times K \quad \textbf{(Equation 1)}$$

e. Leaf Area Index (LAI): This was calculated by the equation
f.

$$LAI = \frac{\text{Leaf Area (LA)}}{\text{Ground Cover}} \quad \textbf{(Equation 2)}$$

Where K is a constant whose value is 0.7

g. Canopy Spread: The canopy spread was measured from the last leaf on one side to the last leaf on the other side using a meter rule in centimetre (cm).
h. Number of Pods Per Plant: This was done by counting the number of pods produced by each plant tagged and finding the mean
i. 100 Seeds Weight: This was measured by counting 100 groundnut seeds and weighing them using a digital weighing balance in grams (g)
j. Shelling percentage: The pods from the net plots of groundnut were each air-dried thoroughly. Harvest from ten tagged groundnut plants was weighed before and after shelling, the shelled nuts were weighed and recorded.

The shelling percentage was determined as

$$SP = \frac{\text{Weight of groundnut seed}}{\text{Weight of pods.}} \times 100\% \qquad \textbf{(Equation 3)}$$

k. Pod Yield: The weights of groundnut harvested from each net plot were recorded before shelling using a weighing balance. The total weight of groundnut from the respective net plots was then extrapolated to give the total pod yield per hectare.
l. Total plant biomass: The groundnuts stover from the net plots were dried and weighed. This was added to the total weight of pods harvested from the net plots to give the total plant biomass of groundnut produced from each net plot. These values were then converted to biomass yield per hectare.
m. Harvest Index (HI). This is the ratio of total economic yield to the biomass produced by the system at harvest.

Harvest Index (HI) =$\underline{\text{Seed weight}}$ **(Equation 4)**

Total dry matter at harvest

Data collected were subjected to analysis of variance (ANOVA) at 5% level of significance using XLSTAT 2019 statistical package and where significance was declared. Duncan Multiple Range Test (DMRT) was used to compare the means.

RESULTS AND DISCUSSION

Physical and Chemical Properties of Soil in The Study Area

Table 1 presents the findings of the physical and chemical characteristics of the soil sample at the test location prior to planting. The finding shows that the ground was mostly textured sandy loam. With a pH value of 5.78, the soil was mildly acidic. The phosphorus availability was low (9.5 and 6.8mg/kg), whereas the exchangeable cations were low in particular in K, Ca, Mg and Na. Therefore, the soil was in low nutritional condition.

Table 1. Physical and chemical soil properties at the Jos Demonstration Farm Federal College of Forestry.

Sample (cm)	PH	N %	Om %	P Ppm	Na Ppm	Ca Ppm	Mg Ppm	K Cmol/kg	H^+mMol/100g	CEC mMol/100g	Clay %	Silt %	Sand %	Textural class
0-15	5.96	0.71	1.18	9.5	0.97	4.5	4.8	4.5	1.4	3.5	4.2	10.8	85.0	sandy Loam
15-30	4.47	0.42	1.84	6.8	0.95	4.9	3.6	3.4	1.4	3.4	4.0	13.0	83.0	sandy Loam

Source: Field work, 2019

Growth Attributes of Groundnut (*Arachis hypogea*) As Influenced by Population Density and Phosphorous Fertilizer

The growth attributes of groundnut (*Arachis hypogea*) as influenced by population density and phosphorous fertilizer is presented in **Table 2**. A plant population of 100,000 plants/hectare produced the tallest plant (34.87cm) followed by a plant population of 133,333 plants/hectare (34.31cm) and 80,000 plants/hectare (33.81cm). The result shows that population density significantly ($p \leq 0.001$) influenced the plant height of groundnut. The low groundnut height at higher population plant density could be attributed to the competition of the plant for available resources. This finding is contrary to a study that demonstrates similar phenomenon due to overcrowding and intense competitiveness of the growth variables, in particular solar light that typically fosters vertical development, the higher plants reached their greatest plant density (142.857 plants/hectare). There were substantial influences on the number of rainbow branches ($p<0.05$) by the plant population [31]. This is similar to Konlan *et al*. [13].

A plant population of 100,000 gave more branches (13.89) than those of 133,333 (13.72) and 80,000 (13.51). similarly, the plant population of 100,000 per hectare gave the highest stem girth of 4.48cm while 133,333 and 80,000 plants per hectare gave statistically similar stem girth which is at par. The number of leaves of groundnut plants was significantly ($p \leq 0.05$) influenced by plant population with the highest number of leaves (41.68) obtained at a plant population of 100,000 plants per hectare while the least (40.54) was obtained at 80,000 plants per hectare. A plant population of 100,000 plants/hectare produced the highest leaf area index of 0.35 followed by a plant population of 133,333 plants/hectare and 80,000 plants/hectare with the least LAI of 0.34 respectively.

The result shows that population density significantly ($p \leq 0.05$) influenced the plant height of groundnut. Plant population significantly ($p \leq 0.001$) influences canopy spread. A plant population of 100,000 plants per hectare gave the largest spread (44.75cm) with 133,333 and 80,000 plants per hectare measuring statistically similar canopy spread. Close spacing significantly reduced canopy width in both years as plants were compelled to grow vertically to compete for space and light [32]. Close spacing resulted in complete and early canopy closure, consistent with the findings of Tillman *et al*. [21] and Brown *et al*. [9].

The growth attributes of groundnut (*Arachis hypogea*) as influenced by phosphorous fertilizer is presented in **Table 2**. Groundnut height was found to have significantly ($p \leq 0.001$) influenced by phosphorous fertilizer. The application of 40kgP_2O_5/ha produced taller plants (36.50cm) followed by the application of 60 (35.42cm), 20 (33.42cm) and 0(32.00cm) kgP_2O_5/ha respectively. The number of branches developed per plant was improved by phosphorus fertilization.However, fertilizing with 40kgP_20_5 /ha appeared to have a more favourable effect on the branches of the crop which was reflected in the development of more branches (14.59) than the application of 60 (14.16), 20 (13.37) and 0(12.72) kgP_2O_5/ha. Similarly, a significant ($p \leq 0.001$) influence of phosphorous fertilizer was measured on stem girth.

Application of 40kgP_20_5 /ha recorded the highest stem girth of 4.52cm while no fertilization gave the least stem girth of 3.99cm. The number of leaves of groundnut was significantly ($p \leq 0.001$) influenced by phosphorous fertilization. More leaves (43.77) were obtained at the application of 40kgP_20_5 /ha followed by 42.47 leaves at 60kgP_2O_5/ha, 40.10 leaves at 20kgP_2O_5/ha and

38.15 leaves at 0kgP_2O_5/ha. Leaf area index was significantly ($p \leq 0.001$) influenced phosphorous fertilization with the application of 40kgP_2O_5 /ha recording the highest LAI (0.36) while 0kgP_2O_5/ha gave the least LAI (0.31). Also, the canopy spread at the application of 40kgP_2O_5 /ha (44.58cm) was found to be higher than the application of 60 (43.50cm), 20 (43.33cm) and 0(42.08 cm) kg P_2O_5/ha respectively. According to one study, the application of 60kgP_2O_5/ha gave the highest growth characters of groundnut plants [12] which was contrary to the findings of this research work.

Table 2. Growth Attributes of Groundnut (*Arachis hypogea*) As Influenced by Population Density and Phosphorous Fertilizer.

Treatment	Plant Height (cm)	Number of Branches	Stem Girth (cm)	Number of Leaves	Leaf Area Index	Canopy Spread (cm)
Population Density (plants/ha)						
133,333	34.31^{ab}	13.72^{ab}	4.08^{b}	41.15^{ab}	0.34^{b}	42.87^{b}
100,000	34.87^{a}	13.89^{a}	4.48^{a}	41.68^{a}	0.35^{a}	44.75^{a}
80,000	33.81^{b}	13.51^{b}	4.17^{b}	40.54^{b}	0.34^{b}	42.50^{b}
LSD(0.05)	***	*	***	*	*	***
Phosphorous (kgP_2O_5/ha)						
0	32.00^{d}	12.72^{d}	3.99^{d}	38.15^{d}	0.31^{d}	42.08^{c}
20	33.42^{c}	13.37^{c}	4.16^{c}	40.10^{c}	0.33^{c}	43.33^{b}
40	36.50^{a}	14.59^{a}	4.52^{a}	43.77^{a}	0.36^{a}	44.58^{a}
60	35.42^{b}	14.16^{b}	4.31^{b}	42.47^{b}	0.35^{b}	43.50^{b}
LSD(0.05)	***	***	***	***	***	***
Interaction						
PD * PH	NS	NS	NS	NS	NS	NS

Means in a column of any set of treatment(s) followed by different letter (s) are significantly different using DMRT, NS = Not Significant, * = Significant at $p \leq 0.05$, *** = Significant at $p \leq 0.001$.

Yield Attributes of Groundnut (*Arachis hypogea*) As Influenced by Population Density and Phosphorous Fertilizer

The yield attributes of groundnut (*Arachis hypogea*) as influenced by population density and phosphorous fertilizer is presented in **Table 3**. The yield and yield attributes of groundnut responded significantly ($p \leq 0.001$) to population density. A plant population of 100, 000 plants per hectare gave the highest number of pods/plant (81.62), 100 seeds weight (126.56g), shelling percentage (63.56%), pod yield (1.82 t/ha), total plant biomass (7.30 t/ha) and harvest index (0.23) followed by 80,000 and 133, 333 plants per hectare in a similar manner. Planting density is a key element in peanut development and output [1]. When the plant density dropped, podium number and pod weight per plant was raised.

The yield per hectare has been enhanced by the increase in plant density [1]. Reduced spacing the plant, pod number and average weight of seeds, but the extra plants more than compensated for decrease, leading to greater pod output [13]. Ahmad et al. reported such compensatory effects [33], Thus, the spacing system leading to a high population density of plants made the utilization of solar energy and other resources more efficient for pod production [34]. The main response of groundnut to the phosphorous application (**Table 3**) on yield attributes shows significant influence exists for a number of pods/plant, 100 seeds weight pod yield, total plant biomass and harvest index except for shelling percentage where non-significance was declared.

The application of 40 kg P_2O_5/ha produced the highest number of pods/plant (84.17), 100 seeds weight (125.17), pod yield (2.04 t/ha), total plant biomass (8.17 t/ha) and harvest index (0.22) which shows the statistically similar result with 60, 20 and 0kgP_2O_5/ha. According to Kamara *et al.* [20], the significant response of grain yield and yield components to P application confirming the importance of P for groundnut production in the Nigerian savannas. This result is similar to that of Shiyam [28] who reported that groundnut yield increased when 30 and 40 kg/ha of phosphorus were applied. They recorded reduced seed yield in plots fertilized with 50 and 60 kg/ha of phosphorus and stated that it might be a reflection of the suppressive effect of phosphorus on pod filling. Carsky [35] reported that P is a major limiting nutrient for legumes in the West African Savanna.

Table 3. Yield attributes of Groundnut (*Arachis hypogea*) as influenced by population density and phosphorous fertilizer.

Treatment	Number of Pods/Plant	100 Seeds Weight (g)	Shelling Percentage (%)	Pod Yield (t/ha)	Total Plant Biomass (t/ha)	Harvest Index
Population Density (Plants/ha)						
133,333	71.94^{c}	114.75^{c}	59.43^{b}	1.57^{b}	6.27^{b}	0.21^{b}
100,000	81.62^{a}	126.56^{a}	63.56^{a}	1.82^{a}	7.30^{a}	0.23^{a}
80,000	76.56^{b}	118.37^{b}	62.62^{a}	1.64^{b}	6.57^{b}	0.21^{b}
LSD(0.05)	***	***	***	***	***	***
Phosphorous (kgP_2O_5/ha)						
0	71.50^{c}	115.50^{c}	60.83	1.44^{c}	5.77^{c}	0.21^{b}
20	74.42^{b}	118.67^{bc}	61.08	1.61^{b}	6.43^{b}	0.22^{a}
40	84.17^{a}	125.17^{a}	62.83	2.04^{a}	8.17^{a}	0.22^{a}
60	76.75^{b}	120.25^{b}	62.75	1.62^{b}	6.50^{b}	0.22^{a}
LSD(0.05)	***	***	NS	***	***	**
Interaction						
PD * PH	***	*	NS	***	***	NS

Means in a column of any set of treatment(s) followed by different letter (s) are significantly different using DMRT, NS = Not Significant, * = Significant at $p \leq 0.05$, ** = Significant at $p \leq 0.01$, *** = Significant at $p \leq 0.001$

Interaction between plant population density and phosphorus fertilizer on pod yield

Pod yield of groundnut was favourably influenced by the interaction between plant population density and phosphorus fertilizer applied (**Table 4**). Significantly ($P \leq 0.001$) highest pod yield (2.50 t/ha) was recorded by fertilizing 100,000 plants/ha with 40 kg P_2O_5 /ha, which also gave the highest mean pod yield across the various plant population densities. Pod yield (1.35 t/ha) was least at 0 kg P_2O_5 /ha and highest plant density.

Table 4. Interaction between plant population density and phosphorus fertilizer on pod yield.

Phosphorous (kgP_2O_5/ha)	Population Density (Plants/ha) 133,333	100,000	80,000
0	1.35^{d}	1.42^{cd}	1.55^{bcd}
20	1.55^{bcd}	1.65^{bc}	1.62^{bcd}
40	1.82^{b}	2.50^{a}	1.80^{b}
60	1.55^{bcd}	1.72^{b}	1.60^{bcd}
LSD(0.05)	***		

Means in a column of any set of treatment(s) followed by different letter (s) are significantly different using DMRT, *** = Significant at $p \leq 0.001$

CONCLUSION

The result from the research work conducted reveals that the soil in the study area was low in nutrient. This may be as a result of continuous farming activities on the site. Based on the result of this research work it can be concluded that a plant population density of 100,000 plants/ha and the application of 40kgP_2O_5/ha produced the highest growth and yield characters of groundnut respectively. No significant influence of interaction was recorded on the growth and yield characters but significantly influence the yield of the groundnut plant. It is therefore recommended that a plant population of 100,000 plants/ha and the application of 40kgP_2O_5/ha be encouraged for farmers of groundnut in the study area for optimum production.

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