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RESEARCH ARTICLE

EFFECTS OF NITROGEN, PHOSPHORUS, AND POTASSIUM ON GROUNDNUT YIELD AND YIELD COMPONENTS IN TROPICAL CONDITIONS

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ABSTRACT

Peanut, a crucial legume crop in tropical and semiarid regions, serves as a significant source of edible oil and vegetable protein. This study, conducted at the Savannah Agricultural Research Institute (SARI) during the 2021 cropping season, aimed to assess the impact of nitrogen, phosphorus, and potassium on groundnut yield and its components. Employing a 3 x 3 x 2 factorial experiment design, the trial was arranged in a randomized complete block with three replications. Various parameters including plant height at harvest, plant population at harvest, pod yield (kg/plant), number of mature pods/plants, number of immature pods/plants, pod yield (kg/ha), and haulm weight (kg/ha) were collected and analyzed using Analysis of Variance (ANOVA). Significance levels were determined by Least Significance Difference (LSD) at a 5% probability level. Results indicated significant effects ($p < 0.05$) of nitrogen, phosphorus, and potassium on the number of mature pods per plant. Specifically, the application of 30 kg/ha of nitrogen and 20 kg/ha each of phosphorus and potassium resulted in the highest number of mature pods per plant (9.2). Furthermore, the combination of 60 kg/ha of nitrogen and 20 kg/ha of potassium without phosphorus application exhibited the highest haulm weight (265.11 kg/ha). Additionally, prevalent weed species within the experimental field included *Digitariasanguinalis*, *Cyperus esculentus*, *Cynodondactylon*, and *Commelinalatifolia*. These findings underscore the importance of balanced nutrient management for optimizing groundnut yield in tropical agricultural settings.

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INTRODUCTION

Groundnut (*Arachis hypogaea* L.), a member of the Fabaceae family, stands as a vital legume species native to South America, Mexico, and Central America. With its annual herbaceous nature and a modest height ranging from 30 to 50 cm, groundnut displays distinctive opposite, pinnate leaves adorned with four leaflets. Recognized by a plethora of names including earthnuts, peanuts, and monkey nuts, groundnuts play a crucial role in various culinary and agricultural contexts (Polthanee *et al.,* 2021). Despite its widespread cultivation, groundnut production faces significant challenges, particularly concerning the availability of major nutrients such as nitrogen (N), phosphorus (P), and potassium (K). While groundnuts possess the capacity for biological nitrogen fixation, external nitrogen sources often trigger a positive response, especially in regions marked by moisture stress (Singh & Singh, 2001; Kandil *et al.,* 2007).

Moreover, phosphorus is indispensable for root system development and nodulation in groundnuts, crucial for effective nitrogen fixation (Kumar *et al.,* 2014). Despite groundnut's minimal potassium requirement, adequate potassium levels are essential for optimal growth and reproduction (Madkour *et al.,* 1992). The optimization of mineral nutrition emerges as a cornerstone in enhancing groundnut production, given its high nutrient demands and the nutrient-depleting nature of high-yielding varieties. However, inadequate fertilizer application is a prevalent issue, resulting in severe nutrient deficiencies and declining soil fertility, particularly in Africa (Sanchez & Jama, 2002; Negassa*et al*., 2005; Tesfaye *et al*., 2011). The consequences of prolonged inadequate fertilizer application extend to soil degradation, reduced productivity, and ultimately, food shortages (Bagarama*et al.*, 2012). Despite high nutrient losses, external fertilizer use remains minimal due to various constraints such as limited knowledge and high costs (Okello *et al*., 2010; Angadi *et al.,* 1990). Amidst escalating global population growth and the imperative to address food insecurity, enhancing agricultural efficiency through improved nutrient management becomes paramount (Shamsudeen *et al*., 2011). This research endeavors to provide efficient fertilizer rates to maximize groundnut yield, addressing both yield components and overall productivity. Fertilizer application plays a pivotal role in crop growth and quality yield. Groundnut, being a nutrient-intensive crop, rapidly depletes soil nutrients without appropriate replenishment (Aulakh et al. 1985). Proper fertilizer management, encompassing the right nutrient types, timing, and application methods, significantly impacts yield and quality (Ghosh *et al*., 2002). Understanding the interaction effects of nitrogen, phosphorus, and potassium on groundnut yield components is crucial for developing tailored fertilizer management strategies. Nitrogen fertilization, for instance, has been shown to enhance photosynthesis, metabolite production, and seed yield in groundnuts (El-Habbasha, 2015). This study therefore aims to determine optimal N, P, and K fertilizer rates to maximize groundnut yield components.

MATERIALS AND METHODS

Experimental Site and Location: The field trial was conducted at the Savannah Agricultural Research Institute (SARI) during the 2021 rainy season. The experiment took place at the SARI experimental field in Nyankpala, situated in the Tolon District of the Northern Region of Ghana. Geographically, the farm is positioned at coordinates 9º23'21"N 1º00'22"W and an elevation of 682 meters above sea level.

Climate and Weather Conditions: The area experiences a modest unimodal rainfall, with an average annual rainfall ranging from 1000 to 1200 millimeters. Relative humidity varies from a minimum of 46% to a maximum of 76.8%. Temperature remains relatively consistent, with monthly mean minimums of 21.9°C and maximums of 34.1°C, as reported in the SARI Annual Report (2007).

Soil Sampling and Analysis: Soil samples were collected from a depth of 0-15 cm along the diagonals of the experimental field at various locations. These samples were combined to create a representative composite sample for analysis. Physical and chemical properties of the soil, including basal soil physico-chemical properties, were examined (Table 1).

Table 1. Physicochemical properties of the soil at experimental site within 0-30cm depth

LAB.NO	ID.NO	pH H_2O (1:2.5)	% O.C	% N	mg/kg p	mg/kg k	Cmol+/kg Ca	Cmol+/kg Mg	TEXTURE % SAND	% SILT	% CLAY	CLASSES
485/21	SAMPLE 2	4.48	0.41	0.037	3.87	42	1.2	0.4	80.4	17.6	2	Sandy Loam

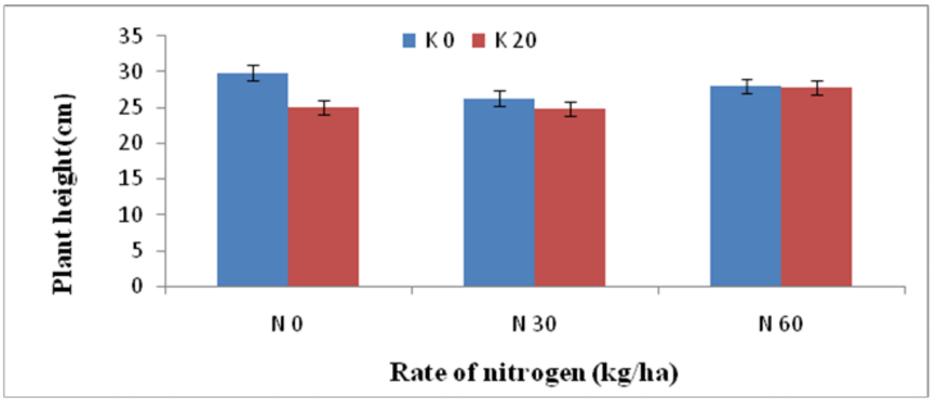

Figure 1. Interaction effect of nitrogen by potassium on plant height at harvest

Experimental Design and Treatments: The experiment utilized a 3 x 3 x 2 factorial design laid out in a randomized complete block design with three replications. Factors studied included nitrogen (N) at rates of 0, 30, and 60 kg/ha; phosphorus (P) at rates of 0, 20, and 40 kg/ha; and potassium (K) at rates of 0 and 20 kg/ha. Each experimental unit measured 3 m × 5 m, with interrow spacing of 20 cm and 50 cm. The alley between plots and replications were 1 m and 2 m respectivelyPlanting was conducted on May 26th, 2021, using the 'Nkatie SARI' variety.

Data Collection: Data collection involved the measurement of various parameters, including plant height at harvest, plant population at harvest, number of mature pods per net plot (15 m2), number of immature pods per 15 m2, yield weight (g/15m2), yield weight (g) per 5 plants, and haulm weight (g) per 15 m2. Cultural practices and pest control measures were implemented to ensure optimal crop growth, while weed species and density were assessed using a 1m2 quadrat.

Data Analysis: Data analysis was performed using GENSTAT 12th edition and Analysis of Variance (ANOVA). Least Significance Difference (LSD) at 5% was used for mean separation. Count data underwent transformation, and analyzed outcomes were presented graphically for interpretation.

RESULTS

Plant Height at Harvest: Plant height at harvest was significantly ($p < 0.05$) influenced by the interaction effect of Nitrogen and Potassium. The main effects of nitrogen, potassium, and phosphorus also had a significant ($p < 0.05$) impact on plant height. However, the interaction effect of Nitrogen, potassium, and Phosphorus did not yield any significant ($p > 0.05$) differences. Notably, the highest plant height of 28.00 cm was recorded without N and K applications, statistically similar to 60 kg N/ha plus 20 kg K/ha (27.79 cm) and 60 kg N/ha without K applicationsat 27.79 cm (Figure 1). Error bars indicates standard error of means (SEM).

Plant Population: The interaction effects of Nitrogen and Potassium significantly ($p < 0.05$) affected plant population. Nitrogen had a significant impact on plant population, with the highest population of 58593 plants/harecorded with the application of 60 kg N/ha plus 20 kg K/ha (Figure 2).

Error bars indicates standard error of means (SEM)

Matured Pods per Plant: The second-order interaction of Nitrogen, Phosphorus, and Potassium significantly ($p < 0.05$) determined the number of matured pods per plant. Nitrogen, phosphorus, and potassium had significant ($p < 0.05$) effects on the number of matured pods per plant. Higher numbers of matured pods at 9.2 per plantwere observed with the application of 30 kg N/ha and 20 kg P/ha plus 20 kg K/ha (Figure 3).

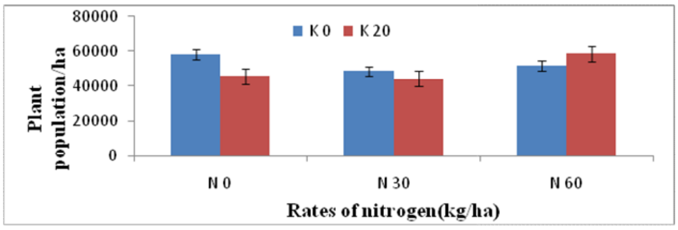

Figure 2. Interaction effect of nitrogen by potassium on plant population at harvest

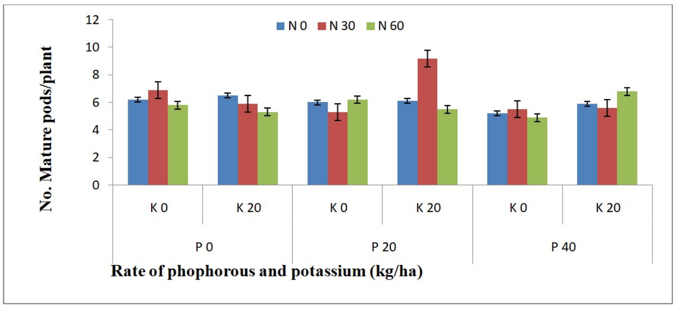

Figure 3. Interaction effect of Phosphorus, Potassium and Nitrogen on matured pods per plant. Error bars represent SEM.

Number of Immature Pods per Plant: The interaction of Nitrogen, phosphorus, and Potassium significantly ($p < 0.05$) affected the number of immature pods per plant. Potassium had a significant ($p < 0.05$) impact on the number of immature pods per plant, with the highest count observed with the application of 20 kg P/ha plus 20 kg K/ha without Nat 5 per plant whilst the lowest of 2.6 per plant was recorded by 40 kg P/ha without N and K application (Figure 4).

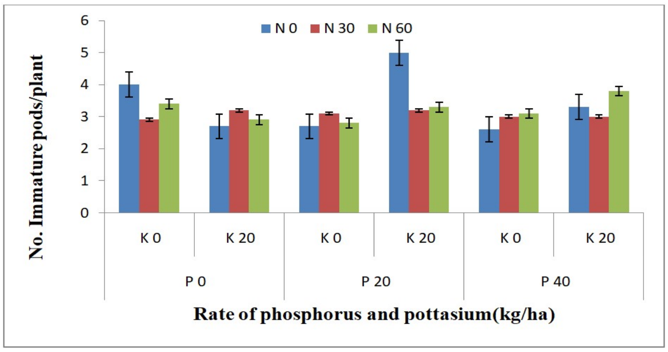

Figure 4. Interaction of nitrogen by phosphorus and potassium on the number of matured pods per plant. Error bars represent standard error of means (SEM)

Haulm Weight: Interaction of Nitrogen, Phosphorus, and Potassium significantly ($p < 0.05$) influenced haulm weight. Nitrogen significantly determined haulm weight, with the highest weight of 265.11kg/harecorded with the application of 60 kg N/ha plus 20 kg K/ha without P (Figure 5).

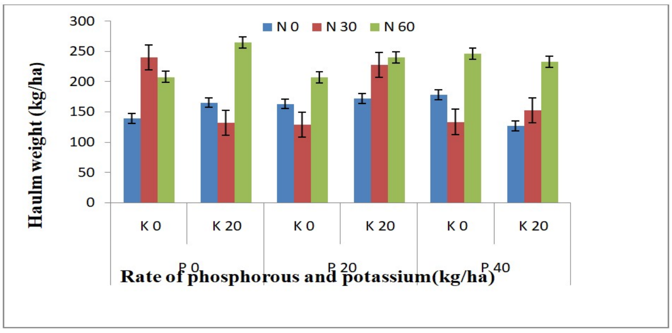

Figure 5. Interaction effects of nitrogen by phosphorus and potassium on haulm weight (kg/ha). Error bars indicates standard error of means (SEM)

Pod Yield Weight Per Plant: The interaction effect of nitrogen, phosphorus, and potassium significantly ($p < 0.05$) affected pod yield. Nitrogen had a significant impact on pod yield, with the highest yield of 0.269kg/plant observed with the application of 30 kg N/ha plus 20 kg P/ha without K (Figure 6).

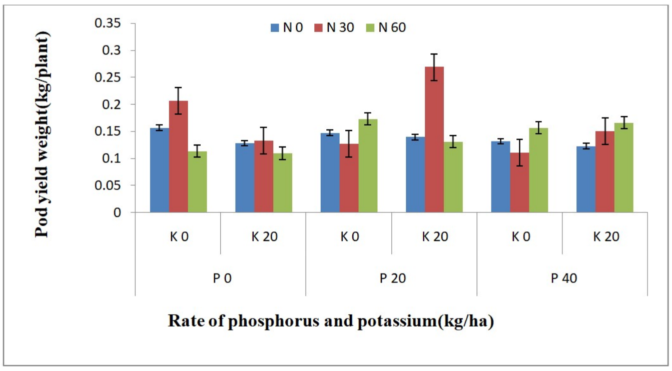

Figure 6. Interaction effects of nitrogen by phosphorus and potassium on yield weight per plant. Error bars indicates standard error of means (SEM)

Pod Yield Weight per Hectare: The interaction effect of nitrogen and potassium significantly ($p < 0.05$) influenced yield weight per hectare. Nitrogen significantly ($p < 0.05$) affected yield weight per hectare, with the highest yield of 1331.3kg/harecorded with the application of 30 kg N/ha plus 20 kg K/ha (Figure 7).

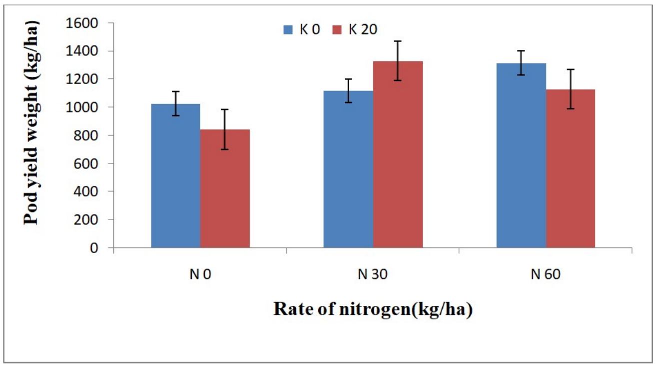

Figure 7. Interaction effects of nitrogen and potassium on yield weight per plot

DISCUSSIONS

Plant height at harvest: The results showed that application of 60 kg N/ha without K recorded a highest plant height of 28 cm which is statistically similar with 60 kg N/ha plus 20kg K/ha giving a plant height of 27.79 cm (Figure 1). This could be as a result of the higher application rate of nitrogen.Groundnut showed a significant increase in plant height with increasing levels of Nitrogen in soils with low N status. This finding is in agreement with that of Tsegaye (2022) and Ghosh *et al.* (2022). The nitrogen helps the cells of the apical meristem to enlarge. Apical meristem helps in shoot growth which affects plant growth.

Plant population: The results showed that application of 60kg N/ha plus 20kg K/ha recorded the highest plant population of 58593 plants/ha whilst treatments with application of 30kg N/ha plus 20k K/ha recorded the lowest plant population of 44370 plants/ha. This could be attributed to higher rate of nitrogen application. Nitrogen is thekey plant nutrient that stimulates root and shoot growth as agreed by the findings of Medinipur and Bengal (2020) who observed plant population increased with increasing nitrogen levels.

Number of Matured pods ($\sqrt[2]{x}_{+\ 0.5}$): Generally, the highest number of matured pods was with application of 20 kg K/ha plus 20kg P/ha and 30kg N/ha. The highest number of matured pods/plant was recorded when P was applied at 20kg/ha. The increase in yield and yield characters due to P fertilizer might be attributable to the activation of metabolic processes, where it plays a role in building phospholipids and nucleic acid. This finding conforms with the Kamboj et al. (2023) which reported increased matured pod yield due to P application. In a groundnut experiment in West Bengal, Karmakar et al. (2011) found that combining 30 kg N, 60 kg P2O5, and 20 kg K2O per ha resulted in higher haulm production (4643 kg/ha) and pod yield (2715 kg/ha) than other treatment combinations.

Number of Immature pods ($\sqrt[2]{x}_{+\ 0.5}$): The interaction of Nitrogen, phosphorous and Potassium significantly ($p< 0.001$) affected number of immature pods per plant. The highest number of immature pods was recorded P was applied at 20kg/ha and decreased when P was applied above 20kg/ha. No nitrogen application recorded the highest number of immature pods.

Haulm weight (kg/ha): The results showed that application of 60kg N/ha plus 20kg k/ha without P recorded the highest haulm weight of 265.11kg/ha (Figure 5). This could be because of the higher rate of nitrogen application.Taneja *et al*. (2022)averred considerable increase in haulm yields with the increase in the applicationof nitrogen.Similarly, Samim *et al*. (2023) found that nitrogen fertilizer application increased dry matter buildup significantly.

Pod Yield Weight /plant: The interaction effect of nitrogen, phosphorus and potassium, significantly ($p<0.001$) affected pod yield (kg/plants). 30kg N/ha plus 20kg P/ha without K recorded the highest pod yield weight of 0.269kg/plant whilst, 60kg N/ha plus 20kg K/ha without P recorded the lowest pod yield weight of 0.1097kg/plant. These results were in accordance with the findings of Chitdeshwari*et al.* (2007) who reported declined pod yield at increase fertilization. This is however in contrast with findings by Veeramani et al., (2012) where it was noted that higher NPK corresponded with high yield of pods. (Figure 6).

Pod Yield Weight /hector: The results showed that application of 30kg N/ha plus 20kg K/ha recorded the highest pod yield weight of 1331 kg/ha whilst 20kg K/ha without N recorded the lowest pod yield weight of 843.56kg/ha (Figure 7). This could be because of the increasing Nitrogen level. Which is in line with what (Narasimhamurthy et al., 2019)observed that increasinglevel of nitrogen increased the nodule number, nodule mass, total dry mass, total nitrogen content, pod yield andharvest index in groundnut (Bekele *et al*., 2019)**.**

CONCLUSION

The characteristics of the groundnuts and its variation with respect to application of the different combination of treatments showed significance on plant height at harvest, plant population, number of matured pods per plant, number of immature pods per plant, haulm weight and pod yield weight. N at 30 kg/ha and application of 20kg P/ha plus 20kg K/ha gave the highest number of matured pods of 9.2 per plant. The best haulm weight was recorded with 60kg N/ha plus 20kg K/ha without P application. 30kg N/ha plus 20kg P/ha without K recorded the highest pod yield weight of 0.269kg/plant.

Recommendation: Results of this experiment suggests that application of 30kg N/ha, 20kg P/ha and 20kg K/ha resulted in the best yield and yield component of groundnut. The study findings have also brought an expectation that further investigation on different levels of fertilizers along with different varieties, growing seasons and soil types can be a step forward to identify more realistic effect of different fertilizers on the growth and yield of groundnut. Finally, these findings will help our farmer to apply balanced fertilizer application which will be synchronized with crop demand and also will reduce the cost of production.

Compliance with ethical standards

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