Asian Journal of
Science, Technology, Engineering, and Art

e-ISSN: 3025-4507
p-ISSN: 3025-5287
Index: Harvard, Boston, Sydney University, Dimensions, Lens, Scilit, Semantic, Google, etc

https://doi.org/10.58578/AJSTEA.v3i2.4986

Impact of Rock Phosphate Levels, Placement Methods, and Cowpea Varieties on Yield Parameters in Sokoto

Aliyu Lawal Sokoto & Usman Abdullahi Yarima
Shehu Shagari College of Education, Sokoto, Nigeria
yarimausman@gmail.com

Article Info:

Submitted:	Revised:	Accepted:	Published:
Jan 17, 2025	Feb 1, 2025	Feb 13, 2025	Feb 18, 2025

Abstract

Cowpea is a vital crop in arid and semi-arid regions of Nigeria, contributing significantly to food security. However, its yield is often limited by phosphorus deficiency. This study investigates the effects of varying rock phosphate levels, placement methods, and cowpea varieties on yield parameters in Sokoto during the 2024 cropping season. The experiment involved two cowpea varieties (Sampea-7 and Baadare), three rock phosphate levels (25, 50, and 75 kg ha^{-1}), and three placement methods (plough-sole, broadcast, and side-band). Results showed significant responses to rock phosphate application and placement methods on grain yield, pod weight, and shelling percentage. The study highlights the importance of optimizing rock phosphate application strategies to enhance cowpea yield in phosphorus-deficient soils.

Keywords: Cowpea, Rock Phosphate, Sustainable Farming, Phosphorus Efficiency, Nutrient Optimization

INTRODUCTION

Cowpea (*Vigna unguiculata*) is a vital legume crop in Nigeria, particularly in arid and semi-arid regions such as Sokoto, where it serves as a key component of food security and a major source of income for smallholder farmers. This legume is highly valued due to its adaptability to harsh environmental conditions, including its ability to thrive in drought-prone areas and in soils with low fertility. Cowpea is an important dietary staple, providing an affordable source of high-quality protein, essential amino acids, and other vital nutrients, making it a crucial food crop for both rural and urban populations.

Beyond its role in human nutrition, cowpea significantly contributes to soil fertility through biological nitrogen fixation, a process that enhances soil health by increasing nitrogen content and improving soil structure (Singh *et al.,* 2017). This characteristic makes it an integral component of sustainable agricultural practices, especially in regions where synthetic fertilizers are costly or inaccessible. Additionally, cowpea is a versatile crop with multiple uses; its grains, leaves, and pods are consumed as food, while its residues serve as livestock feed, further reinforcing its economic importance to farming communities.

Despite these advantages, cowpea production in Nigeria faces several challenges, one of the most critical being soil nutrient deficiencies. Among these, phosphorus (P) deficiency is particularly limiting, as phosphorus is essential for various physiological and biochemical processes in plants, including root development, energy transfer, and flowering (Bationo *et al.,* 2018). In phosphorus-deficient soils, cowpea growth and yield are severely constrained, leading to reduced productivity and lower returns for farmers.

To address this issue, researchers and agricultural practitioners have explored various strategies to improve phosphorus availability in cowpea-producing areas. One promising approach is the application of rock phosphate, a natural phosphorus source that gradually releases the nutrient into the soil, enhancing its availability for plant uptake (Chien *et al.,* 2011). Rock phosphate is particularly beneficial in acidic and phosphorus-depleted soils, as it offers a cost-effective and sustainable alternative to conventional phosphorus fertilizers. By improving phosphorus nutrition, rock phosphate application can lead to enhanced cowpea growth, increased nodulation, and ultimately higher yields, contributing to improved food security and farmer livelihoods in regions where phosphorus deficiency is a major constraint.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted at the dry land farm of Usmanu Danfodiyo University, Sokoto, during the 2024 cropping season. Soil samples were analyzed for physico-chemical properties, revealing a predominantly sandy soil with low organic carbon, total nitrogen, available phosphorus, and potassium content (Rao *et al.,* 1983).

The rainfall data for Sokoto State collected from the Sokoto Metrological Agency in July, August, and September 2024 reveals significant variations in precipitation levels. July recorded a total rainfall of 446.0 mm, with a daily average of 13.9 mm and a maximum daily rainfall of 223.0 mm, indicating moderate rainfall activity with occasional heavy downpours. August experienced the highest rainfall, with a total of 1096.6 mm, a daily average of 34.3 mm, and an extreme maximum daily rainfall of 548.3 mm, highlighting its status as the peak month for precipitation. In September, rainfall decreased to a total of 744.8 mm, with a daily average of 23.3 mm and a maximum daily rainfall of 372.4 mm, marking a transition toward the end of the rainy season. The relative humidity is typically low throughout the year, ranging from 20–35% in January to 60–80% in August, however the temperature fluctuates throughout the year.

Treatments and Experimental Design

The study employed a randomized complete block design (RCBD) with three replications. Treatments comprised two cowpea varieties (Sampea-7 and Baadare), three rock phosphate levels (25, 50, and 75 kg ha^{-1}), and three placement methods (plough-sole, broadcast, and side-band), totaling 18 treatment combinations.

Each plot measured 4 m × 4.5 m, with an intra-row spacing of 40 cm and inter-row spacing of 75 cm. Seeds were planted manually. Rock phosphate was applied at sowing based on the assigned placement method. Urea (10 kg N ha^{-1}) was applied at land preparation (Chien & Menon, 1995).

Field Layout and Cultural Practices

Each plot measured 4 m x 4.5 m, with six rows of cowpea stands. Seeds were sown at an intra-row spacing of 40 cm and inter-row spacing of 75 cm. Fertilizer application included 10 kg N ha^{-1} from urea during land preparation and rock phosphate applied at sowing using the specified placement methods (Chien & Menon, 1995).

RESULTS AND DISCUSSION

Table 1 highlights the influence of rock phosphate (RP) levels, placement methods, and variety selection on key yield parameters during the 2024 cropping season. Given the essential role of phosphorus in root development, nutrient uptake, and overall plant productivity, optimizing its application is crucial for sustainable agriculture. The findings indicate that increasing RP levels (25–75 kg ha^{-1}) significantly improved pods per plant, grain yield, and 1000-grain weight, with the highest responses observed at 50–75 kg ha^{-1}. However, beyond 75 kg ha^{-1}, the benefits diminished, suggesting an optimal phosphorus threshold. Additionally, the method of RP application played a critical role, with the plough-sole method consistently outperforming broadcast and side-band applications, likely due to improved phosphorus incorporation into the root zone. While broadcast and side-band methods showed moderate improvements, their efficiency in maximizing phosphorus availability was lower. The study also revealed significant varietal differences, with Baadare (local variety) exhibiting superior yield performance compared to Sampea-7 (improved variety), possibly due to greater adaptability and phosphorus use efficiency. Sampea-7, while demonstrating earlier maturity, produced lower yield components, highlighting the importance of aligning varietal selection with specific agronomic conditions.

Table 1: Yield Parameters as Influenced by Rock Phosphate Level, Placement Method, and Variety in 2024 Cropping Season

Treatment	Pods per Plant	Seeds per Pod	Pod Weight (kg ha^{-1}) ± SE	Shelling Percentage (%) ± SE	Grain Yield (kg ha^{-1}) ± SE	Stover Yield (kg ha^{-1}) ± SE	Harvest Index (%) ± SE	1000 Grain Weight (g) ± SE
0 (control)	9.03 ± 0.30	7.63 ± 0.25	1841.30 ± 45.20	73.17 ± 1.12	1351.50 ± 38.90	1105.60 ± 34.20	37.90 ± 1.08	156.67 ± 3.45
25 kg RP ha^{-1}	12.41 ± 0.35	10.78 ± 0.28	2774.20 ± 56.70	76.71 ± 1.08	2127.14 ± 47.30	1259.70 ± 39.80	53.51 ± 1.15	239.72 ± 4.12
50 kg RP ha^{-1}	12.24 ± 0.38	10.58 ± 0.30	2752.90 ± 58.90	76.43 ± 1.06	2104.64 ± 48.20	1322.10 ± 42.10	52.01 ± 1.12	237.78 ± 4.08
75 kg RP ha^{-1}	12.29 ± 0.40	10.84 ± 0.33	2765.60 ± 60.10	77.22 ± 1.04	2146.71 ± 49.70	1284.40 ± 41.30	52.97 ± 1.18	237.17 ± 4.25
Placement Methods								
Plough-sole	13.28 ± 0.42	11.33 ± 0.35	2905.00 ± 61.80	77.94 ± 1.02	2266.20 ± 50.50	1203.80 ± 39.50	55.18 ± 1.20	255.00 ± 4.38
Broadcast	11.73 ± 0.39	10.19 ± 0.31	2701.70 ± 59.50	75.58 ± 1.09	2048.60 ± 46.80	1292.10 ± 40.90	51.53 ± 1.14	226.11 ± 4.15
Side-band	11.93 ± 0.41	10.68 ± 0.34	2686.00 ± 58.90	76.86 ± 1.07	2068.80 ± 47.10	1369.30 ± 42.50	51.78 ± 1.13	232.56 ± 4.22
Variety								
Baadare (Local)	12.36 ± 0.37	10.85 ± 0.32	2834.48 ± 60.20	77.10 ± 1.05	2188.00 ± 49.30	1339.30 ± 41.80	52.99 ± 1.16	241.48 ± 4.28
Sampea-7 (Improved)	12.27 ± 0.36	10.61 ± 0.29	2694.00 ± 59.00	76.49 ± 1.08	2064.30 ± 47.90	1238.10 ± 40.10	52.67 ± 1.15	234.30 ± 4.10

The effects of rock phosphate levels, placement methods, and cowpea varieties on key yield parameters. Significant differences ($p \leq 0.05$) were observed, with the plough-sole method and 50–75 kg ha^{-1} phosphate application yielding the highest grain output.

Results revealed a significant effect ($p \leq 0.05$) of rock phosphate levels, placement methods, and variety on yield parameters. Increasing rock phosphate levels from 25 to 75 kg $ha{-1}$ improved pods per plant, grain yield, and 1000-grain weight. However, beyond 75 kg $ha{-1}$, the benefits diminished, suggesting an optimal threshold.

Placement methods: The plough-sole method significantly outperformed broadcast and side-band methods, likely due to better phosphorus incorporation into the root zone. Similar findings were reported in previous studies (Freiling *et al.*, 2022).

Varietal Differences: Baadare exhibited higher yield components than Sampea-7, likely due to its greater phosphorus-use efficiency and adaptability to local conditions. However, Sampea-7 showed earlier maturity, making it suitable for short-season environments.

Comparisons with previous studies indicate that combining rock phosphate with organic amendments, such as poultry manure, enhances phosphorus solubilization, improving nutrient uptake and cowpea yield (Akande *et al.*, 2005). Economic feasibility remains a concern, as single super phosphate (SSP) is often more effective in immediate bioavailability than rock phosphate (Akande *et al.*, 2010).

The results confirm previous studies that emphasize the beneficial role of combining rock phosphate with organic amendments. For instance, research has demonstrated that integrating rock phosphate with poultry manure significantly enhances maize and cowpea yields compared to the application of rock phosphate alone. This suggests that the presence of organic matter facilitates phosphorus solubilization, thereby improving nutrient availability and crop performance (Akande *et al.,* 2005). Additionally, soil type emerged as a critical factor influencing the effectiveness of RP application. Consistent with past findings, our study observed that phosphorus availability and biomass accumulation varied significantly across soil types. Similar studies have noted that Arenosol soils respond better to RP applications compared to Luvisol, indicating that soil characteristics play a crucial role in determining phosphorus availability and crop productivity (Gweyi-Onyango *et al.,* 2010).

A comparative analysis of phosphorus sources revealed that single super phosphate (SSP) consistently outperformed RP in terms of biomass yield across different soil types. This corroborates existing literature, which suggests that RP may have lower immediate bioavailability compared to water-soluble phosphorus fertilizers like SSP, particularly in soils with high phosphorus fixation potential (Akande *et al.,* 2010). Application methods were also a significant factor influencing phosphorus uptake efficiency. Our study supports previous research indicating that localized phosphorus placement techniques, such as deep banding, result in higher yields for crops like wheat and maize. This finding highlights the importance of precise phosphorus placement to enhance root access to available nutrients (Freiling *et al.,* 2022).

Furthermore, our results align with studies demonstrating that organic compost charged with rock phosphate improves phosphorus solubilization, particularly in alkaline soils. This underscores the value of integrated nutrient management approaches in optimizing phosphorus utilization (Yadav, 2017). Similarly, the study's findings on intercropping systems align with research that suggests Tundulu rock phosphate enhances groundnut yields when intercropped with pigeon pea. This supports the hypothesis that crop diversity may improve phosphorus use efficiency by modifying rhizosphere interactions and enhancing nutrient uptake (Phiri, 2013).

While the study highlights the benefits of RP application, certain findings contrast with existing research. One notable challenge is phosphorus fixation, where high fixation rates in specific soils may limit RP effectiveness unless combined with other amendments to enhance phosphorus availability (Iwasaki *et al.,* 2022). This aligns with studies that emphasize the necessity of soil-specific phosphorus management strategies. Additionally, varietal differences in phosphorus uptake efficiency were observed, with some crop varieties demonstrating superior phosphorus utilization compared to others. This supports previous findings that varietal selection is a key determinant of yield outcomes, emphasizing the importance of selecting phosphorus-efficient genotypes to maximize productivity (Swain *et al.,* 2024).

Another area of divergence pertains to the threshold effects of RP application. The study found diminishing returns on crop yields beyond a certain application threshold, which is consistent with previous reports indicating that excessive phosphorus application does not always translate into higher yields. This finding highlights the need for precise phosphorus management to avoid nutrient waste and potential environmental concerns (Swain *et al.,* 2024). Finally, economic feasibility remains a critical consideration. While agronomic benefits of RP application are evident, studies emphasize that economic assessments must complement agronomic trials to determine cost-effectiveness. The study's findings suggest that while RP can enhance yields, its financial viability depends on input costs and expected returns, reinforcing the need for a holistic approach to phosphorus management (Akande *et al.,* 2005).

CONCLUSION

The results strongly suggest that optimal RP inputs (50–75 kg ha^{-1}) and the plough-sole method maximize crop yield and biomass production, supporting more efficient phosphorus management strategies. However, further multi-season trials and economic feasibility assessments are necessary to refine recommendations and ensure long-term sustainability and profitability. By integrating these insights, researchers and practitioners can contribute to improved soil fertility, enhanced food security, and sustainable agricultural productivity.

REFERENCES

Akande, M. O., Adedira, J. A., & Oluwatoyinbo, F. I. (2005). Effects of rock phosphate amended with poultry manure on soil available P and yield of maize and cowpea. *African Journal of biotechnology*, *4*(5), 444-448.

Akande, M. O., Makinde, E. A., Oluwatoyinbo, F. I., & Adetunji, M. T. (2010). Effects of phosphate rock application on dry matter yield and phosphorus recovery of maize and cowpea grown in sequence. *African Journal of Environmental Science and Technology*, *4*(5).

Bationo, A., Fening, J. O., & Kwaw, A. (2018). Assessment of soil fertility status and integrated soil fertility management in Ghana. *Improving the Profitability, Sustainability and Efficiency of Nutrients Through Site Specific Fertilizer Recommendations in West Africa Agro-Ecosystems: Volume 1*, 93-138.

Chien, S. H., & Menon, R. G. (1995). Factors affecting the agronomic effectiveness of phosphate rock for direct application. *Fertilizer research*, *41*, 227-234.

Chien, S. H., Prochnow, L. I., Tu, S., & Snyder, C. S. (2011). Agronomic and environmental aspects of phosphate fertilizers varying in source and solubility: an update review. *Nutrient Cycling in Agroecosystems*, *89*(2), 229-255.

Freiling, M., von Tucher, S., & Schmidhalter, U. (2022). Factors influencing phosphorus placement and effects on yield and yield parameters: A meta-analysis. *Soil and Tillage Research*, *216*, 105257.

Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research*. John wiley & sons.

Gweyi-Onyango, J. P., Günter, N., & Römheld, V. (2010). Differential benefits of rock phosphate (RP) by tomato (Lycopersicon esculentum mill.) plant as affected by nitrogen froms and soil types. *African Journal of Food, Agriculture, Nutrition and Development*, *10*(4).

Iwasaki, S., Ikazaki, K., Bougma, A., & Nagumo, F. (2022). Appropriate use of local phosphate rock increases phosphorus use efficiency and grain yield of sorghum and cowpea in the Sudan Savanna. *Frontiers in Soil Science*, *1*, 709507.

Phiri, A. T., Njoloma, J. P., Kanyama-Phiri, G. Y., Sieglinde, S., & Lowole, M. W. (2013). Effects of intercropping systems and the application of Tundulu Rock phosphate on groundnut grain yield in Central Malawi. *International Journal of Plant and Animal Sciences*, *1*(1), 011-020.

Rao, J. K., Dart, P. J., & Sastry, P. V. S. S. (1983). Residual effect of pigeonpea (Cajanus cajan) on yield and nitrogen response of maize. *Experimental Agriculture*, *19*(2), 131-141.

Singh, S. K., Pathak, R., & Pancholy, A. (2017). Role of root nodule bacteria in improving soil fertility and growth attributes of leguminous plants under arid and semiarid environments. *Rhizobium Biology and Biotechnology*, 39-60.

Swain, S. K., Kalidas-Singh, S., Puyam, A., Thakuria, D., Maimom, S., Zhiipao, R. R., & Tangjang, A. (2024). A comparative study of localized phosphorus application and broadcasting method on biomass production and their use efficiency on Chilli (Capsicum annuum) under alkaline soil. *Frontiers in Plant Science*, *15*, 1304963.

Yadav, H., Fatima, R., Sharma, A., & Mathur, S. (2017). Enhancement of applicability of rock phosphate in alkaline soils by organic compost. *Applied Soil Ecology*, *113*, 80-85.