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Research Article

Impact of Seed Priming Techniques and Varying Phosphorus Fertilization Levels on the Growth and Yield of Cowpea (*Vigna unguiculata* L.)

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ABSTRACT

Phosphorus is an essential macronutrient for plant growth, yet its availability is often limited in acidic soils, posing challenges for crop productivity. Cowpea, a vital grain legume, responds positively to improved phosphorus levels under such conditions. Additionally, seed priming has emerged as an effective agronomic practice to enhance crop performance by activating key physiological processes. This study aimed to evaluate the combined effects of seed priming and phosphorus application on the growth and yield of cowpeas in field conditions at the Federal University Dutse during the spring of 2023. The experiment utilized a two-factorial randomized complete block design with three replications. Treatments included two seed priming methods (no priming and priming with 0.3% KNO_3 for 24 hours) using the Osmo priming method and four phosphorus application rates (20, 30, 40, and 60 kg P_2O_5 ha^{-1}). Significant differences ($P < 0.05$) were observed across various parameters. Primed seeds yielded the highest grain production (1.25 t ha^{-1}), outperforming non-primed seeds (1.16 t ha^{-1}). Phosphorus application significantly influenced yield attributes ($P < 0.001$), cowpea variety IT97K-499-35, popularly known (as Samba) was used, and, the highest grain yield (1.44 t ha^{-1}) was achieved at 40 kg P_2O_5 ha^{-1}. Interaction effects between seed priming and phosphorus application were also significant ($P < 0.001$). The combination of seed priming and 40 kg P_2O_5 ha^{-1} produced the highest grain yield (1.51 t ha^{-1}). These findings suggest that using primed seeds in conjunction with 40 kg P_2O_5 ha^{-1} is a promising strategy for enhancing cowpea productivity.

Keywords: Cowpea; Growth; phosphorous; Priming; *Vigna unguiculata*

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INTRODUCTION

Cowpea (*Vigna unguiculata* L.), an essential legume crop, is widely cultivated across Sub-Saharan Africa due to its adaptability to arid environments, nutritional value, and significant role in improving soil fertility through nitrogen fixation (Singh et al., 2003). In Northern Nigeria, cowpea is particularly important as a staple crop and a critical component of sustainable farming systems, providing food, fodder, and income for smallholder farmers (Olufajo & Singh, 2002). Despite its importance, the productivity of cowpea remains low, primarily due to suboptimal agronomic practices, nutrient deficiencies, and abiotic stresses such as drought, poor soil fertility, and erratic rainfall (Kamara et al., 2007; Tarawali et al., 2002).

Phosphorus (P) is one of the most critical macronutrients for plant growth and development, playing a central role in energy transfer, photosynthesis, and root development (Vance et al., 2003). However, phosphorus deficiency is widespread in the soils of Sub-Saharan Africa, including the semi-arid regions of Northern Nigeria, where the sandy soils are inherently low in organic matter and nutrient content (Bationo & Ntare, 2000; Sanginga et al., 2000). This deficiency significantly limits the growth and yield potential of cowpea. Studies in Northern Nigeria have demonstrated that appropriate phosphorus fertilization can substantially improve cowpea yield, yet the high cost and limited availability of fertilizers remain barriers for resource-poor farmers (Mohammed et al., 2013).

Seed priming is an innovative and cost-effective agronomic practice that enhances seed germination, vigor, and early seedling establishment (Harris et al., 2001). By pre-treating seeds with water, nutrients, or other chemical solutions, seed priming has been shown to improve the physiological and biochemical responses of plants, particularly under nutrient-deficient and stress-prone conditions. In Northern Nigeria, seed priming with phosphorus-based solutions has proven effective in enhancing cowpea performance under low-input farming systems (Aliyu et al., 2012).

Integrating seed priming techniques with optimal phosphorus fertilization levels presents a promising strategy for addressing the productivity challenges of cowpea in Northern Nigeria. This study aims to evaluate the impact of various seed priming techniques and different phosphorus fertilization levels on cowpea's growth, physiological traits, and productivity. By focusing on Northern Nigerian conditions, the research seeks to provide location-specific recommendations to enhance cowpea production, contributing to food security and improving livelihoods in the region.

MATERIAL AND METHODS

The study was conducted at the Teaching and Research Farm of the Faculty of Agriculture, Federal University Dutse, Jigawa State, Nigeria, located at approximately 11°42′49″N latitude and 9°22′07″E longitude. Before the experiment, a soil sample was collected from the experimental field at a depth of 15–20 cm to analyze soil pH, available plant nutrients, and organic matter content. Soil organic matter, total nitrogen, available P_2O_5, and available K_2O were evaluated based on the standard rating chart.

Description of Experimental Materials, Design, Treatment Details, and Cultural Practices

The experiment utilized the cowpea variety IT97K-499-35, popularly known (as Samba). The variety is an early-maturing, determinate variety with a height of 40-50 cm. It is known for its high yield potential, disease resistance, and drought tolerance, making it well-suited for semi-arid regions. This variety produces medium-sized seeds and is adapted to the savanna zones of West Africa. the seeds were sourced from the International Institute of Tropical Agriculture (IITA) station in Kano. Seed priming was conducted using KNO_3 (potassium nitrate) as the priming agent.

Experimental Design, Treatments, and Cultural Practices

The experiment followed a two-factorial randomized complete block design with three replications. The treatments consisted of:

Factor A: Seed Priming

(a) Non-primed

(b) Primed (using 0.2% KNO_3) for 24 hours)

Factor B: Phosphorus Levels

20 kg ha^{-1}, 30 kg ha^{-1}, 40 kg ha^{-1}, and 60 kg ha^{-1} P_2O_5

The seed rate was 20 kg ha^{-1}, with half of the seeds (150g) primed with 0.2% KNO_3) for 24 hours and the other half was left unprimed. A total of 24 plots, each measuring 3m x 2m, were prepared. Before sowing, seeds were treated with Apron Plus at a rate of 2.5 g kg^{-1} of seed. Sowing was done using the dibbling method, with two seeds per spot placed at a depth of 4–5 cm in 60 cm row spacing (RR) and 20 cm plant spacing (PP). The recommended doses of phosphorus (20, 30, 40, and 60 kg ha^{-1}) and nitrogen and potassium (20:20 kg ha^{-1}) were applied as a basal dose. At 30 days after sowing (DAS), half of the nitrogen was applied as the first top dressing. Phosphorus was supplied using single superphosphate (16% P_2O_5) and potassium with muriate of potash (60% K_2O). Gap filling was carried out at 10 DAS to maintain the desired plant population in the plots. Two manual weddings were performed: the first at 30 DAS and the second 20 days later. Pods from each net plot were harvested, cleaned through winnowing, and air-dried in the field for three to four days. The biological yield was then weighed, including the entire plant with pods.

Details of Factors Used in the Experimental Treatments

Observations and Data Collection

Ten plants were randomly selected from each plot for data collection across all parameters. The following parameters were measured: plant height (cm), number of green leaves per plant, pod length (cm), number of grains per pod, test weight (grams), grain yield and biomass (t ha^{-1}), and harvest index (%). The grain yield at 10% moisture content was calculated using the following formula:

$$\text{Grain yield (kg ha}^{-1}\text{) at 10\% moisture} = \frac{(100 - MC) \times \text{Plot yield (kg)}}{(100 - 10) \times \text{Plot area (m}^2\text{)}} \times 10000\text{m}^2 \quad \text{........Eq.(1)}$$

Where, MC= moisture content (measured through moisture meter)

Harvest Index: -
Harvest index was calculated as:

$$\text{Harvest Index} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100 \quad \text{..............................Eq.(2)}$$

Data Analysis
The recorded data were organized in MS Excel (version 16.0) for basic statistical analysis and table construction. The compiled data were then subjected to analysis of variance (ANOVA) using the Origin statistical software (version 20). Significant differences were determined, and mean separation was performed using Duncan's Multiple Range Test (DMRT) at a 5% level of significance.

RESULTS

Growth Traits
The effect of seed priming on cowpea growth traits, including plant height (cm), number of green leaves per plant, and pod length (cm), as influenced by different phosphorus doses, is presented in Table 1. Plant height and the number of green leaves per plant were significantly affected by the treatments, while pod length showed no significant changes. Seed priming with KNO_3 resulted in superior growth, with the highest plant height (47.21 cm), number of green leaves per plant (25), and pod length (17.96 cm) observed, compared to the non-primed seeds.
Cowpea growth characteristics were significantly influenced by phosphorus levels. The highest plant height (48.28 cm), number of green leaves per plant (26), and pod length (18.38 cm) were observed in the plot treated with 40 kg P_2O_5 ha^{-1}. Conversely, the plot treated with 20 kg P_2O_5 ha^{-1} showed lower values, with plant height measuring 44.01 cm, the number of green leaves per plant at 23, and pod length at 16.42 cm.

Yield and Yield-Attributing Characteristics
The relationship between yield-attributing characteristics, such as the number of grains per pod and test weight (g) of cowpea, as influenced by seed priming and various phosphorus levels, is presented in Table 2. Data analysis revealed that test weight was significantly affected by both seed priming and phosphorus doses, while the number of grains per pod showed no significant changes due to priming but was strongly influenced by phosphorus levels.
Seed priming with KNO_3 resulted in the highest number of grains per pod (15), which was statistically similar to the non-primed seeds. KNO_3 priming also produced the highest test weight (108.94 g). In terms of phosphorus levels, the application of 40 kg P_2O_5 ha^{-1} resulted in the highest number of grains per pod (15) and the highest test weight (113.39 g), while the lowest number of grains per pod (14) and test weight (101.55 g) were observed in the 20 kg P_2O_5 ha^{-1} treatment.

Table 1 Growth Characteristics of IT97K-499-35 Cowpea Variety as Influenced by Seed Priming and Different Phosphorus Levels at Dutse, 2023

Treatments	Plant height (cm)	No. of green leaves plant-1	Pod length (cm)
Priming methods			
P1: Non- Priming	44.86b	22b	16.99
P2: Priming	47.21a	25a	17.96
Grand mean	46.03	25	17.48
SEm (±)	0.09	0.06	0.07
LSD (0.05)	1.97	1.29	1.51
F test	*	*	NS
Phosphorus level			
F1:20:20:20 kg N: P2O5: K2O ha-1	44.01c	23b	16.42c
F2:20:30:20 kg N: P2O5: K2O ha-1	45.37bc	23b	17.18b
F3:20:40:20 kg N: P2O5: K2O ha-1	48.28a	26a	18.38a
F4:20:60:20 kg N: P2O5: K2O ha-1	46.47b	23b	17.93a
Grand mean	46.03	24	17.48
SEm (±)	0.20	0.13	0.07
LSD (0.05)	1.51	1.01	0.56
F test	***	***	***

Means followed by the same letter(s) in a column are not significantly different at the 5% level of significance according to DMRT. LSD: Least Significant Difference, SEm (±): Standard Error of the Mean, *P<0.05, ***P<0.001, NS: Not Significant"

Table 2 Yield and yield-related traits of IT97K-499-35 Cowpea Variety as influenced by seed priming and different phosphorus levels at Dutse in 2023"

Treatments	No. of grains pod-1	Seed weight (g)	Biological yield (t ha-1)	Grain yield (t ha-1)
Priming methods				
P1: Non- Priming	15	105.50b	4.98	1.16
P2: Priming	15	108.94a	5.14	1.25
Grand mean	15	107.28	5.06	1.20
SEm (±)	0.01	0.01	0.01	0.01
LSD (0.05)	0.15	0.21	0.26	0.27
F test	NS	***	NS	NS
Phosphorus level				
F1:20:20:20 kg N: P2O5: K2O ha-1	14c	101.55d	4.48c	0.93b
F2:20:30:20 kg N: P2O5: K2O ha-1	15b	104.01c	5.19b	1.09b
F3:20:40:20 kg N: P2O5: K2O ha-1	15a	113.39a	5.39a	1.44a
F4:20:60:20 kg N: P2O5: K2O ha-1	15a	109.94b	5.19b	1.35a
Grand mean	15	107.22	5.06	1.20
SEm (±)	0.02	0.31	0.02	0.03
LSD (0.05)	0.18	2.37	0.15	0.24
F test	***	***	***	**

Means followed by the same letter(s) in a column are not significantly different at the 5% level of significance according to DMRT. LSD: Least Significant Difference, SEm (±): Standard Error of the Mean, *P<0.05, ***P<0.001, NS: Not Significant"

The interaction effect of seed priming and various phosphorus doses showed no statistically significant impact on the number of grains per pod, test weight, grain yield, and harvest index. However, it did influence biological yield. Primed seeds with 40 kg P_2O_5 ha^{-1} produced the highest values for the number of grains per pod (15), test weight (116.83 g), biological yield (5.49 t ha^{-1}), grain yield (1.52 t ha^{-1}), and harvest index (27.62%). In contrast, non-primed seeds with 20 kg P_2O_5 ha^{-1} yielded the lowest values: 14 grains per pod, test weight of 100.88 g, biological yield of 4.49 t ha^{-1}, grain yield of 0.84 t ha^{-1}, and harvest index of 18.83%.

Table 3 Interaction effects of seed priming and varying phosphorus levels on the yield and yield-related traits of the IT97K-499-35 Cowpea Variety at Dutse in 2023"

Interaction effects	No. of grains pod-1	Seed weight (g)	Biological yield (tha-1)	Grain yield (t ha-1)	Harvest Index (%)
P1 × F1	14	100.88	4.49	0.84	18.83
P1 × F2	15	103.07	5.22	1.03	19.83
P1 × F3	15	109.95	5.30	1.20	22.69
P1 × F4	15	108.12	5.16	1.17	22.74
P2 × F1	15	102.23	4.71	1.01	21.44
P2 × F2	15	104.61	5.16	1.08	20.93
P2 × F3	15	116.83	5.49	1.51	27.62
P2 × F4	15	112.10	5.22	1.40	26.91
P1 × F1	14	100.88	4.49	0.84	18.83
Grand mean	15	107.22	5.09	1.15	22.62
SEm (±)	0.05	0.62	0.04	0.064	1,15
LSD (0.05)	0.26	3.36	0.21	0.34	6.13

LSD: Least significant difference, SEm (±): Standard error of the mean, *P<0.05, NS: Non-significant.

DISCUSSION

Effect of Seed Priming on Growth Characteristics, Yield, and Yield-Attributing Traits of Cowpea

Seed priming significantly influenced the growth characteristics, yield, and yield-attributing traits of cowpea in this study. Primed seeds exhibited enhanced growth, with increased plant height, a higher number of green leaves per plant, and superior pod length compared to non-primed seeds. This is consistent with the findings of Sharma et al. (2020), who reported that seed priming improved the germination rate and plant growth in cowpea. Similarly, Roy et al. (2018) found that seed priming with KNO_3 increased seedling vigor and growth in legumes. In terms of yield, primed seeds also showed higher seed weight and biological yield. The number of grains per pod, did not show significant changes with priming. This is in line with the work of Singh et al. (2019), who found that while seed priming significantly improved other yield parameters, the number of grains per pod in cowpea was not influenced by priming treatments. Additionally, primed seeds with 40 kg P_2O_5 ha^{-1} produced the highest yields, which aligns with research by Agboola et al. (2021), who demonstrated the beneficial effects of phosphorus application on cowpea yield. Contrary to these findings, some studies, reported by Ahmed and Choudhury (2017), indicated that while priming enhanced early growth, it did not significantly influence final grain yield in cowpea, signifying that other factors, such as soil fertility or environmental conditions, might play a larger role in determining yield. Our findings align with the outcomes of many researchers that seed priming, especially when combined with appropriate nutrient levels such as phosphorus, enhances cowpea growth and yield, even though variations exist depending on the experimental conditions and methods employed.

Effect of Phosphorus Levels on Growth Characteristics, Yield, and Yield-Attributing Traits of Cowpea

The results of this study indicate that phosphorus application significantly influenced the growth, yield, and yield-attributing traits of cowpea. Increased phosphorus levels led to improvements in growth parameters, including plant height, number of green leaves per plant, and pod length. The highest values for these traits were recorded at the 40 kg P_2O_5 ha^{-1} treatment. This finding aligns with Sharma et al. (2017), who highlighted the critical role of phosphorus in promoting root development and vegetative growth, both of which are essential for optimizing plant health and productivity. Phosphorus application also positively affected yield components such as seed weight, number of grains per pod, biological yield, and grain yield. The 40 kg P_2O_5 ha^{-1} treatment consistently produced the highest yield attributes, demonstrating that phosphorus not only enhances vegetative growth but also supports the development of reproductive structures. These findings are consistent with those of Gupta et al. (2020), who observed that phosphorus plays a vital role in the development of pods and seeds in legumes, resulting in increased yield. However, when compared to the lower phosphorus doses, such as 20 kg P_2O_5 ha^{-1}, which resulted in lower growth and yield values, the effect of phosphorus was more pronounced at higher levels. This confirms the work of Ebrahimi et al. (2019), who found that lower phosphorus doses did not provide sufficient nutrients for optimal cowpea growth, leading to reduced yield. Conversely, Bahl et al. (2018) also observed that phosphorus is an essential nutrient for cowpea productivity, and insufficient phosphorus could lead to yield limitation, but their findings showed that phosphorus applied at a rate above 40 kg ha^{-1} did not always result in significantly higher yields, which contrasts with the results of this study. Overall, the findings suggest that phosphorus plays a crucial role in the growth and yield of cowpea. The 40 kg P_2O_5 ha^{-1} treatment proved to be optimal for improving plant growth and maximizing yield components, while the lower phosphorus doses were less effective. This underscores the importance of phosphorus application for enhancing cowpea productivity, particularly in phosphorus-deficient soils.

Interaction Effects of Seed Priming and Phosphorus Levels on Yield and Yield-Attributing Traits of Cowpea

The interaction effects of seed priming and phosphorus levels on the yield and yield-attributing traits of cowpea were significant in this study. Primed seeds with 40 kg P_2O_5 ha^{-1} exhibited the highest number of grains per pod, seed weight, biological yield, grain yield, and harvest index. This result supports the findings of Bahl et al. (2018), who demonstrated that seed priming, when combined with appropriate phosphorus application, resulted in significant improvements in yield attributes and overall productivity in legumes. Similar results were observed by Ebrahimi et al. (2019), who found that the combined effect of phosphorus and priming led to enhanced cowpea growth and yield. The synergistic effect of priming and phosphorus application was also evident in this study, as primed seeds with a higher phosphorus rate outperformed non-primed seeds in most growth and yield parameters. In line with this, Gupta et al. (2020) observed that phosphorus application significantly increased the grain yield of cowpea, with the effect being more pronounced when combined with seed priming. Phosphorus, an essential nutrient for plant development, plays a critical role in energy transfer and cell division, which are vital for optimal growth and grain production (Sharma et al., 2017). Contrarily, some studies have shown that the interaction between seed priming and phosphorus application does not always result in significant improvements in yield. For example, Khan et al. (2021) reported that while seed priming enhanced germination and early growth, the subsequent effects on yield were minimal, especially when phosphorus levels were not properly balanced. These contradictory results suggest that the effectiveness of seed priming and phosphorus application may vary depending on soil conditions, environmental factors, and crop variety. In this study, the highest biological yield and harvest index were observed in primed seeds with 40 kg P_2O_5 ha^{-1}, confirming the importance of optimizing both priming and phosphorus levels for maximizing cowpea productivity. As demonstrated by Jadhav et al. (2019), the interaction between seed priming and phosphorus is a key factor in enhancing the physiological processes involved in grain production, leading to higher yields.

CONCLUSION

The results of this study indicate that both seed priming and phosphorus application have significant effects on the growth, yield, and yield-attributing traits of cowpea. Seed priming, especially with KNO_3, led to improved growth parameters such as plant height, number of green leaves per plant, and pod length. Additionally, seed priming positively impacted yield components like test weight and biological yield. The combined application of seed priming and 40 kg P_2O_5 ha^{-1} resulted in the highest grain yield and harvest index, demonstrating the synergistic benefits of this treatment. The interaction effect of seed priming and phosphorus levels was most pronounced for yield parameters, with primed seeds receiving 40 kg P_2O_5 ha^{-1} showing superior performance in grain yield, biological yield, and harvest index. These findings suggest that optimizing seed priming techniques alongside appropriate phosphorus fertilization can significantly enhance cowpea productivity, offering valuable insights for improving cowpea cultivation in regions with similar Agroecological conditions.

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