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Determination of an Integrated Compost and Phosphorus Management Strategy for Cowpea Production in the Wet Savannah Ecosystem of Nigeria

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Abstract
The trial was conducted at two sites within the Wet Savannah zone of Kwara State, Nigeria. The primary objective was to promote cowpea as a major crop in this ecological region and to evaluate the effects of compost manure and phosphorus application on cowpea productivity. Compost was applied at a rate of 2.5 t ha^{-1}, while P_2O_5-only was applied at 50 kg ha^{-1}. Additional treatments included combinations of compost and P_2O_5, as well as a control group. The results demonstrated that the control and P_2O_5-only treatments yielded statistically similar outcomes for most growth and development parameters ($p \leq 0.05$), both of which were inferior to the other treatments. This reduced performance was attributed to soil acidity. The number of days to 50% flowering decreased to 57.94, suggesting adaptation toward early maturity to avoid abrupt life cycle termination. The combined application of compost and P_2O_5 produced a synergistic effect ($p \leq 0.05$), resulting in enhanced branching (9.71), leaf area (100.45 cm^2), nodulation (45.47), and grain yield (1,081.20 kg/ha). These improvements were attributed to the synergistic interaction between compost manure and P_2O_5. It is therefore recommended that compost be applied at 2.5 t ha^{-1}, supplemented with P_2O_5 at 50 kg ha^{-1}, to optimize cowpea production in the Wet Savannah zone.

Keywords: *Cowpea, Compost, Nitrogen and Phosphorus*

INTRODUCTION

Cowpea plays a crucial role in ensuring food security, especially in light of challenges such as soil degradation (Jadoon et al., 2025), climate change (Ogar et al., 2025) and migration due to conflict (Amadi-Robert et al., 2024; Yisa et al., 2025). Although cowpea is nutritionally valuable, achieving optimal yields in tropical soils can be challenging. According to Sohani and Mukhtar (2018), one reason for the low yields is that farmers mistakenly believe that cowpea, which is autotrophic, does not require mineral fertilizers. While cowpeas fix nitrogen, there can be temporary nitrogen deficiencies before nodule formation occurs, and relying solely on biological nitrogen fixation often results in insufficient yields. Nigerian cowpea yields are notably low, averaging just 450 kg per hectare, as reported by Danso et al. (2025). This figure falls significantly short of the global average and the impressive theoretical potential of over 2000 kg per hectare identified by Kouakou et al. (2022) and Mkhonta et al. (2025). Several critical factors contribute to this low yield, including inefficient planting spacing, the prevalence of pests and diseases, the use of unimproved seed varieties, and limited access to essential agricultural inputs and markets. These challenges highlight the pressing need for targeted research and effective interventions to enhance cowpea production in Nigeria

Given climate change and migration, investigating sustainable nutrient management for adapted cowpea varieties is crucial, especially for immigrant farmers in the Wet Savannah. Previous research identified promising varieties for this zone (Omoigui et al., 2023; Petu-Ibikunle et al., 2025). High mineral fertilizer costs (Baoua et al., 2021; Kebede & Bekeko, 2020) and acidic soil (Ajadi et al., 2025) hindering nutrient uptake necessitate sustainable alternatives to support these varieties for immigrant farmers.

Previous research has examined compost and phosphorus separately, but their combined impact on cowpea varieties in Nigeria's acidic Wet Savannah soils remains underexplored. This study seeks to bridge the gap between academia and practical farming by engaging both native and immigrant farmers—a participatory approach is crucial for the successful adoption of new agricultural technologies.

The core research question addresses the inherent fertility of Nigeria's Wet Savannah soil for optimal cowpea grain yield. The primary objective is to identify sustainable alternatives to mineral nitrogen fertilizer for cowpea in this ecosystem. Sub-objectives include: (i) evaluating the individual and combined effects of phosphorus and compost on cowpea's agronomic traits and biological yield for adoption by immigrant farmers in Nigeria's Wet Savannah ecological zone.

MATERIALS AND METHODS

Description of the Experimental Site:

Location 1: Iloffa, Oke Ero, Kwara State, Nigeria (Coordinates: 5° 8' 32" E). The soil at this location demonstrates significant agricultural potential, with a composition of 72% sand, 12% clay, and 16% silt. The soil pH is 5.45, which falls within an ideal range for many crops. Although macro-nutrient levels are modest (Nitrogen: 32 PPM, Phosphorus: 38 PPM, Potassium: 0.17 PPM), the organic carbon content is 0.84. This is supported by a high base saturation of 6.60, which enhances nutrient retention.

Location 2: Ilorin, the capital of Kwara State in western Nigeria (Coordinates: Latitude 8° 29' 47.90" N, Longitude 4° 32' 31.70" E). The soil in Ilorin is characterized by 75% sand, 15% clay, and 10% silt. Its slightly acidic pH of 5.2 is also suitable for various crops. The macro-nutrient levels include Nitrogen: 28 PPM, Phosphorus: 26 PPM, and Potassium: 0.15 PPM, with a healthy base saturation of 5.1 cmol/kg (Ajadi et al., 2025).

The zones in Kwara State where the trials were conducted experience a climate characterized by tropical wet savanna conditions. They receive up to 101.45 millimeters (3.99 inches) of rainfall over approximately 148.38 days annually. The average monthly temperature ranges from 22°C at night to 33°C during the day (NiMet, 2023)

Land preparation and cultural practices: Bush clearing began during the August break of the 2022 cropping season. We manually removed weeds and shrubs with a cutlass and cleared away rubble obstructing the farmland, preparing it for a growing season. The demarcation of plots was methodically carried out; plots measuring 4 m × 2 m were prepared using hoes. The soil was e turned into ideal friable seed beds. P_2O_5 at 50 kg/ha was applied and worked during land preparation as recommended by (Mikai & Ilallah, 2022).

Compost manure was applied at a rate of 2.5 t/ha according to the methodology of (Alabi et al., 2024). Seeds (Cowpea variety Ife Brown) were sown at a rate of three seeds per hill, with thinning carried out seven days after sowing. A spacing of 50 cm by 20 cm was adopted to achieve a total of 105 plants per plot. To achieve formidable pest control, tobacco leaf extract was applied using a knapsack sprayer containing tobacco leaf extract (nicotine, d-limonene, pyridine, and indole), according to Tjokrosoedomo et al. (2022). Three applications were performed: first at 50% blooming, second at 100% blooming, and third at the pod maturity stage. Weeds were manually removed using hoes at the 3rd and 6th weeks after sowing to reduce competition. This weeding process also helped further incorporate the manure into the soil and facilitated earthing up around the base of the plants, which were initially planted on flat ground. Compost was prepared and applied according to (Girish et al. 2020)

Compost was prepared using methods described by Nehander and Munyati (1999) and Xu et al. (2023). Microbial content was analyzed according to Adegunloye et al. (2007), Njoku et al. (2019) ; Tyohemba et al. (2020). For application, the compost was flail-spread and then lightly hand-tilled into the topsoil.

Experimental design and treatment allocation:
An on-farm adaptive research methodology, as described by Low et al. (1991), Clayton et al. (1983), and Eldon et al. (2020), was adopted. Consultative farmers' fields at each location were used for the experiment.

A Randomised Complete Block Design (RCBD) was used to test four treatments: (i) a control (no compost or P_2O_5 fertiliser), (ii) basal compost, (iii) basal P_2O_5 fertiliser, and (iv) basal compost and P_2O_5. A net plot size of 8 m² × 4 treatment plots = 32 m² on each farmer's field served as the experimental (i.e., treatment) units. Each of the three farmers' fields per location containing four experimental treatment units translated to one replication each. Randomisation ensured that treatment allocations to plots did not follow a deliberate similar sequence across the three blocks/replications. (i.e., the other two farmers' fields).

Data collection: Growth and yield parameters were assessed as follows: Days to 50% flowering were determined by daily observations of when 50% of cowpea plants in each plot began to flower. Branching was quantified by counting main branches on fifteen sampled plants at six weeks after sowing. Nodule count involved uprooting fifteen plants within 50 cm × 50 cm frames, rinsing their roots, and counting nodules with a hand lens. Leaf area was measured using the method by Kaushik et al. (2021). Grain yield (kg ha-1) was determined by hand-harvesting pods when brown and dry, sun-drying for five days until shattering, threshing with a stick, winnowing, and weighing the grains with an electronic scale.

Data analysis: A Completely Randomized Block Design (RCBD) assessed the effects of four treatments (Check, Phosphorus, Compost, and Phosphorus + Compost) on days to 50% flowering, branching, leaf area, nodule count, and grain yield. Data underwent normality and homogeneity of variance testing (Levene, 1960) before a one-way ANOVA (Fisher, 1935) at $P \leq 0.05$ identified significant treatment differences. Pairwise comparisons used Fisher's Least Significant Difference (LSD) post-hoc test ($P \leq 0.05$), with a compact letter display indicating significant differences. Results from two locations were harmonized by averaging parameter values. Statistix 8.0 performed all statistical analyses.

RESULTS AND DISCUSSION

The compost exhibited optimal characteristics for crop growth, including a neutral pH of 6.9 (Wright et al. 2022). Its 29% organic carbon content (52% total organic matter) falls within the recommended 30–70% range for finished compost (Jia et al. 2023). A C:N ratio of 29 indicates an ideal environment for microbial activity, promoting decomposition and preventing ammonia release (Eiland et al. 2021). The high cation exchange capacity (CEC) signifies excellent maturity and nutrient retention, acting as a biological "sponge" for plant nutrients (Ćirić et al. 2023). With 4% P_2O_5, this compost is a highly concentrated phosphorus source, far exceeding typical levels (0.15% to 1.00%), and it is ideal for replenishing depleted phosphorus (Khater, 2015).

Compost analysis (Table 2) revealed a diverse microbial community, including bacteria (*Trichoderma*, *Penicillium*, *Aspergillus*), fungi (*yeast*, *Archaea*), protozoans (*Acanthamoeba*, *Naegleria*, *Colpoda cucullus*), and nematodes (*Rhabditidae*, *Cephalobidae*, *Aphelenchoididae*, *Mononchoides*). This aligns with findings by Osamede (2019) and Oni (2022). Scholars explain that these microorganisms decompose organic matter into stable, plant-friendly materials, releasing essential nutrients like nitrogen, phosphorus, and potassium into the soil. This process facilitates slow-release nutrition, prevents nutrient leaching, and enhances long-term soil productivity.

Compost and phosphorus application significantly ($P \leq 0.05$) increased the time to 50% flowering in cowpea at both locations (Table 3). The control group showed the greatest delay, with 57.88 days to 50% flowering at Location 1, where P_2O_5, compost, and P_2O_5 + compost applications showed no significant difference. At Location 2, the control and P_2O_5 applications resulted in similarly early flowering, while compost and compost + P_2O_5 caused a similar, but more significant, delay. The mean flowering times across both locations were 57.94, 57.47, 59.65, and 59.11 days for the control, P_2O_5, compost, and P_2O_5 + compost, respectively. These findings align with previous research (Atakora et al., 2023; Dorvlo et al., 2022; Emmanuel et al., 2020).

Early flowering in check and P_2O_5 treatments likely occurred due to a lack of immediately available inorganic phosphorus. Tropical soils, particularly Oxisols and Ultisols, are typically phosphorus-deficient due to extensive weathering, high acidity, and specific mineralogy, which makes total phosphorus largely inaccessible to plants (Mabagala, 2022;

Tiessen, 2005; Ayodele & Oso, 2014; Ajadi et al., 2025). This is further supported by observations in many cowpea-growing regions, especially West Africa, where acidic, highly weathered soils cause aluminum and iron to bind with soluble phosphorus, creating insoluble compounds unavailable for plant uptake (Silva & Santos, 2023; Mohammed et al., 2020).

Table 1: Proximate Analysis of Compost for Nutrient Content.

S/N	Chemical parameter	Value
1	pH (H_2O)	6.9
2	Organic Carbon (%)	29.0
3	Total Nitrogen (%)	1.43
4	C: N ratio	20.1
5	P_2O_5 (%)	4.5
6	K_2O (%)	2.49
7	Ca	0.38
8	Mg	0.21
9	CEC (meq/100 g)	46.1

Early flowering can serve as a phosphorus-stress escape mechanism, allowing the plant to complete its life cycle before severe stress sets in. Conversely, late flowering in savannas may be a better adaptation to prolonged rainy seasons, maximizing the utilization of the growing period (Petu-Ibikunle et al. 2024; Singh et al. 2023).

Compost and mineral phosphorus application (Table 2) significantly ($p \leq 0.05$) increased cowpea branching across two locations ($p \leq 0.05$). Treatments with P_2O_5 and the control showed the lowest branching, while compost and compost + P_2O_5 yielded statistically higher branching. Mean branch numbers were 9.71 for compost + P_2O_5, 9.08 for sole compost, 8.78 for sole P_2O_5, and 8.74 for the control.

This aligns with Islam et al. (2023), suggesting a synergistic effect between compost and phosphorus. Omoigui et al. (2023) propose this combination enhances vegetative growth, leading to more flower nodule points and branches. Tang et al. (2025) further suggest that nitrogen-fixing bacteria (Table 2) contribute by improving phosphorus absorption through increased microbial activity and nitrogen fixation, making phosphorus more accessible.

Table 2: Composition and Diversity of Compost Micro flora Species Identified in the Compost Sample.

S/N	Bacteria	Fungi	Protozoan	Nematodes
1	*Bacillus*	*Aspergillus*	*Difflugia globulosa, ,*	*Archaea*
2	*Pseudomonas*	*Penicillium*	*Euglypha*	*Rhabditis saprophila*
3	*Actinobacteria*	*Tricoderma*	*Arcella*	*P. gracilis,*
4	*Rhizobium phaseoli*	*Paecilomyces*	*Acanthamoeba*	*P. parvus*
5	*Rhizobium tropici*	*Pichia species*	*Vermamoeba vermiformis*	*Plectonchus galeatus*
6	*Bradyrhizobium elkanii*	*Geotrichum species*	*Naegleria*	*Mononchoides vulgaris*
7	*Rhizobium etli:*	*Candida species*	*Cercomonas*	
8	*Bradyrhizobium japonicum:*			

Cowpea leaf area (Table 3) was significantly increased ($p \leq 0.05$) by compost and phosphorus (P_2O_5) at both study sites, with their combined application yielding the largest leaf area (100.45 cm²). While P_2O_5 alone performed similarly to the control (95.74 cm² vs. 93.84 cm²), the combined treatment consistently surpassed individual applications (compost alone: 98.54 cm²). At Location A, compost alone and the combined treatment produced statistically similar leaf areas. This synergistic effect, consistent with previous research (Li et al. 2021; Masmoudi et al., 2020), likely stems from increased ammonium availability, improved root development, and enhanced soil structure (Yetgin et al., 2025; Zhang et al., 2024). Compost's organic matter alleviates soil limitations, while phosphorus fuels leaf expansion. Moreover, compost microorganisms, especially phosphorus-solubilizing bacteria like *Pseudomonas* and *Bacillus*, convert insoluble phosphorus into plant-available forms (Aguilar-Paredes et al., 2023; Chen et al., 2015; Saeid et al., 2018; Strachel et al., 2017).

Amanullah & Khan (2015) suggest that combined treatments enhance root development, enabling plants to access a larger soil volume. Optimal phosphorus (P) absorption occurs with a robust root system and high soil P availability. Amarasinghe (2022) and Cantero et al. (2025) explain that phosphorus stimulates ATP production (the plant's primary energy carrier), increases P availability, boosts chlorophyll content, and enhances photosynthesis. This provides the energy needed for increased leaf area. Consequently, combined applications likely elevate leaf P concentration and chlorophyll content more significantly than individual applications. This is further supported by Amarasinghe (2022) and Cantero et al. (2025), who note that increased phosphorus improves leaf area. Phosphorus availability is maximized when soil structure is improved through compost and manure application.

Nodulation in cowpea (Table 4) was significantly increased ($p \leq 0.05$) by nutrient amendments. The results were consistent in trend between the two locations. The highest nodulation was recorded for the combination of compost manure and P_2O_5. The nodulation recorded from the check and the application of P_2O_5 were statistically similar. The mean nodulation from the two locations was 45.47, 43.36, 41.43, and 41.48 nodules, respectively, for compost manure + P_2O_5, sole compost, sole P_2O_5, and check. This result was consistent with Odongo et al. (2025). Compost manure functions as a moderating and a chelating factor. This, according to Matin et al. (2019) is achieved by releasing organic acids during decomposition. These organic acids consequently minimize P-fixation and convert phosphorus that is locked up in the soil into plant-absorbable forms. Compost also prevents the fixation that always occurs as soon as P_2O_5 is applied to acidic soils. Phosphorus, according to Bhavya et al. (2018), probably provided the required energy for nodulation, while nitrogen from compost possibly supported root proliferation, thus enhancing the plant's ability to have more sites for root attachment by Rhizobium bacteria. The combined treatment, according to Petu-Ibikunle et al. (2024), is possibly a balanced nutrient supply that is also capable of supplying microbes that are beneficial for nitrogen-fixing bacteria and mycorrhizal fungi. Okoro et al. (2020) reported that resources from compost also make starter nitrogen available for the plants to cater to the early nitrogen starvation usually experienced prior to nodule formation. The availability of nitrogen from compost possibly served as a major resource needed to aid nodulation, as reported by Odongo et al. (2006); Hemananthy et al. (2017); and Duan et al. (2023)

Grain yield of cowpea (Table 4) was significantly increased ($P \leq 0.05$) by nutrient augmentation from the two locations of the experiment. The results were inconsistent in trend at Locations 1 and 2. The grain yields among the three nutrient amendments were significantly ($P \leq 0.05$) different from one another at Location 1. At Location 2, compost + P_2O_5 recorded the highest grain yield. Compost and P_2O_5 yielded similar grain harvests. Compost + P_2O_5, compost, P_2O_5, and the control yielded average grain yields of 1081.20, 1072.57, 1070.10, and 1062.54 kg/ha, respectively, across two locations. It is, however, relevant to remark that although the yield improvement was statistically significant, it was practically minor. These findings align with previous research (Emmanuel et al., 2020; Sodji et al., 2025; Ulzen et al., 2019; Adjei-Nsiah and Ulzen, 2024). Cowpea, a legume, has a higher phosphorus requirement than nitrogen.

The combination of compost and phosphorus probably acted as an effective biofertilizer, improving nutrient availability, accelerating organic matter decomposition, and increasing crop yields. This observed response, consistent with Umadevi et al. (2019) may lead to increased plant nutrient uptake, enhanced root growth, and reduced reliance on chemical fertilizers. Studies by Andrade et al. (2021) ; Otoidobiga et al. 2025) ; Salih et al. (2025); Zhang et al. (2022) have also demonstrated enhanced cowpea grain yields. Improved nutrient availability, as suggested by Bibi et al. (2024), may explain this response. Trichoderma possibly plays a crucial role by converting insoluble phosphorus into usable forms (e.g., citric acid-soluble P) for plants, acting as a potent bioactivator in composting, especially when combined with phosphorus, particularly insoluble sources like rock phosphate. Thus, the observed response may be partly attributed to the activities of Trichoderma and other beneficial microflora and fauna that were observed in the applied compost.

Combined treatment, as supported by Amanullah & Khan (2015), enhances root development, enabling plants to access more soil volume for optimal phosphorus (P) absorption. Phosphorus is vital for ATP production, enhancing chlorophyll content and photosynthesis, thus increasing leaf area. The combined application likely boosted leaf phosphorus and chlorophyll more effectively than separate applications, consistent with Amarasinghe (2022) and

Cantero et al. (2025) highlights that compost and manure improve soil structure and phosphorus availability, particularly in acidic soils, as reported by Ajadi et al. (2025)

Table 3: Growth and Development of Cowpea in Response to Compost and Phosphorus Application

Nutrient Treatment	Days to 50% flowering			Number of Branches			Leaf Area (Cm^2)		
	LA	LB	Mean	LAs	LB	Mean	LA	LB	Mean
Check	88b	58.00a	57.94	9.31c	8.16c	8.74	91.98b	99.70c	95.84
P_2O_5 (50kgha^{-1})	56.48a	58.46b	57.47	9.33c	8.14c	8.72	91.85b	99.63c	95.74
Compost + 2.5 t ha^{-1}	56.34a	61.88a	59.11	9.63b	8.47b	9.05	96.07a	101.00 b	98.54
P_2O_5 compost (50 kg/ha + 2.5 t ha^{-1})	56.31a	60.98a	58.65	10.29a	9.13a	9.71	96.57a	104.33a	100.45
SE±	*0.207*	*1.145*		*0.36*	*0.02*		*0.89*	*0.30*	
LSD ($P \leq 0.05$) or α at 5%	*0.416*	*2.299*		*0.72*	*0.04*		*1.79*	*0.6*	

Key: Location A (LA) = Iloffa, Location B (LB) = Ilorin, SE = Standard Error, LSD = Least Significant Difference. Values sharing the same alphabets are not significantly different from one another at an LSD of $p \leq 0.05$

Table 4: Yield Components and Nodulation of Cowpea in Response to Compost and Phosphorus Application

NutrientTreatment	Nodulation			Grain Yield (Kg/ha)		
	LA	LB	Mean	LA	LB	Mean
i. Check	40.51c	42.45 c	41.48	1060.3 d	1065.5 c	1062.54
ii. P_2O_5 (50 kg/ha)	40.44 c	42.41c	41.43	1065.9c	1070.3b	1070.10
iii. Compost (2.5 t/ha)	42.93b	44.44b	43.36	1070.9b	1075.4b	1072.57
iv. P_2O_5/Compost (50kg/ha+2.5t/ha)	43.82a	47.11a	45.47	1075.9a	1086.5a	1081.20
SE±	0.31	0.04		0.03	3.60	
LSD ($P \leq 0.05$) or α at 5%	0.62	0.07		006	7.23	

Key: Location A (LA) = Iloffa, Location B (LB) = Ilorin, SE = Standard Error, LSD = Least Significant Difference. Values sharing the same alphabets are not significantly different from one another at an LSD of $p \leq 0.05$

CONCLUSION

The sole application of mineral phosphate fertilizer (P_2O_5) in the present study did not yield the best agronomic performance of cowpea. Based on the (acidic) nature of the soil as reported for the experimental area, fixation and insolubility were attributed to this result. Soil nutrient augmentation with the combined compost manure and P_2O_5 in the experiment enhanced general crop growth (leaf area, branching, and nodulation) and development (nodulation and grain yield). The combination of compost + P_2O_5 (nutrients) possibly facilitated a synergistic effect, whereby the compost increased the efficiency of the applied mineral P fertilizer, leading to higher root and shoot growth, nodulation, and ultimately superior grain yields. With the obtained results of the present experiment, the misconceived notion that cowpea performs optimally without the application of mineral P_2O_5 fertilizer and compost manure is set right. It is thus reasonable to conclude that the combined application of compost and phosphorus prevents P_2O_5 fixation while it facilitates phosphate solubilization or phosphate mobilization. It is therefore recommended that farmers in the wet Savannah zone adopt the basal application of 2.5 t/ha compost manure + P_2O_5 at a rate of 50 kg/ha to achieve optimum agronomic performance and grain yield of cowpea in the wet Savannah ecology

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Ethical Statement

The author declares that there was no form of environmental degradation, whether consequent or subsequent, to the research activities. Work by other scholars that has been duly cited/referenced. The author wishes to state that all of his professional colleagues who rendered one service or another at various stages of the experiment did so on a consultancy basis and were rewarded as agreed, but not as co-authors in this publication.

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