

EFFECTS OF NITROGEN AND PHOSPHORUS FERTILIZERS ON THE SEEDLING EMERGENCE AND SHOOT HEIGHT OF EUCALYPTUS (*Eucalyptus camaldulensis*) SEEDS IN MINNA, NIGER STATE, NIGERIA

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ABSTRACT

The study on the effects of varied nitrogen (N) and phosphorus (P) fertilizers on the emergence and early growth of *Eucalyptus camaldulensis* seeds was carried out in 2023 and 2024 seasons at the Seed Nursery Unit of the Federal University of Technology, Minna. The experiment was laid in 2 x 4 factorial in a Completely Randomized Design (CRD) and varied at N (0, 20, 40, 60 kg/ha as urea) and P (0, 13.2, 26.4, 52.8 kg/ha as triple superphosphate) levels which gave 16 treatment combinations including a nutrient-free control replicated three times. Soil characterization was also done on the areas where soils were collected. Seeds were pre-soaked for 24 hours and sown in polyethylene pots filled with sandy Alfisol soil. The different levels of fertilizers were applied at sowing. After 21 days post-sowing, data were collected and analysed on seedling emergence percentage, emergence speed index (ESI), and shoot height. The results revealed that N and P significantly ($p < 0.05$) influenced all measured parameters across seasons. The highest emergence percentages (65.5 % in 2023; 66.0 % in 2024), peak ESI (8.0 in 2023; 8.5 in 2024), and greatest shoot heights (7.0 cm in 2023; 7.5 cm in 2024) were observed under 40 kg N/ha. Correspondingly, 26.4 kg P/ha produced optimal emergence (64.5 % - 64.8 %), ESI (7.5 - 7.9), and shoot growth (6.5 - 7.0 cm). Neither higher N (60 kg/ha) nor higher P (52.8 kg/ha) rates conferred additional benefits. No significant interactions between N and P on all the variables measured in both seasons. These findings indicate that 40 kg N/ha combined with 26.4 kg P/ha maximizes early seedling performance of *E. camaldulensis* under the study conditions. Adoption of these fertilizer rates is recommended to enhance establishment efficiency, reduce input costs, and support sustainable plantation development in the Northern Guinea Savanna of Nigeria.

Keywords: Nitrogen, Phosphorus, *Eucalyptus camaldulensis* and Seedling Emergence

INTRODUCTION

Eucalyptus, a genus encompassing over 700 species within the Myrtaceae family, stands as one of the most economically and

ecologically significant tree species globally. Originating from Australia, *Eucalyptus* has been widely adopted in tropical and subtropical regions for its rapid

growth, versatile wood properties, and adaptability to diverse environmental conditions (Brooker and Kleinig, 2016). In forestry and industry, Eucalyptus species such as *Eucalyptus grandis*, *Eucalyptus camaldulensis*, and *Eucalyptus urophylla* are prized for their high-quality timber, pulpwood for paper production, and biomass for fuelwood and charcoal. The global trade in Eucalyptus products contributes billions of dollars annually, with plantations spanning millions of hectares across continents, including Africa, South America, and Asia (Rejmánek and Richardson, 2021).

The establishment of *Eucalyptus* plantations, while economically and environmentally promising, faces significant challenges during the seedling emergence phase, particularly in regions with marginal growing conditions like Niger State, Nigeria. Located in the Northern Guinea Savanna, Niger State is characterized by a sub-humid climate with annual rainfall of 1200 – 1300 mm concentrated in a single wet season, followed by a prolonged dry period. The predominant sandy, acidic soils (pH 5.0 – to

specific N and P levels that maximize emergence rates and early growth is thus essential for developing evidence-based strategies that ensure robust seedling establishment, forming the foundation for productive plantations. A primary constraint to successful seedling emergence in this context is the deficiency of key soil nutrients, notably nitrogen (N) and phosphorus (P). Nitrogen, essentially directly translates to anemic and stunted growth, for frequently depleted in savanna soils due to leaching during heavy rains and volatilization under high temperatures. Phosphorus, critical for development and energy transfer via ATP, is similarly managed. Eucalyptus plantations in Niger State contribute to

acidic soils (Sanginga and Swift, 2017). Studies on *Eucalyptus* species, including *Eucalyptus grandis*, indicate that inadequate N restricts shoot elongation and leaf expansion during early growth, while P deficiency impairs radicle penetration and seedling vigor (Graciano *et al.*, 2022). General fertilizer recommendations often fail to account for species-specific requirements or regional soil constraints, potentially leading to over- or under-application, both of which can inhibit germination. Excessive N, for instance, may cause osmotic stress, while insufficient P limits root establishment (Turnbull and Eldridge, 2020). *Eucalyptus* species, valued for their rapid growth and versatility, exhibit varying responses to nitrogen (N) and phosphorus (P) during germination and early development, influenced by soil type, climate, and species-specific traits (Turnbull and Eldridge, 2020). Research by Graciano *et al.* (2022) demonstrates that balanced nutrient inputs significantly improve *Eucalyptus* seedling vigor, yet these findings are rarely tailored

West African contexts. Determining the

reforestation efforts aimed at combating deforestation, which has depleted over 50% of Nigeria's forest cover since 1999 (FAO, 2020). Therefore, the objective of this study was to determine the effect of varying nitrogen and phosphorus levels on the seedling emergence of eucalyptus seeds.

MATERIALS AND METHODS

The experiment was a two-season evaluation at the Forestry Nursery Unit Federal University of Technology Minna, mixed to homogenize nutrient distribution before sowing. The pots seedlings emerged cut in a pyramid to be left for 202 days and 2024 planting days on sowing (Day 10) the period of the rainy season and the green findings and emerged seedling emergence for these planting periods based on plantation records (Ladipo, 2020). Seeds of *Eucalyptus camaldulensis* (Swartz) are the species is widely of Emergent Seedlings. Total Number of Seeds Sown = 100 (Ladipo, 2020). Ullah and Eldridge (2020) seed speed in water (ESI) distilled water at 25°C for 24 hours to soften the seed coat and Maguire (2012), also cited in Ladipo (2020). ESI = $(E_1/N_1) + (E_2/N_2) + \dots + (E_n/N_n)$. Where $E_1, E_2, \dots, E_n$ = number of seeds with hard seed coats to improve water uptake and initiate germination. Seeds were sown. The seedling vigor index was determined using the formula by Abdul-Baki and Anderson (2024). SVI = Seedling Length (cm) × Emergence (%). The emerged seedlings is as shown in Plate A and B. Three variables were measured to assess the effects of nitrogen and phosphorus treatments on *Eucalyptus camaldulensis* seedling emergence: seedling emergence percentage, emergence rate, and seedling vigor. These metrics were selected to provide a comprehensive evaluation of germination success and early growth performance.

as triple superphosphate (TSP, 20% P), chosen for its solubility and effectiveness in acidic soils like those in Niger State (Sanginga and Swift, 2020). Seeds of *Eucalyptus camaldulensis* were sown in 1 kg polyethylene pots filled with a substrate of sandy Alfisol soil collected from the experimental site in Minna, Niger State. The soil was sieved through a 2 mm mesh to remove debris and ensure uniformity, then air-dried and thoroughly

mixed to homogenize nutrient distribution

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This study employed a 2×4 factorial design within a completely randomized design (CRD) to evaluate the effects of varying nitrogen (N) and phosphorus (P) levels on the seedling emergence of *Eucalyptus camaldulensis*. Four levels of nitrogen (0, 20, 40, and 60 kg/ha) and four levels of phosphorus (0, 13.2, 26.4, and 52.8 kg/ha) were tested, resulting in 16 treatment combinations, including a control with no added nutrients (0 kg/ha N and 0 kg/ha P) with three replications. Nitrogen was supplied as urea (46% N), a widely used N fertilizer in Nigeria due to its high N content and availability. Phosphorus was provided

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Given the 2×4 factorial design within a completely randomized design (CRD), it

was subjected to analysis of variance (ANOVA) using SAS as a statistical tools. The pairs of means were separated using Duncan Multiple Range Test (DRMT) at a 5% level of probability.

RESULTS

The soil used for the experiment was sandy loam with a slightly acidic soil reaction. The organic carbon and total nitrogen were both low. The available phosphorus and exchangeable bases were moderate in the soil in both years Table 1. The total annual rainfall of the area was 1875 mm and 1950

mm. The area has daily mean temperature of 37.5°C [Meteorological station FUT Minna (MET), 2024].

Table 2 shows that both nitrogen (N) and phosphorus (P) rates had highly significant effects on seedling emergence percentage in both the 2023 and 2024 seasons ($p < 0.05$). 40 and 60 kg N/ha both have the highest emergence, 65.50 % and 63.5 % in 2023; 66.0 % and 64.5 % in 2024 and are not significantly different from each other but are significantly higher than all other rates. 20 kg N/ha is significantly lower than the rest but significantly higher than the Zero-N treatment. 0 kg N/ha is significantly lower than all other nitrogen rates.

About 26.4 kg P/ha yields the highest emergence, 64.5 % in 2023, 64.75 % in 2024 and is significantly higher than the other P rates. 13.2 and 52.8 kg P/ha are not significantly different from each other but are significantly lower than 26.4 kg P and significantly higher than the Zero-P treatment. 0 kg P/ha has the lowest emergence and is significantly lower than all P-fertilized treatments. There was no significant interaction between nitrogen and phosphorus on seedling emergence in 2023

Table 3 shows that both nitrogen (N) and phosphorus (P) rates had highly significant

effects on the Emergence Speed Index (ESI) in both 2023 and 2024 ($p < 0.05$), and that the N×P interaction was also not significant on the emergence speed index in both years. Forty kilogram (40 kg) N/ha produced the highest ESI is significantly greater than all other N rates. 60 kg N/ha is not significantly different from the 40 kg rate but is higher than the lower rates. 20 kg N/ha is significantly lower than the rest but higher than the control. 0 kg N/ha is the lowest and significantly below all fertilized treatments. The highest ESI was recorded at 26.4 kg P/ha, 7.5 in 2023, 7.9 in 2024 and is significantly above the other P levels. 13.2 kg P/ha and 52.8 kg P/ha are not significantly different from each other but are below the 26.4 kg rate and above the control. 0 kg P/ha is the lowest, and significantly lower than any P-applied treatment. Table 4 demonstrates that both nitrogen and phosphorus rates had highly significant effects on seedling shoot height in 2023 and 2024 ($p < 0.05$). 40 kg N produced the tallest seedlings, 7.0 cm in 2023 and 7.5 cm in 2024, and it is significantly greater than all other N rates. 60 kg N gave 6.5 cm (2023) and 7.0 cm (2024) and is not significantly different from the 20 kg rate but is lower than 40 kg and higher than the control. 20 kg N yielded 6.0 cm/6.5 cm, significantly taller than the control but shorter than the 40 kg rate. 0 kg N produced the shortest shoots and is significantly lower than all other treatments. The highest shoot height was achieved at 26.4 kg P, which is significantly above all other P levels. 13.2 kg P and 52.8 kg P are both not significantly different from each other, but are below the 26.4 kg rate and above the zero-P control. 0 kg P is the lowest and significantly inferior to any P-applied treatment.

Table 1: Physical and Chemical Properties of Soil at the Experimental Site During 2023 and 2024 Seasons

Parameters	Values	
	2_0_2_3	2_0_2_4
Particle size analysis (g kg ⁻¹)		
Sand	752	753
Silt	111	109
Clay	137	138
TexturalClassification	Sandyloam	Sandyloam
pH(0.01M CaCl ₂)	6.95	7.41
TotalN(%)	0.31	0.33
OrganicCarbon(gkg ⁻¹)	0.39	0.4
AvailableP(mgkg ⁻¹)	8	7.7
Exchangeable Cations (mol.kg ⁻¹)		
K	0.8	0.83
Mg	2.9	2.9
Ca	4.1	4.09
Na	0.41	0.44
CEC	278	282

Source:DepartmentofSoilandLandManagement,FederalUniversityofTechnologyMinna.

Table 2: Effect of Nitrogen and Phosphorus on the Mean Seedling Emergence Percentage (%) in 2023 and 2024 Seasons

Treatments	Mean Emergence Percentage (%)	
	2023	2024
N Level (kg/ha) 0		
20	52.5 ^c	53.0 ^c
40	60.5 ^b	61.0 ^b
60 SE±	65.5 ^a	66.0 ^a
P Level (kg/ha)	63.5 ^a	64.5 ^a
0	2.0	2.0
13.2		
26.4	55.75 ^c	56.25 ^c
52.8	60.00 ^b	61.00 ^b
SE±	64.50 ^a	64.75 ^a
InteractionN×P	61.75 ^b	62.0 ^b
	2.0	2.0
	NS	NS

Means followed by the same letter are not significantly different (p < 0.05).



Plate A: Emerged seedling in 2023 at Forest Plantation site, FUT, Minna



Plate B: Emerged seedling emergence in 2024 at Forest Plantation site, FUT, Minna

Table 3: Effect of Nitrogen and Phosphorus on Emergence Speed Index (ESI)

Treatments	N	Mean ESI	
		2023	2024
Level (kg/ha)	0		
20		6.0 ^c	6.5 ^c
40		7.0 ^b	7.5 ^b
60		8.0 ^a	8.5 ^a
SE±		7.5 ^{ab}	8.0 ^{ab}
P Level (kg/ha)	0.5		
0			
13.2		6.5 ^c	7.0 ^c
26.4		7.0 ^b	7.4 ^b
52.8		7.5 ^a	7.9 ^a
SE±		7.2 ^b	7.7 ^b
InteractionN×P	0.5		
	NS		NS

Means followed by the same letter are not significantly different ($p < 0.05$).

Table 4: Effect of Nitrogen and Phosphorus levels on Seedling Shoot Height

Treatments	Mean Shoot Height (cm)	
	2023	2024
NLevel (kg/ha)		
0	5.0 ^c	5.5 ^c
20 40 60 SE±	6.0 ^b	6.5 ^b
	7.0 ^a	7.5 ^a
P Level (kg/ha)		
0	6.5 ^{bc}	7.0 ^{bc}
13.2	0.3	0.3
26.4		
52.8	5.5 ^c	5.9 ^c
SE±	6.0 ^b	6.5 ^b
Interaction N× P	6.5 ^a	7.0 ^a
	6.2 ^b	6.5 ^b
	0.3	0.3
	NS	NS

Means followedby thesame letterarenot significantly different (p < 0.05).

DISCUSSIONNP/ha produced the tallest shoots, The results demonstrate that both N and P significantly outperforming other P levels, significantly influenced seedling while 13.2 and 52.8 kg P/ha were similar emergence percentages in both seasons, but superior to the control.). For Eucalyptus with p < 0.05. These findings align with seedlings, adequate N promotes rapid shoot prior research demonstrating the critical elongation and leaf expansion, critical for role of N and P in early seedling establishing a functional canopy were development. For instance, Smith *et al.* obtained when N application was (2018) reported that moderate N increased to 40 kg N/ha and P at 26.4 kg applications (30 – 50 kg/ha) significantly P/ha which agreed to the studies of Gracia enhanced fruit tree seedling emergence by *et al.*, (2021) on seedling emergence in improving metabolic processes and cell *Eucalyptus*. Studies on *Eucalyptus grandis* division, consistent with the peak demonstrate that N fertilization increases performance at 40 kg N/ha in this study.leaf area and biomass accumulation within The ESI results reinforce the importance of weeks of emergence, enhancing early vigor N and P in accelerating seedling (Graciano *et al.*, 2022). These results emergence, which is critical for highlight the importance of N and P in establishing uniform crop stands. The peak promoting shoot growth, likely due to their ESI at 40 kg N/ha aligns with findings by roles in protein synthesis and energy Kumar *et al.* (2020), who reported that transfer, respectively. The peak at 40 kg moderate N rates (35 - 45 kg/ha) enhanced N/ha is consistent with findings by Wang *et* ESI in barley by promoting rapid cell *al.* (2018), who reported that N rates of 30 - elongation and metabolic activity.50 kg/ha maximized shoot height in rice by The tallest seedlings were observed at 40 kg enhancing cell division and elongation. N/ha, significantly taller than other N rates. Also, in Eucalyptus seedlings, P The 60 kg N/ha treatment was similar to 20 availability enhances root system kg N but inferior to 40 kg N. For P, 26.4 kg expansion, improving water and nutrient

acquisition a crucial adaptation in sandy, drought-prone soils (Tariq *et al.*, 2019). Research on *Eucalyptus camaldulensis* shows that P supplementation accelerates root-shoot ratios and seedling vigor, enabling plants to overcome soil physical barriers (Tariq *et al.*, 2019).

CONCLUSION

This study which determined the effects of nitrogen (N) and phosphorus (P) fertilization on seedling emergence percentage, emergence speed index (ESI), and seedling shoot height of eucalyptus seeds across two seasons (2023 and 2024), showed that both N and P had highly significant effects ($p < 0.05$) on these parameters, underscoring their critical roles

in early seedling development. Farmers should apply 40 kg N/ha and 26.4 kg P/ha to achieve maximum seedling emergence, emergence speed, and shoot height. These rates consistently outperformed other treatments and represent an efficient use of fertilizers, balancing cost and agronomic benefits. Higher rates, such as 60 kg N/ha or 52.8 kg P/ha, did not significantly improve outcomes and may lead to nutrient saturation, toxicity, or imbalance. Farmers should avoid over-fertilization to prevent diminishing returns and potential environmental impacts, such as nutrient runoff.

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