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N and P Nutrition of *Gmelina arborea* Roxb. Seedlings on Latosolic Soil. 1: Effects of N and P Fertilizers and their Combinations on Growth and Physical Properties of *Gmelina arborea*

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ABSTRAK

Kesan baja N dan P dan kombinasi masing-masing dengan dos berubah ke atas pertumbuhan dan sifat fizikal anak benih Gmelina arborea *Roxb. pada tanah latosolik telah diselidiki. Empat paras N dan P(0.0, 9.5, 19.0 dan 28.5g/pokok masing-masing bersepadanan dengan paras 0,1,2 dan 3) digunakan dalam semua kombinasi yang mungkin. N dibekalkan sebagai kalsium ammonium nitrat dan P dibekalkan sebagai superfosfat. Paras sifar bagi N dan P(N0P0) digunakan sebagai kawalan N dan kombinasinya dengan P membantu meningkatkan graviti tentu kayu, pertumbuhan tinggi pokok, pertumbuhan jejarian (root collar diameter) dan pembentukan jisim kering. Kombinasi-kombinasi N dan NP juga berkesan ke atas pertumbuhan atas tanah (iaitu nisbah akar-tunas rendah) berbanding dengan P sahaja dan kawalan. Walau bagaimanapun nisbah luas daun semakin menurun bagi semua kombinasi nutrien berbanding dengan kawalan. Kombinasi nutrien N dan P dengan nisbah 3:1 (N3P1) adalah disyorkan untuk pertumbuhan anak benih* G. arborea *pada tanah latosolik di tapak semaian atau pada peringkat awal di ladang.*

ABSTRACT

The effects of various doses of N and P fertilizers and their combinations on the growth and physical properties of Gmelina arborea *Roxb. seedlings on latosolic soil were investigated. Four levels of N and P (0.0, 9.5, 19.0 and 28.5 g/plant corresponding to 0,1,2 and 3 levels, respectively) were applied in all possible combinations. N was supplied as calcium ammonium nitrate and P as superphosphate. Zero levels of N and P (N0P0) were incorporated as the control. N and its combinations with P contributed significantly to improved wood specific gravity, plant height growth, radial growth (root collar diameter), and dry matter production. N and NP combinations were also the most effective in above-ground production (i.e. low root-shoot ratio) compared to P alone and the control. Leaf area ratio (LAR), however, was reduced by most of the nutrient combinations compared with the control. N1P3 produced the best wood specific gravity, N1P2 the most height growth, N3P1 the most radial growth and dry matter production, N3P2 the highest LAR, while the lowest root-shoot ratio or highest shoot production was obtained with N2P0 and N3P1 nutrient combinations. Nutrient combinations involving N and P in the ratio of 3:1 (N3P1) are recommended for the growth of* G. arborea *seedlings on latosolic soil at the nursery or early establishment stage in the field.*

INTRODUCTION

The roles of N and P in plant growth and development have been widely studied. N is important in both protein and carbohydrate synthesis (Novoa and Loomis 1978; Hall *et al.* 1972; Metivier and Dale 1977), whereas P is involved in the synthesis of phospholipids, various nucleotides and co-enzymes (Goodwin and Mercer 1972).

Few reports are available on the growth response of *G.arborea* seedlings to the application of N and P fertilizers. In Malaysia Zwierinck (1983) reported that a treatment involving 2:2 (0.6:2.6g/pot) ratio of N to P increased plant growth tremendously. In similar studies with *Pinus caribaea* var. *hondurensis,* Srivastava and Zainorin (1979) and Manikam and Srivastava (1980) showed that

P is the most important single nutrient element required for growth. However, Ogbonnaya (1992) reported that fertilization of *G.arborea* with N and P did not improve the histo-chemical properties (relevant to pulp and paper production) of *G. arborea* seedlings on latosolic soil in Nigeria.

Gmelina arborea (Verbenaceae) is an important timber crop for plywood, veneers and matchwood. Its large-scale production to feed the paper mills in the tropics has been encouraged (Anon 1980) because it has good pulping qualities. It is envisaged that the establishment of *Gmelina* on a commercial scale would reduce imports of paper and paper products, and generate socio-economic growth by improving employment opportunities (Momo 1986).

As *Gmelina arborea* has a relatively high growth rate, fertilization is expected to further improve the growth of this species. The main objective of the study, therefore, was to determine the response of *G.arborea* to different levels and combinations of N and P fertilizers on latosolic soil. Latosol is a major marginal soil in the tropics, available for large-scale tree plantations because of its low demand for agriculture.

TABLE 1
Physical and chemical properties of the experimental soil (latosolic soil)

Properties	Latosolic Soil
Physical Properties	
Sand (%)	64.50
Silt (%)	3.30
Clay (%)	32.30
Textural class	clay-loam
Chemical Properties	
pH (1:1H_2O)	4.40
pH (1:1 KC1)	3.53
Organic matter (%)	1.42
Total N (%)	0.03
Avail. P (ppm)	2.11
Exch. Cations (meq/100 g soil)	
K	0.74
Na	1.77
Ca	0.59
Mg	6.16
Effective CEC (meq/100g soil)	4.17

MATERIALS AND METHODS

Potting Medium and Seedlings

Latosolic soil was used as the growth medium. The soil was sun-dried for a week and undecomposed plant materials were removed. The soil was potted into 12.5-litre plastic buckets with drainage holes at the bottom and adequately watered. Two-week-old seedlings showing uniform height growth were transplanted into the pots, one seedling per pot.

Treatments

Four levels (0.0, 9.5, 19.0 and 28.5 g/plant corresponding to 0, 1, 2 and 3 levels respectively) of N and P were applied in all possible combinations. The complete dose for each treatment was given at one instance. The levels were chosen to present the presumed optimum range for this species after a preliminary trial on the soil type. N was applied as calcium ammonium nitrate ($Ca(NH_4)_2NO_3$) and P as superphosphate ($Ca(H_2PO_4)H_2O$). The nutrients were applied in granular form in 5 cm deep trenches made around the seedlings and covered thinly with soil. The plants were grown for a period of 20 weeks. The physical and chemical properties of the soil are shown in Table 1.

Measurement of Assessment Parameters
Physical Properties - Specific Gravity of Wood

Specific gravity was used as a measure of the physical strength of the wood. This was measured as the ratio of the oven-dry weight to its original green volume. The dry matter of the sample was obtained by drying at 105°C to a constant weight while the green volume was determined under water (Akachukwu 1976).

Growth Measurements

Five growth parameters, namely total height growth, root collar diameter growth, dry matter production, leaf area ratio and root-shoot ratio were measured at the end of the 20-week experimental period.

Total height growth was measured with the aid of a metre rule from the base of the stem at the soil level to the terminal bud of the main stem. Root collar diameter was measured at the root collar with a micrometer screw gauge to the nearest 0.01 mm. Dry matter production was obtained by carefully uprooting the seedlings from the pot. The roots were thoroughly washed and each plant separated into shoot and roots. The plant parts were oven-dried at 85°C until a constant weight was attained. The dry weight of each component was determined to the nearest 0.01 g with a top-loading meter balance. The leaf area ratio (LAR) was obtained as the ratio of total leaf area to whole plant dry weight. Leaf area was measured with leaf area meter. Root-shoot ratio was obtained as the ratio of the dry weight of root to the dry weight of the shoot.

Experimental Design and Statistical Procedure

The experiment incorporated a 4 x 4 factorial design based on randomized blocks with each treatment replicated five times. The basic factors were N and P while N x P was the interaction. The pots were laid out (1m apart) on a grassy field at the University of Port Harcourt Botanical Garden. A total of 80 pots, including the control(N0P0) were used for the 16 treatment combinations.

The parameters measured were subjected to analysis of variance and a least significant difference (LSD) test was performed on the treatments to determine if means were significantly different from each other. 'CRISP' statistical package was used in carrying out the data analysis, using IITA computing system.

Holistic Assessment of Measured Parameters

The results obtained were subjected to holistic analysis. To achieve this, the treatment effects of each parameter measured were scored according to their relative performances. The scores ranged from one for the worst treatment effect to sixteen (corresponding to the number of treatments) for the best treatment effect. The mean scores for each treatment were obtained, on the basis of which comparisons were made and conclusions drawn.

RESULTS

Physical Properties - Specific Gravity of Wood

Analysis of variance indicated significant (P=0.05) variations in wood specific gravity due to the applications of N, P and their combinations. Application of N alone, except N3P0, significantly enhanced specific gravity with reference to the control value (0.55 ± 0.39). While P alone did not affect specific gravity of wood, its combinations significantly increased the values, with the exception of N3P1 which was homogeneous with the control. The values obtained varied from 0.553 ± 0.030 with N0P2 to 0.682 ± 0.035 with N1P3, and the LSD (P=0.05) between the means was obtained as 0.066 (Table 2).

Growth Attributes

Height growth: The variations in plant height due to N, P and their combinations were significant (P=0.05). All the treatments significantly enhanced plant height growth compared to the control. The values recorded ranged from 19.84 ± 2.56 cm (N0P0) to 52.66 ± 4.13 cm (N2P0), and the LSD (P=0.05) among the means was 5.695 cm (Table 1).

Root-collar diameter (radial growth): Analysis of variance showed significant variations in collar diameter growth as a result of the nutrient elements and their interaction at P=0.01. With the exception of N0P1, N1P1 and N3P2, all the treatments significantly improved radial growth when compared with the control. The values recorded varied from 9.21 ± 0.48 mm (N0P0) to 15.92 ± 3.41 mm (N3P1), and the LSD (P=0.05) between the means was obtained as 2.702 mm (Table 1).

Dry matter production: The nutrient elements and their interaction brought about significant (P=0.05) variations on the dry matter production of *Gmelina arborea* seedlings on latosolic soil. The values recorded ranged from 8.68 ± 1.71 g with N0P0 (control) to 37.75 ± 3.52 g for N3P1 and the LSD (P=0.05) among the means was 4.75 g. Whereas P alone did not affect dry matter production with respect to the control, its combinations with N significantly enhanced dry matter growth (Table 2).

Leaf area ratio (LAR): Application of N did not bring about any significant variation in LAR, while P alone and its interaction with N showed significant differences (P=0.05). N1P3 and N3P0 did not affect LAR, N3P1 and N3P2 significantly (P=0.05) increased it, while the rest of the treatments significantly reduced it compared to the control value (40.82 ± 4.61). The values obtained ranged from 20.71 ± 3.39 (N0P1) to 49.51 ± 4.21 (N3P2). The LSD (P=0.05) between the means was 6.572 (Table 2).

Root-shoot ratio (RSR): Analysis of variance did not show any significant differences due to the application of various levels of N. Variations as a result of P and its interactions with N were, however, significant at P=0.01. Application of P alone did not affect RSR compared to the control, whereas the rest of the treatments significantly reduced it. The value obtained with the control was 1.36 ± 0.28, those for P alone ranged from 1.27 ± 0.04 to 1.47 ± 0.38, and those for N and its combination with P varied from 0.64 ± 0.12 to 0.84 ± 0.15. The LSD (P=0.05) between

TABLE 2
Effects of N and P fertilization on wood specific gravity, height growth and collar diameter growth of *G. arborea* seedlings on latosolic soil.

Nutrient Combination	Assessment Parameters		
	Specific gravity of wood	Height growth (cm)	Collar diameter growth (mm)
N0P0	0.555 ± 0.039	19.84 ± 2.56	9.21 ± 0.48
P1	0.553 ± 0.030	35.24 ± 4.70	11.89 ± 0.85
P2	0.562 ± 0.021	30.03 ± 2.88	12.60 ± 1.92
P3	0.570 ± 0.031	28.25 ± 2.79	13.48 ± 1.82
N1P0	0.639 ± 0.024	39.30 ± 5.06	15.29 ± 3.18
P1	0.614 ± 0.043	40.68 ± 5.10	11.91 ± 2.06
P2	0.650 ± 0.044	53.44 ± 7.31	14.25 ± 3.61
P3	0.682 ± 0.035	44.00 ± 5.43	13.73 ± 3.05
N2P0	0.619 ± 0.049	52.66 ± 4.13	13.88 ± 2.50
P1	0.621 ± 0.065	46.98 ± 5.09	13.82 ± 2.13
P2	0.663 ± 0.074	43.20 ± 5.75	13.06 ± 2.49
P3	0.589 ± 0.011	48.02 ± 5.81	14.64 ± 2.74
N3P0	0.606 ± 0.066	45.42 ± 3.71	13.50 ± 3.55
P1	0.579 ± 0.019	50.43 ± 4.07	15.92 ± 3.41
P2	0.659 ± 0.011	39.96 ± 5.87	10.98 ± 0.45
P3	0.613 ± 0.032	41.06 ± 4.20	13.08 ± 3.00
LSD (P=0.05)	0.066	5.695	2.702

the treatment means was obtained as 0.264 (Table 2).

Holistic Assessment

Table 3 shows the holistic assessment of the effects of N and P fertilization on the growth and physical properties of *Gmelina arborea* seedlings raised on latosolic soil. The highest mean score was recorded with N3P1 (13.50) and the lowest (2.50) with N0P1. Generally, very low values were obtained when P was applied alone, and these values were not significantly different from the control value (3.67). The LSD (P=0.05) between the mean scores was 3.38.

DISCUSSION

Physical Properties

The results of the study showed that N, both alone and in combinations with P, is a very important nutrient in improving specific gravity of *G. arborea* wood on latosolic soil, while P when applied alone is ineffective. Specific gravity of wood is directly related to its strength properties, pulp yield and growth rate (Sanwo 1984). Wilde (1958) reported that low specific gravity of wood may be caused by starvation of seedlings leading to an underdevelopment of the pith or it could be a consequence of excessive application of fertilizers which leads to the thinning of cell walls.

Growth

The study showed that N and its combination with P contributed significantly to height growth, radial growth (root collar diameter) and dry matter production. LAR was significantly reduced by most of the treatments. N3P1 and N3P2, however, significantly enhanced it compared to the control. N and its combinations were the most effective in above-ground (shoot) production (i.e. low root ratio), while P alone and the control were responsible for high root production (i.e. high root-shoot ration).

The improved growth when N was applied alone or in combination with P would not be unusual because of the role of this mineral element in protein and nucleic acid synthesis which are the core of life processes (Novoa and Loomis 1978). Nitrogen also affects photosynthetic activity of plants through its effects on chloroplast structure and composition (Hall *et al.* 1972).

TABLE 3
Effects of N and P fertilization on dry matter production, leaf area ration and root-shoot ratio of *G. arborea* seedlings on latosolic soil

Nutrient Combinations	Growth Parameters		
	Dry matter production (g)	Leaf area ratio	Root-shoot ratio
N0P0	8.68 ± 1.71	40.82 ± 4.61	1.36 ± 0.28
P1	13.06 ± 2.08	20.71 ± 3.39	1.43 ± 0.48
P2	12.27 ± 3.80	24.86 ± 5.17	1.47 ± 0.38
P3	12.67 ± 3.02	23.05 ± 2.97	1.27 ± 0.04
N1P0	24.92 ± 2.24	20.86 ± 1.21	0.80 ± 0.18
P1	20.79 ± 1.91	32.63 ± 6.53	0.72 ± 0.15
P2	35.68 ± 2.76	30.42 ± 1.25	0.76 ± 0.18
P3	27.57 ± 3.37	38.85 ± 5.04	0.73 ± 0.04
N2P0	31.49 ± 6.01	32.76 ± 3.33	0.64 ± 0.12
P1	27.00 ± 2.66	33.36 ± 5.75	0.69 ± 0.12
P2	30.62 ± 3.76	32.36 ± 5.46	0.84 ± 0.15
P3	35.07 ± 4.95	31.51 ± 6.04	0.72 ± 0.19
N3P0	31.75 ± 3.52	36.70 ± 5.98	0.76 ± 0.11
P1	37.47 ± 3.85	47.01 ± 4.40	0.64 ± 0.07
P2	20.53 ± 3.52	49.51 ± 4.21	0.50 ± 0.03
P3	26.15 ± 3.29	30.61 ± 4.49	0.65 ± 0.08
LSD (P=0.05)	4.97	6.572	0.264

The high root-shoot ratio recorded with P fertilizer meant that the seedlings were making more root growth than shoot growth. The long-held view that P promotes the growth of roots at the expense of shoot growth (Black 1968; Tisdale and Nelson 1975) also applies to *Gmelina arborea* seedlings on latosolic soil. Black (1968) explained that translocation of carbohydrate to the roots is limited as long as leaf growth continues and maximum leaf weight is attained earlier in P-fertilized plants than in P-deficient plants. Hence the plants make more root growth.

The low root-shoot ratio obtained when N was alone or with P could be explained by the theory of Brouwer (1962). He proposed that if N is not limiting, more N reaches the tops and causes the use of carbohydrates there for protein synthesis and growth. Consequently, less carbohydrate remains for translocation to the roots, and growth of roots then is limited relative to growth of tops.

CONCLUSION

Based on the results of the holistic assessment, it can be concluded that fertilization of *G. arborea* seedlings on latosolic soil with P alone does not improve growth. N is the most important single nutrient element, but its combination with P, however, is needed to enhance growth and physical properties. The nutrient combination involving N and P in the ratio of 3:1 (N3P1) is recommended for the growth of *G.arborea* seedlings at the nursery or at the early establishment stage in the field on latosolic soil in Nigeria.

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TABLE 4
Holistic assessment of the effects of N and P fertilizers and their combinations on growth and physical properties of *G. arborea* seedlings on latosolic soil

Parameters	Nutrient combinations and performance scores															
	N0P0	N0P1	N0P2	N0P3	N1P0	N1P1	N1P2	N1P3	N2P0	N2P1	N2P2	N2P3	N3P0	N3P1	N3P2	N3P3
Wood Specific Gravity	2	1	3	4	12	9	13	16	10	11	15	6	7	5	14	8
Plant Height	1	4	3	2	5	7	16	10	15	12	9	13	11	14	6	8
Collar Diameter	1	3	5	8	15	4	13	10	12	11	6	14	9	16	2	7
Dry Matter	1	4	2	3	7	6	15	10	12	9	11	14	13	16	5	8
Leaf Area Ratio	14	1	4	3	2	9	5	13	10	11	8	7	12	15	16	6
Root-Shoot Ratio	3	2	1	4	6	11	8	9	15	12	5	11	8	15	16	13
Mean Score*	3.67	2.50	3.0	4.0	7.83	7.67	11.6	11.33	12.33	11.0	9.0	10.83	10.0	13.5	9.83	8.33

* The least significant difference (LSD) between the mean scores was 3.38 at P=0.05

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