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

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ABSTRAK

Kesan-kesan paras baja N dan P dan kombinasinya yang berbeza terhadap sifat-sifat histokimia anak benih Gmelina arborea *Roxb. di atas tanah latosolik telah disiasat. Empat paras (0.00, 9.50, 19.00 dan 28.50g/pot) N dan P telah digunakan dalam semua kombinasi yang mungkin. N telah digunakan sebagai kalsium amonium nitrat* ($Ca(NH_4)_2\ N0_3$) *dan P sebagai superfosfat* ($Ca(H_2P0_4)H_20$)). *Sukatan N dan P yang sama (N2P2) menghasilkan gentian yang paling panjang. Penggunaan N tanpa P meningkatkan garispusat gentian dan saiz lumen gentian. Semua perlakuan tersebut telah menambah ketebalan dinding gentian yang begitu ketara dalam hubungan terhadap kawalan. Semua perlakuan tersebut telah mengurangkan pekali kelembutan dan meningkatkan nisbah runkel berbanding dengan kawalan. Penggunaan P semata-mata sahaja meningkatkan nisbah kekecilannya. N semata-mata sahaja tidak menghasilkan apa-apa perbezaan yang ketara. Nilai yang paling tinggi diperolehi dengan N2P2. Kadar pH kayu telah dikurangkan oleh semua perlakuan manakala larutan alkohol benzene, larutan alkali (1% NaOH), dan larutan air panas telah ditingkatkan oleh pembajaan. Penilaian menyeluruh (holistic) terhadap perlakuan-perlakuan tersebut menunjukkan bahawa pembajaan anak benih* G. arborea *diatas tanah latosolik dengan N dan P tidak memperbaiki/meningkatkan sifat-sifat histokimia yang berkaitan (relevant) dengan pengeluaran/penghasilan palpa dan kertas bila dibangdingkan dengan kawalan. Manakala prestasi kebanyakkan kombinasi treatment adalah homogen dengan kawalan, ada sedikit kombinasi yang menunjukkan prestasi yang ketara rendah daripada kawalan. Bagaimana kombinasi terbaik yang diperoleh ialah N0P3 dan N1P1.*

ABSTRACT

The effects of different levels of N and P fertilizers and their combinations on the histochemical properties of Gmelina arborea *Roxb. seedlings on latosolic soil were investigated. Four levels (0.00, 9.50, 19.00 and 28.50 g/pot) of N and P were applied in all possible combinations. N was applied as calcium ammonium nitrate* ($Ca(NH_4)_2NO_3$) *and P as superphosphate* ($Ca(H_2PO_4)\ H_2O$). *Equal doses of N and P (N2P2) produced the longest fibres. Application of N without P increased fibre diameter and fibre lumen size. All the treatments significantly increased fibre wall thickness in relation to the control. All the treatments reduced coefficient of suppleness and increased runkel ratio in comparison with the control. Application of P alone raised slenderness ratio. N alone did not produce any significant differences. The highest value was obtained with N2P2. Wood pH was reduced by all the treatments while alcohol-benzene solubles, alkali (1% NaOH) solubles, and hot water solubles were increased by fertilization. Holistic assessment of the treatments showed that fertilizing* G. arborea *seedlings on latosolic soil with N and P did not improve the histochemical properties relevant to pulp and paper production when compared with the control. While the performances of most of the treatment combinations were homogeneous with the control, a few combinations performed significantly lower than the control. The best treatment combinations were, however, obtained as N0P3 and N1P1.*

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INTRODUCTION

Gmelina arborea Roxb., commonly known as gmelina, belongs to the family Verbenaceae. *Gmelina* is exotic to Nigeria and was introduced as a firewood plant from tropical Asia (Gledhill 1972).

G. arborea is a valuable tree for timber and has featured prominently in plantation forestry in Nigeria. At the end of 1986 over 100,000 hectares of the species had been established on plantations (Adegbehin *et al.* 1988). The wood is one of the best utility timbers of the tropics, useful for hardboards, plywood core stock and veneers suitable for light construction, general carpentry, packaging and furniture fitments (Rassaque and Khan 1977).

G. arborea is also very valuable as a matchwood and in Nigeria it has been found to be superior to *Populus nigra,* a traditional timber for matchmaking (Anon. 1965). Most importantly, gmelina has good pulping characteristics and because of this its large-scale cultivation to supply the existing and proposed paper-mills in Nigeria and in other parts of the tropics has been encouraged (Anon. 1970).

The roles of N and P in plant growth and development have been widely studied. It is known that N is an essential constituent of proteins and nucleic acid which are the core of life processes (Novoa and Loomis 1978). P plays a key role in energy metabolism. It is incorporated into adenosine triphosphate (ATP), and it is part and parcel of the universal 'energy currency' of all living cells of whatever species (Epstein 1972).

It is necessary to see the importance of the nutrient elements not merely in terms of their individual and separate actions but in terms of their interactions with each other and with climate and environmental conditions (Hewitt 1963). The maximum effect of one particular element may not be as expected if the supply of other plant nutrients is not adequate. For this reason the ratio in which plant nutrients are applied in fertilizers is also important. This ratio depends on number of factors such as soil fertility status, in addition to plant species (Mengel and Kirkby 1979).

The main objective of the study, therefore, was to determine the response of *G. arborea* seedlings to different levels of N and P, and their combinations on latosolic soil. It was hoped that the result would be of practical value in recommending a balanced dose of N and P fertilizers to the potting medium and at the initial stages of growth in the field for this species which is by far one of the most promising fast-growing tree plants in the tropics.

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 (at 2-leaf stage) showing uniform height growth were transplanted into the pots. Each pot received only one seedling. The physical and chemical properties of the soil are shown in Table 1.

TABLE 1
Physical and chemical properties of the experimental 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/100g soil)	
K	0.74
Na	1.77
Ca	0.59
Mg	6.16
Effective CEC (meq/100g soil)	4.17

Treatments

Four levels (0.00, 9.50, 19.00 and 28.50 g/plant corresponding to 0, 1, 2 and 3 levels respectively) of N and P were applied in all possible combinations and permutations. The levels were chosen to present the presumed optimum range for this species after a preliminary trial on the soil type. The complete dose for each treatment was given at one instance, and both nutrients were applied at commercial grades. N was applied as calcium ammonium nitrate (CAN) ($Ca (NH_4)_2 NO_3$), P as superphosphate ($Ca(H_2PO_4).H_2O$). The nutrients were applied in granular form in trenches about 2 cm deep made around the seedlings, and covered with a thin layer of soil.

Measurement of Assessment Parameters
Histological Properties of Wood and the Derived Values

Stemwood samples for the fibre studies were obtained at the second internode from the base and immediately fixed with standard formalin-acetic acid-alcohol (FAA) preservative until needed for maceration. Small slivers or slices for maceration were obtained form the outer part of the stem (inside the bark) and thoroughly washed with distilled water to remove excess fixative. The slivers were placed into test-tubes containing 10 ml 60% nitric acid and boiled in a water bath for ten minutes. Macerated materials were washed several times with distilled water to remove the acid. Small quantities of the macerated material were placed on a clean slide, gently teased out and stained with 1:1 aqueous safranin-glycerol solution (Okoegwale and Gill 1988). The prepared slide was viewed with a calibrated microscope.

Fibre length (fl), fibre diameter (fd), fibre lumen diameter (fld) and fibre wall thickness (fwt) were measured in millimetres (mm) using an eyepiece micrometer. At × 100 and × 400 magnification one division of the eyepiece micrometer amounted to 0.01 mm and 0.0025 mm respectively. Thirty fibres were measured per sample and mean values calculated.

The following values were obtained from the fibre dimensional measurements:

a) slenderness ratio or relative fibre length: this was computed by using the formula (Rydholm 1967)

$$SR = \frac{\text{fibre length}}{\text{fibre diameter}}$$

b) Coefficient of suppleness (CS) or flexibility coefficient: this was obtained with the formula (Petri 1952)

$$CS = \frac{\text{fiber lumen diameter}}{\text{fibre diameter}} \times 100$$

c) Rukel ratio (RR) : this was caculated with the formula (Okereke 1962)

$$RR = \frac{2 \times \text{fibre wall thickness}}{\text{fibre lumen diameter}}$$

Chemical Properties
pH of Wood

Gmelina wood converted to 40 mesh sawdust was used for the determination of pH. 5g (oven-dry weight) was stirred in double distilled water (25g) and left to stand for 30 minutes with occasional stirring. The pH was measured with the glass electrode of a pH meter (Pye Unicam, PW9418 model) after standardization with buffer solutions. An average of 3 readings was obtained (Anon. 1980)

Ash Content of Wood

Loss-on-ignition method was used for the determination of percentage ash content. 1g of ground wood passed through 40 mesh, dried at 105°C in the oven, was ignited in a muffle furnace at 500°C for 3 hours. The ash content was calculated as follows (Allen *et al.* 1974):

$$\text{Ash content (\%)} = \frac{\text{ash weight (g)}}{\text{oven-dry weight of sample (g)}} \times 100$$

Alcohol-benzene Soluble Substances Content (%)

TAPPI, T6 m-59 method was used (Grant 1961). 1g of oven-dried (105°C for 24 hours) ground wood passing through 40 mesh was extracted in soxhlet apparatus with 100 ml of a mixture of 33 ml 95% alcohol and 67 ml benzene for 8 hours. At the end of the extraction the solvent system was distilled off and the residue dried at 105°C until a constant weight was obtained. The amount of residue was expressed as a percentage of the total plant material used for the extraction.

Alkali (1% NaOH) Soluble Substances Content (%)

The test was carried out by digesting 1 g of oven-dried sawdust (passing a 40 mesh screen) in 100 ml of 1% NaOH solution on a water bath at 100°C for exactly 1 hour with three stirring periods. After digestion the material was filtered and washed in a water and 10% acetic acid solution. The residue was dried at 85°C until a constant weight was obtained. The weight of the residue was expressed as a percentage of the total plant sample used for the extraction (Casey 1960).

Hot Water Soluble Substances Content (%)

The method employed was TAPPI, T1 m-59 (Grant 1961). 1g of oven-dried sawdust (passing a 40 mesh screen) was placed in a conical flask fitted with a reflux condenser. 100 ml of distilled water was added and the flax was then immersed in a boiling water-bath for 3 hours. After the boiling period the material was filtered and washed several times with hot water and dried at 85°C until a constant weight was obtained. The loss in weight expressed as a percentage of the oven-dried material was the matter soluble in water.

Experimental Design and Statistical Procedure

The experiment incorporated a 4^2 factorial design based on randomized blocks with each treatment replicated 5 times. The basic factors N and P were the main effects while N×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, was used for the 16 treatment combinations.

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

Holistic Assessment of Measured Parameters

The results obtained were subjected to holistic analysis in order to obtain a conclusive view. For each parameter measured the treatment effects including the control were scored according to their relative performances. The scores ranged from 1 for the worst treatment effect to 16 (corresponding to the total number of treatments) for the best treatment effect. The total score for each treatment was obtained, on the basis of which comparisons were made and conclusions drawn (Ogbonnaya 1990).

RESULTS

Fibre Dimensional Properties

There was very strong significant variation due to N, P and their interactions on fibre length (fl). The values obtained ranged from 0.56 ± 0.03mm (control) to 0.83 ± 0.00 mm (N2P2). The LSD (P = 0.05) between the means was obtained as 0.038 mm. Applications of P without N significantly enhanced fl when compared with the control, similarly N alone significantly improved fl at N2P0 and N3P0 while N1P0 did not. Combinations of N and P also increased significantly the fl with the exception of N3P3 (0.59 ± 0.03mm) combination (Table 2).

Analysis of variance showed that the different treatments of N, P and their interactions brought about significant (P = 0.01) variations on the fibre diameter (fd). The LSD (P = 0.05) among the means was recorded as 0.0022 mm (Table 2). In relation to the control all levels of P alone and N1P0 did not affect fd. Combinations of N and P gave erratic responses and the values ranged from 0.22 ± 00mm (N2P1) to 0.027 ± 0.001 mm (N1P2).

Significant variations (P = 0.01) on fibre lumen diameter (fld) as a result of the different treatments of N, P and their combinations were obtained. The three levels of N without P produced the same value (0.017 ± 0.001 mm) which was not significantly different from the control value (0.016 ± 0.002 mm). Application of P alone adversely affected fld. The values recorded for N and P combinations were highly variable and ranged from 0.014 ± 0.00 (N2P1) to 0.018 ± 0.001 mm (N3P1) (Table 2).

Variations due to the various applications of N, P and their interaction on fibre wall thickness (fwt) were also significant (P = 0.01). The LSD (P = 0.05) between the means was 0.4×10^{-3}mm (Table 2). All the values obtained with N, P and their combinations were significantly higher than the control. The values ranged from 2.97×10^{-3}mm (N0P0) to 4.72×10^{-3}mm (N1P2).

Derived Values from Fibre Dimensions

Coefficient of suppleness (CS) showed significant (P =0.01) variations due to N, P and their interactions. The LSD (P = 0.05) between the means was obtained as 3.7305. The control produced the highest CS and this was significantly higher than the rest of the treatments with the exception of N1P0, N1P3 and N3P0 (Table 3).

The variations in slenderness ratio (SR) due to N, P and their interactions were significant (P = 0.01), and the LSD (P = 0.05) between the means was 2.2114 (Table 3). Application of P alone raised SR with reference to the control, while N alone did not produce any significant differences. The values recorded with the combinations ranged from 22.48 ± 1.04 (N1P2) to 31.94 ± 0.87 (N2P2).

TABLE 2
Effects of N and P fertilizers and their combinations on fibre length, fibre diameter, fiber lumen diameter, and fibre wall thickness of wood of *Gmelina arborea* seedlings raised on latosolic soil.

Nutrient Combinations	Fibre dimensions			
	Fibre length (mm)	Fibre diameter (mm)	Fibre lumen diameter (mm)	Fibre wall thickness ($x10^{-3}$mm)
N0P0	0.56 ± 0.03	0.022 ± 0.001	0.016 ± 0.002	2.97 ± 0.35
P1	0.66 ± 0.02	0.023 ± 0.00	0.014 ± 0.00	3.90 ± 0.16
P2	0.64 ± 0.01	0.023 ± 0.001	0.015 ± 0.004	4.07 ± 0.30
P3	0.63 ± 0.02	0.022 ± 0.001	0.014 ± 0.00	4.16 ± 0.14
N1P0	0.58 ± 0.01	0.024 ± 0.001	0.017 ± 0.001	3.93 ± 0.19
P1	0.68 ± 0.07	0.023 ± 0.00	0.015 ± 0.00	3.93 ± 0.19
P2	0.61 ± 0.02	0.027 ± 0.001	0.017 ± 0.002	4.72 ± 0.22
P3	0.70 ± 0.02	0.026 ± 0.001	0.018 ± 0.001	4.24 ± 0.43
N2P0	0.60 ± 0.02	0.025 ± 0.001	0.170 ± 0.001	3.97 ± 0.12
P1	0.66 ± 0.01	0.022 ± 0.00	0.040 ± 0.00	4.29 ± 0.16
P2	0.83 ± 0.00	0.026 ± 0.001	0.016 ± 0.001	4.81 ± 0.27
P3	0.71 ± 0.001	0.024 ± 0.002	0.016 ± 0.002	4.22 ± 0.50
N3P0	0.61 ± 0.001	0.025 ± 0.001	0.017 ± 0.001	3.79 ± 0.11
P1	0.74 ± 0.02	0.024 ± 0.001	0.014 ± 0.001	4.05 ± 0.31
P2	0.72 ± 0.02	0.025 ± 0.001	0.015 ± 0.00	4.47 ± 0.26
P3	0.59 ± 0.03	0.024 ± 0.001	0.016 ± 0.001	4.10 ± 0.31
LSD (P=0.05)	0.038	0.0022	0.0014	0.400

The results on runkel ratio (RR) showed significant variation due to the different treatments of N, P and their interaction at P = 0.01. Application of P alone significantly (P = 0.05) increased RR as compared with the control. The lowest RR was obtained with the control (0.38 ± 0.05) and the highest (0.59 ± 0.07) with N2P2. The LSD (P = 0.05) among the means was obtained as 0.0923 (Table 3).

Chemical Properties

pH values did not show any significant variation due to P application. The variations due to N and N×P interaction were rather significant at P = 0.01, and the LSD (P = 0.05) between means was recorded as 0.847 (Table 4). Application of N at 2nd and 3rd levels significantly lowered wood pH, while the values obtained with the 1st level and all levels of P alone were homogeneous with the

TABLE 3
Effects of N and P fertilizers and their combinations on coefficient of suppleness, slenderness ratio and runkel ratio of *Gmelina arborea* seedlings raised on latosolic soil.

Nutrient Combinations	Derived fibre dimensional values		
	Coefficient of suppleness	Slenderness ratio	Runkel ratio
N0P0	71.41 ± 8.30	25.55 ± 2.90	0.38 ± 0.05
P1	60.20 ± 8.94	28.88 ± 0.67	0.57 ± 0.02
P2	64.41 ± 2.13	27.84 ± 1.02	0.58 ± 0.03
P3	63.14 ± 2.16	28.61 ± 1.8	0.55 ± 0.33
N1P0	68.83 ± 2.24	23.72 ± 0.89	0.47 ± 0.05
P1	64.94 ± 2.61	30.72 ± 1.84	0.53 ± 0.04
P2	63.06 ± 3.02	22.48 ± 1.04	0.55 ± 0.06
P3	68.27 ± 2.16	27.18 ± 0.99	0.48 ± 0.05
N2P0	66.94 ± 1.98	24.05 ± 0.99	0.48 ± 0.01
P1	62.18 ± 1.88	29.83 ± 1.02	0.62 ± 0.04
P2	63.03 ± 2.55	31.94 ± 0.87	0.59 ± 0.07
P3	66.18 ± 4.46	29.20 ± 2.01	0.53 ± 0.05
N3P0	69.17 ± 4.07	24.81 ± 1.02	0.45 ± 0.03
P1	59.07 ± 2.93	30.43 ± 1.27	0.56 ± 0.05
P2	58.78 ± 2.52	28.53 ± 1.53	0.61 ± 0.03
P3	65.78 ± 2.80	24.79 ± 1.78	0.52 ± 0.08
LSD (P=0.05)	3.7305	2.2114	0.0923

control. Combinations of N and P in all cases (except N3P2) significantly reduced the pH in comparison with the control, and the value ranged from 4.22 (N2P1) to 4.87 (N3P2).

The variations due to the effects of N and P applications on wood ash content were significant at $P = 0.01$ and $P = 0.05$ respectively. The interaction between them was not found significant. The LSD ($P = 0.05$) among the means was 0.67%. N when applied alone reduced significantly the ash content of gmelina wood in relation to the control. P alone was the most important nutrient element required by the plant to enhance ash content. The values obtained with N and P were homogeneous with the control (Table 4).

Application of N, P and their combination significantly raised alcohol-benzene soluble substances content (ABSS) with the exception of N1P2, N3P3, N1P1 and N2P2. The highest value (8.34%) was obtained with N3P3. Analysis of vari-

TABLE 4
Effect of N and P fertilizers and their combinations on pH, ash content, alcohol-benzene solubility, alkali (1% NaOH) solubility and hot water solubility of wood of *G. arborea* seedlings raised on latosolic soil

Nutrient Combinations	Chemical properties				
	Wood pH	Ash content of wood (%)	Alcohol-benzene solubility	Alkali (1NaOH) solubility	Hot water solubility
N0P0	5.53	2.00	2.45	16.80	8.63
P1	5.40	3.80	6.21	19.65	12.00
P2	5.36	3.60	4.40	19.10	11.10
P3	5.15	3.50	4.34	15.65	11.10
N1P0	4.95	1.00	6.19	20.07	11.72
P1	4.40	2.50	5.65	21.25	11.17
P2	4.40	2.40	3.70	49.35	10.22
P3	4.23	1.80	4.24	18.75	10.41
N2P0	4.40	1.10	7.45	21.35	13.47
P1	4.22	1.90	4.24	19.70	9.74
P2	4.45	1.80	4.09	19.25	9.90
P3	4.30	1.75	5.21	18.00	11.47
N3P0	4.10	1.30	6.49	21.80	11.50
P1	4.65	2.10	6.74	20.67	11.62
P2	4.87	2.40	7.17	21.20	12.38
P3	4.40	2.10	8.34	22.85	12.77
LSD (P=0.05)	0.847	0.672	1.835	2.187	2.082

ance showed significant variation due to N and P, and none for the interaction. The LSD (P = 0.05) between the means was recorded as 1.835% (Table 4).

Analysis of variance in alkali (1% NaOH) soluble substances content did not indicate any significant variation due to the various treatments of P and NxP interaction, while the variation due to N application was significant (P = 0.05). The LSD obtained among the means was 2.187%. Nitrogen therefore was the most important nutrient element responsible for increased ASS of gmelina wood on latosolic soil.

Variations of hot water soluble substances content (HWSS) due to N and P application were significant while those due to their interactions

TABLE 5
Holistic assessment of the effects of N and P fertilizers and their combinations on the histochemical 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
Fibre length	1	10	8	7	2	11	6	12	4	10	16	13	16	15	14	3
Fibre diameter	16	13	13	16	10	13	1	3	6	16	3	10	6	10	6	10
Fibre lumen diam.	11	4	7	4	15	7	15	16	15	4	11	11	15	4	7	11
Fibre wall thickness	16	14	9	7	12	12	2	5	11	4	1	6	15	10	3	8
Coeff. of suppleness	16	3	8	6	14	9	7	13	12	4	5	11	15	2	1	10
Slenderness ratio	6	9	8	11	2	15	1	7	3	13	16	12	5	14	10	4
Runkel ratio	16	5	4	8	14	10	8	13	13	1	3	10	15	6	2	11
pH of wood	16	15	14	13	12	8	8	3	8	2	9	4	1	10	11	8
Ash content of wood	8	16	15	14	1	13	12	6	2	7	6	4	3	10	12	10
Alcohol-benzene solubility	16	6	10	11	7	8	15	13	2	13	14	9	5	4	3	1
Alkali solubility	15	9	12	16	7	4	10	13	3	8	11	14	2	6	5	1
Hot water solubility	1	13	7	7	12	8	5	4	16	2	3	9	10	11	14	15
Mean score*	11.5	9.75	9.58	10.0	9.0	7.5	9.0	9.83	7.92	7.0	8.16	9.42	9.0	8.5	7.33	7.67

* The Least Significant Difference (LSD) between the means scores was obtained as 3.65 at P = 0.05

were not. All the treatments except N1P2, N1P3, N2P1 and N2P2 produced significantly higher HWSS than the control. The LSD (P = 0.05) between the means was 2.082% (Table 4).

Holistic Assessment

Holistic or overall assessment of the performances (Table 5) showed that all the treatments produced histochemical properties that were no better than the control. Least significant difference test showed that N1P2, N2P1, N3P2 and N3P3 were significantly (P = 0.05) worse than the control, while the rest of the treatments were homogeneous with the control. The best combinations, however, were N0P3 and N1P1.

DISCUSSION

Fibre Dimensions

The longest fibres in the study were obtained with NP nutrient combinations, and N2P2 gave the highest value (0.83 $\pm$ 0.00 mm), while shorter fibres were recorded when P and N were applied alone. Apparently both N and P are required for improved fibre length of gmelina on latosolic soil. The role of both elements in cell development is well known. N increases the rate and extent of protein synthesis required for cell division and elongation (Hewitt 1966) while P as a constituent of nucleus plays an important part in cell division and development (Epstein 1972).

N and NP combinations were responsible for the widest fibre and fibre lumen diameters while P produced the least values. Large fibre diameter, however, is undesirable in pulp and paper manufacture since it reduces slenderness ratio (Rydholm 1967). Fibre wall thickness was significantly increased by all the treatments in relation to the control. This result is equally undesirable in pulp and paper production since it tends to increase the runkel ratio and thereby reduces paper strength (Okereke 1962). The increased fibre dimensions when N was supplied alone or with P can be explained on the basis that carbohydrates are utilized to form more protoplasm when N is in adequate supply. Cells produced under such conditions tend to be large (Letham 1961).

The Derived Values from Fibre Dimensions

The highest CS was obtained with the control (N0P0) which was homogeneous with the value recorded with N1P0, N1P3 and N3P3. All the values obtained were, however, greater than 50. According to the guidelines by Petri (1952), Okereke (1962) and Rydholm (1967) CS > 50 but preferably greater than 60 is required of fibres for paper-making, because paper strength tends to improve with increasing CS. Such fibres with high

CS are flexible, collapse easily and produce good surface contact and fibre-to-fibre bonding. With the results obtained in this study the CS would generally produce good quality paper.

SR was depressed when N was applied alone or at N1P2 and N3P3 combinations. The rest of the treatments increased the ratio in comparison with the control, and these treatments are therefore expected to produce papers with better tearing resistance, since the higher the SR, the stronger the resistance to tearing (Rydholm 1967).

With reference to the control, all the treatments (except N1P0 and N0P3) significantly enhanced RR. All the values obtained, however, were < 1. Going by the recommendations of Okereke (1962) and Rydholm (1967), the fibres produced by all the treatments would make good paper, as the RRs were less than unity in each case. Since paper quality increases with decrease in RR, it is therefore expected that plants treated with N fertilizer alone would produce better quality paper.

Chemical Properties

The pH of sap of many plant species is in the range of about 5-5.5 which is slighty acidic (Mengel and Kirkby 1979). The result obtained showed that P alone did not affect wood pH while N and its combinations with P (except N3P2) significantly reduced wood pH in relation to the control. The increased pH with N and its combination with P can be explained on the basis of the fact that NO_3 when assimilated (reduced) by plant roots yields NO_3^- ion which is a very strong acidic radical. On the other hand phosphate fertilizers when reduced in acidic soil (like the latosolic soil, pH 4.4) yield HPO_4^{2-}, which is a weak acidic radical rather than the stronger $H_2PO_4^-$ radical, and hence the higher pH recorded with P fertilizer. Acidity of wood plays some part in the pulp and paper industry in relation to corrosion of equipment and excessive consumption of alkaline cooking liquor in alkaline puling (Anon 1980).

Results of the study show that ash content of gmelina wood was significantly increased by P alone, significantly reduced by N alone and was not affected by NP combinations in relation to the control. Wood ashes contain 2-8% K_2O, P_2O_5 and a large amount of CaO (Wilde 1958). High ash content recorded with seedlings treated with P fertilizer can therefore be appreciated. The ash of wood is of interest as a measure of the total mineral content (Allen *et al.* 1974). Wood ash is also used as fertilizer and in glass and soap manufacture (Anon. 1974/75).

Fertilizer applications increased soluble substance content of gmelina wood in relation to the control. Alcohol-benzene soluble substances (gums, fats, waxes and resins) are mainly lipids or their derivatives. The roles of N and P in the synthesis of fatty compounds namely lipoproteins and phospholipids respectively are well known. Alcohol-benzene solubles are of great importance because high value adversely affects the pulping process and the quality of the resulting pulp (Grant 1961). The alkali soluble substances made up of pentosans, hexosans and lignin (Casey 1960) and the hot water soluble substances consisting of carbohydrates, sugar and salts (Grant 1961) are mainly carbohydrates or their derivatives. The increased concentrations of these compounds are inconsistent with the fact that supply of N to plants decreases carbohydrate content since they are used to form more protoplasm and cells (Letham 1961). Ulrich (1954), however, observed that the depressing effect of N on carbohydrate content may not be found with low or moderate application of N. High percentage alkali soluble substance predisposes the wood to decay and in the sulphite pulping process, yields are reduced and more alkali is consumed. Hot water soluble substances give no direct information on the pulp value, but do indicate the nature of certain constituents present in the wood.

CONCLUSION

Holistic assessment of the treatments showed that fertilizing *G. arborea* seedlings on latosolic soil with N and P did not improve the histochemical properties relevant to pulp and paper production when compared with the control. While the performance of most of the combinations was homogeneous with the control, a few performed significantly worse than the control. The best treatment combinations were, however, N0P3 and N1P1.

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