The
Nigeria Journal of Forestry

July & December 2009

Published by
The Forestry Association of Nigeria

Nig. Journal For: Vol. 39 (1 & 2) 2009

NIGERIA JOURNAL OF FORESTRY
VOL 39 NO 1& 2
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NUMBER ONE

NUMBER TWO

EARLY GROWTH AND DRY MATTER YIELD OF *GMELINA ARBOREA* (ROXB) ON BASEMENT COMPLEX AND FERRIC LUVISOL SOILS

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Falade, O.F. and Bada, S. O. (2009) Early growth and dry matter yield of *gmelina arborea* (roxb) on basement complex and ferric luvisol soils, Nigerian Journal of Forestry, Vol. 39 (1) 15 - 21

ABSTRACT

The study investigated the use efficiency of selected soil nutrient elements-N, P and K in the synthesis of organic matter by *Gmelina arborea* seedlings. *Gmelina arborea* (family: Verbarnacaea) seedlings were grown on basement complex and ferric luvisol soils for 3-months. Sixty polythene pots were filled with each soil type, which formed an experimental unit. Each experimental unit was replicated three times making a total of 360 *Gmelina arborea* seedlings. Eight seedlings were selected weekly for the first four weeks and four seedlings per week for the remaining six weeks in each experimental unit. Composite samples of soil media and sampled seedling were taken weekly and chemically analyzed for the determination of possible changes in nutrient concentrations. The dried leaves and shoot were combusted at 500^0c, for carbon content determination. Student t-test shows no significant difference in biomass carbon between basement complex and ferric luvisol soils (paired sampled t-test, 80.92 vs 80.35g/kg, respectively, $p<0.05$, $n=10$). Significant relationship exists between leaf area ratio (LAR) and leaf weight ratio (LWR) of seedlings grown on both soil types. Thus, P and N provide a much sensitive measure of the relative cost of dry matter production than potassium in these soils. The study highlights quantitative relationships that would allow silviculturists to estimate accurately the phosphorus and nitrogen-supplying power of basement complex and ferric luvisol soils.

Key Words: Seedlings, Leaf Weight Ratio, Forest Reserve, Biomass

INTRODUCTION

Trial planting of exotic tree species commenced as early as 1930's in some parts of northern Nigeria. *Gmelina arborea* (Roxb), of the family *Verbarnacaea*, is the most widely planted exotic tree species in Nigeria. It accounts for about 40% (130,000ha) of the total forest plantations in the country (FORMECU, 1997). The species is a native to the moist forests of India, Blangladeh, Sri Lanka, Burma and most of South-East Asia and Southern China. *Gmelina arborea* is believed to have been introduced into Nigeria from India, as early as 1900's; although the oldest plantation recorded was that of Olokemeji Forest Reserve, which was established in 1929 (Anon, 1965). Its site requirements are less demanding compared with those of *Tectona grandis*, which belong to the same botanical family (Adegbehin and Dauda, 2000). This study concerns *G. arborea*, which is becoming an increasingly important plantation species in Nigeria with at least 56,378ha in some states where it was established in plantations as at 1985 (FORMECU, 1997). Although the early growth comparison of *Gmelina arborea* and *Tectona grandis* have been studied (Iyamabo, 1990) and the mechanism is well known, but considerable work has not been done on the effect of basement complex and ferric luvisol soils on the early growth of the species. The capacity of a soil can only be fully exploited when land use decisions incorporate knowledge of soil properties.

MATERIALS AND METHODS

Location of the site

This study was carried out in the greenhouse of the Department of Forest Resources Management, University of Ibadan, Ibadan , Nigeria. The University is located on latitude7^026^1 and longitude 3^054^1 at 277m above sea-level. It is in the dry high forest zone (Adedokun, 2000). The climate is the West Africa monsoon type with dry and wet seasons. The mean annual rainfall is approximately 1259.57mm, with two rainfall peaks occurring in the months of June and September/October. Minimum and maximum annual relative humidities are 54.50% and 95.30%, respectively. Daily temperature of Ibadan fluctuates between a minimum of 19^{0}c at night and maximum of 31^{0}c during the day, with variation throughout the year (IITA weather station, 2004).

Methods of sampling

Seeds of *G. arborea* were extracted from freshly collected fruits and air-dried for two days. The seeds were sown into wooden germination trays containing humus soil and watered daily. Germination was first noticed 11 days after sowing and out of 4000 seeds sown 95% sprouted. At the end of the germination period, 360 uniform and vigorous seedlings were selected. At the site of soil collection, basement complex and ferric luvisol soils samples were taken to a depth of 15cm in a grid pattern at various spots in both Gambari Forest Reserve (basement complex soil) and University teak plantation (ferric luvisol soil). The University teak plantation is predominantly ferric luvisol (Moorman et al., 1973) while the parent rock of Gambari soil is crystalline and it is a part of pre-cambrian series shown as 'undifferentiated' basement complex on the geological map of Nigeria (Mackay, 1923). McGregor (1934) refers to it as a light sandy soil. Gambari forest reserve is in high forest zone. The natural vegetation at Gambari district could be described as mature disturbed forest most of which has been logged. The common weed on forest floor is *Chromolaena odoratum* with other climbers and liana, which severely suppress the young regeneration. Some parts of the forest reserve have been converted into plantations of *Tectona grandis*, *Gmelina arborea*, *Nauclea diderrichi*, *Triplochiton scleroxylon*, *Cedrela odorata* and some species of Eucalptus. At present, the two soils are covered with heterogeneous forest consisting of Teak and Gmelina and some species that growing naturally in the plantation. Samples of top-soil (0-15cm) per site were mixed thoroughly and composite samples taken for chemical analysis according to Gilbert (1997). Initial total nitrogen (N), available phosphorus (P), potassium (K), Cation Exchange Capacity (CEC) of the soils were measured using wet combustion method (Murphy and Riley, 1962). Basement complex and ferric luvisol soils were cleared of large stones and plant debris, sieved and kept under room temperature until the commencement of the experiment. A total of 360 polythene pots (dia=14cm, h=25cm) were used for this study. Sixty (60) polythene pots was each filled with 1.5kg basement complex soil while an equal number of polythene pots was filled with the same quantity of ferric luvisol. The soil in each polythene pot was brought to approximate field capacity with addition of tap water and then the seedlings were picked-out and transplanted into the polythene pots, at 2-leaf stage. Only seedling of uniform height and size were carefully selected and transplanted. Two weeks after transplanting, growth parameters were measure weekly for 10 weeks. Each soil-seedling sample represented an experimental unit and the whole set up was replicated three times.

Eight seedlings, representing the range of collar diameters, were selected weekly from each experimental unit for dry matter assessment and nutrient uptake calibration for the first four week; because of seedling size at that age, while only four seedlings were selected per week for the remaining weeks. For biomass assessment, the selected seedlings were carefully uprooted and their roots rinsed with water to remove soil particles. Seedling leaf areas were traced on graph paper before taking them to laboratory, were the seedlings were separated into the root, shoot and leaf components. The fresh weight of the different components was determined for each seedling using electronic metler balance (Metler P 3000). The different components were then oven dried at 60^{0}c until constant weight was attained and re-weighed using electronic metler balance (Metler P 163). The values obtained from seedling dry matter at weekly interval were used to compute the Relative Growth Rate (RGR) as suggested by Hunt (1988).

Soil Chemical Analysis

Soil nutrient concentrations were calibrated from soil samples collected weekly from each experimental unit. The soil were air-dried and sieve to <2.00 and <0.5mm prior to acid extraction in the laboratory. Soil available phosphorus was extracted by Mehlich-3 extraction solution and measured colourimetrically by molybdate blue method (Golterman et al., 1978). Aliquots of these extracts were used to measure soil potassium concentration by flame photometry (Jackson, 1973). Total nitrogen was determined by micro-Kjedahl and steam distillation method. Soil organic carbon was determined by Walkley-Black wet oxidation method and convert to soil organic matter by multiplying by constant (1.72). Particle size analysis was determined by hydrometer method. Sub-sample (1.5g) was dry-ashed at 500^{0}c for 8hours after which the ash weight was subtracted from initial weight to derive the weight of carbon lost. Soil pH was measured with a pH meter and glass plus reference electrode using 1:1 suspension in water for mineral soil. Extractable Ca, Mg, and K were determined by extraction with glacial acid of ammonium acetate solution at pH 7.0 and atomic absoption spectrophotometry (Spectronic (R) 20 Genesis). Exchangeable Al was determined by the Barnihisel and Bertsch (1982) method.

Data analysis

The data from tests of the effects of soil types (basement complex *vs* ferric luvisol), dry matter assessment of each species were subjected to t-test (at $p<0.05$). Correlation analysis was used to test for significant association among the physiological- characteristics, using STATISTICAL 5.1

RESULTS AND DISCUSSION

Table 1: Initial chemical properties of basement complex and ferric luvisol soils

Parameters	Unit	Basement complex	Ferric luvisol
Org.C	mgkg^{-1}	2.166	2.238
Total N	mgkg^{-1}	0.196	0.273
Available P	mgkg^{-1}	6.045	30.840
Available K	mgkg^{-1}	1.223	1.438
Exchangeable Ca	cmol kg^{-1}	5.468	6.023
Exchangeable Mg	cmol kg^{-1}	5.705	6.023
Sodium ion (Na)	cmol kg^{-1}	0.824	0.963
CEC	meq/100g	1.1181	1.1389
pH		6.95±0.03	6.20±0.08
Exchangeable Al	mgkg^{-1}	0.00	0.00
H$^+$		0.15	0.10
Fe	mgkg^{-1}	161.12	164.71
Mn	mgkg^{-1}	243.72	261.14
Cu	mgkg^{-1}	19.10	21.72
Zn	mgkg^{-1}	79.42	98.83
Fine sand	gkg^{-1}	666.00±3.00	746.00±2.00
Silt	gkg^{-1}	274.00±2.00	174.00±2.00
Clay	gkg^{-1}	60.00±2.00	80.00±2.00

Cation exchange capacity (CEC) of basement complex was 1.138meq/100g while that of ferric luvisol was 1.118meq/100g. For soil properties topsoil 0-15cm of basement complex compose of 80.0g/kg of clay, 174.0g/kg of silt and 764.0g/kg of fine sand while ferric luvisol compose of 60.0g/kg of clay, 274.0g/kg of silt, and 666.0g/kg of fine sand (Hydrometer method). The soil texture classes of basement complex and ferric luvisol soils are sandy loam and loamy sand respectively. Organic matter of basement complex and ferric luvisol soils was 3.86% and 3.74% at 0-15cm depth respectively. Furthermore, there is evidence suggesting that clay particles promote accumulation of organic materials (Bohn et al., 1985; Stevenson, 1994). The low mean CEC could be attributed to low organic matter (OM) contents of the sites. According to Asadu et al. (1997), organic matter of soils of the sub-saharan African alone could account for about 60% of the mean ECEC of soils and that silt also contributed significantly to ECEC. Nitrogen is a growth-limiting nutrient in most luvisols (Robertson and McGill, 1983). Gray luvisols have a thin A horizon which is slightly acidic (pH 6.0-6.5) and have low oganic carbon content (10-20g/kg) and nutrient-supplying capacity (Broersma et al., 1996).

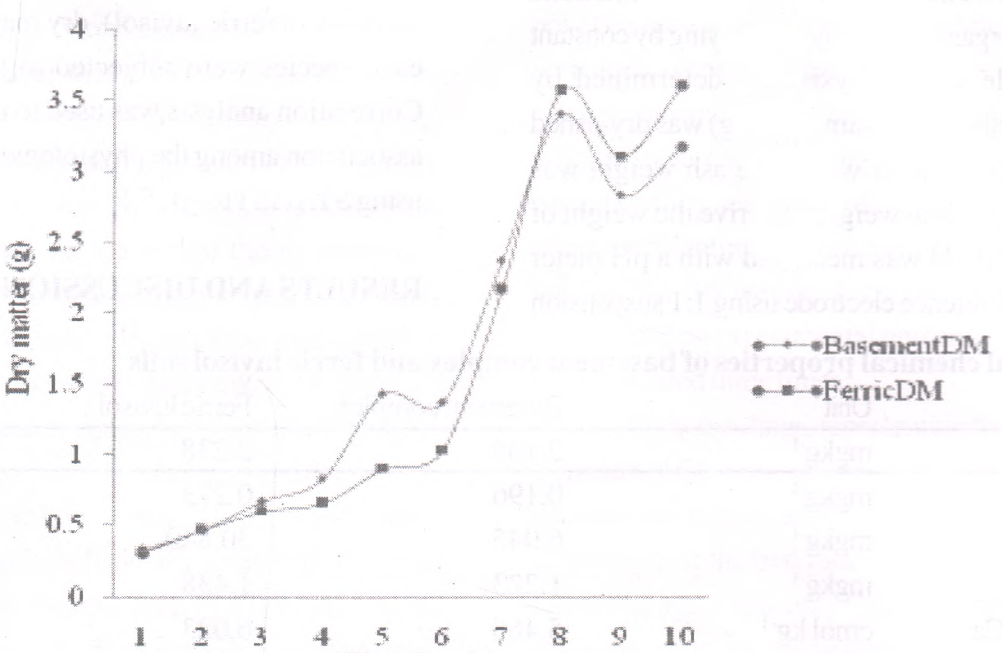

Fig. 1: Dry matter yield of *Gmelina arborea* seedling grown on basement complex and ferric luvisol soils

The dry matter yield varies from 0.33g to 3.17g on basement complex and 0.31g to 3.60g on ferric luvisol over the three-month period (Figure 1). The decline in dry matter after week five in both soils was mainly due to initiation of ontogeny development, as indicated by 8.33% decline in shoot dry matter for basement complex soil. In spite of difference in chemical properties between soils, th dry matter yield of both soil types were nearly similar.

Table 2: Properties of *Gmelina arborea* seedlings and soil media sampled during the period of the study

	Basement complex			Ferric luvisol		
Nutrient	Shoot	Leaf	Soil	Shoot	Leaf	Soil
Nitrogen(mg/g)	1.25±0.68	2.21±0.51	0.28±0.13	1.19±0.46	2.70±0.91	0.23±0.10
Phosphorus(mg/g)	0.34±0.31	0.60±0.76	20.54±4.11	0.29±0.13	0.36±0.13	6.75±1.14
Potassium(mg/g)	0.47±0.15	0.47±0.15	0.31±0.03	0.51±0.21	0.52±0.17	0.32±0.04
Org.Matter(g)	2.16±1.33	2.89±1.86	3.09±0.14	1.95±1.44	2.99±2.44	3.14±0.32
Org.Matter/N	1.74	1.31	12.51	1.63	1.11	13.40
Total carbon(%)	70.74±12.01	80.35±8.30	2.00±0.13	73.45±10.72	80.92±8.43	2.10±0.15

Values are means ±S.D

G arborea seedling grown on ferric luvisol had 60.39% of its biomass yield stored in leaf while that of the seedlings grown on basement complex soil was 58.19%. Moreover, 13.85% to 16.59% of their biomass yield was stored in the root. Student t-test indicates that the leaf total carbon of seedlings grown on basement complex soil (paired sampled t-test, 80.92g/kg:p<0.05, n=10) did not differ significantly from seedlings grown on ferric luvisol (paired sample t-test, 80.35g/kg:$p<0.05$, n=10). Also, shoot total carbon of seedling grown on both soils were not significantly different ($p<0.05$, t-test) from each other. This agreed with Falade (2005). The implication is that seedling grown on basement complex soil would return more organic carbon into the soil than those grown on ferric luvisol. Low Organic Matter/ Nitrogen quotient reported for the leaf of *G arborea* seedlings appear to be the upshot of the substantial carbohydrate allocation to the leaf structure. In both soils, laboratory analysis indicates that 3.0% of the total leaf organic matter consists of nitrogen, although nitrogen seems to be higher in basement complex than ferric luvisol soils (Table 2). The photosynthetic capacity of leaves is related to the nitrogen content primarily because the protein of the calving cycle and thylakoids represents the majority of leaf nitrogen. Relatively, *G arborea* seedling grown of ferric luvisol allocated more potassium to leaf structure than other parts of the seedlings (Table 2).

Table 3: Correlation analysis results of Physiological characteristics of *Gmelina arborea* grown on ferric luvisol soil

Variable	RGR_FER	LWR_FER	LAR_FER	SLA_FER	NAR_1_FER	NAR_2_FER
RGR_FER	1.00	0.72*	-0.62	-0.50	0.54	0.46
LWR_FER	-	1.00	-0.84*	0.07	0.45	0.18
LAR_FER	-	-	1.00	-0.10	-0.40	-0.37
SLA_FER	-	-	-	1.00	-0.40	-0.43
NAR_1_FER	-	-	-	-	1.00	0.41
NAR_2_FER	-	-	-	-	-	1.00

Marked correlation are significant at $P<0.05$, N=10 (case wise deletion of missing data)

Significant positive correlation was observed between relative growth rate (RGR) and leaf weight ratio (LWR) (0.72). Also, a significant but negative relationship was observed between leaf area ratio (LAR) (-0.84). Relative growth rate (RGR) correlated significantly with net assimilation rate on a leaf area basis (NAR_1) (0.72).

Table 4: Correlation analysis results of Physiological characteristics of *Gmelina arborea* grown on ferric luvisol soil

Variable	RGR_BAS	LWR_BAS	LAR_BAS	SLA_BAS	NAR_1_BAS	NAR_2_BAS
RGR_BAS	1.00	0.28	0.27	0.02	0.82*	0.48
LWR_BAS	-	1.00	-0.46	0.06	0.16	0.35
LAR_BAS	-	-	1.00	0.30	0.47	-0.35
SLA_BAS	-	-	-	1.00	0.10	-0.58
NAR_1_BAS	-	-	-	-	1.00	0.44
NAR_2_BAS	-	-	-	-	-	1.00

Marked correlation are significant at $P<0.05$, N=10 (case wise deletion of missing data)

The overall relationship of RGR to NAR was stronger (0.82) in basement complex soil than LWR (0.72) in ferric luvisol. Among the consequence of this correlation was the species that have higher growth rate in term of dry matter yield have higher allocation of photosynthate to leaves and their leaves are thinner (high specific leaf area) resulting in higher rates of leaf area increase (Poorter, 1989). Currently, a number of other studies have reported strong positive correlations between RGR and NAR, and weak correlation between RGR and SLA or LWR (Ryser and Wahl, 2001; Taub, 2002). The relative importance of SLA and NAR in determining RGR varies between studies because it depend on the ambient light environment.

Slower seedling potential RGR could be attributed to either of the slower net assimilation per unit leaf area (NAR_1) or the lower leaf area per unit plant mass (leaf area ratio, LAR). Lower LAR, in turn, might be as a result of either the lower leaf area per unit leaf mass (specific leaf area, SLA) or through lower leaf mass as a proportion of whole plant masss (leaf weight ratio, LWR). These are in conformity with the finding of Saverimutu and Westoby (1996). Large leaf areas allow for increased rate of transpiration and facilitate more carbon dioxide assimilation and interception of solar radiation, which are processes directly, related to dry matter synthesis (Collinson et al., 1996). This little difference in specific leaf mass (SLM) is indicating that accumulation of carbon compounds could be affected by soil conditions.

CONCLUSION

It was revealed from this study that the proportion of pure structural materials that plant contains increases with increase in plant age. This implies that initial weight is all that is necessary to develop more structure. This is an index of productive efficiency of *G arborea* in relation to soil conditions. Thus, there is inclusion of the weight of mineral element in all physiological structure measured, as an estimate of the carbon-assimilatory capacity of the leaves. In trees, a small increase in relative growth at the early stage can result in large differences in size of individuals at the end of the first year growth, or even after number of years, because of the compound interest rate. The enhancement of seedling growth was greatly related to both light and nutrient levels. Seedling grown on ferric luvisol produced more dry matter but less organic carbon than basement complex soils. Seedling leaf area was significantly related with leaf weight (dry matter) on both soils. Biomass (dry matter) density estimates also provide the means for calculating the amount of carbon dioxide that can be removed from the atmosphere by regenerating forest or by plantations and thus establish the rate of biomass production and the upper bounds for carbon sequestering.

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