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# Disparity in Height Growth Traits in *Tectona grandis* (L.f) Plantation as Influenced by Genetic and Edaphic Factors

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## ABSTRACT

*Genetic information of trees is stored as a sequence of four bases or nucleotides. This genetic information or genotype of trees does not normally change throughout their life time. Observed differences in any trait of interest among individual trees may be due to the differences in genes coding for that trait or variation in environmental conditions. In many cases, it is a combination of the differences in genes coding for the trait and variation in environmental conditions. This research investigated the disparity in growth traits in a teak plantation with the intention to finding out the cause of such growth dissimilarity and harnessing such potential for plus tree selection and subsequent teak plantation improvement. The study was carried out in a private teak plantation located at Itaogbolu, Ondo state. The plantation was established in the year 2000. The one hectare plantation was divided into 25m x 25m plots and four (4) plots were randomly selected using random number generation. All trees within each sample plot were inventorized i.e. diameter at the base, breast height, middle, top and height were measured using relaskop and girth diameter tape. Trees in each plot were grouped into three (3) different height classes namely: Upper Height Class "UHC" (Height >15m), Middle Height Class "MHC" (height between 10m and 15m) and Lowest Height Class "LHC" (height < 10m). Trees under each height class were identified and tagged. In each class, nine (9) trees were selected randomly to uncover the disparity in their height trait. Soil samples were collected at 0-20cm, 20-40cm and 40-60cm depths from three points around each of the selected trees using soil auger. Soil samples from the same depth were bulked to form a composite sample. These composite soil samples were labeled accordingly and taking to the laboratory for analysis. The results indicated that 5.73% of the trees in the plantation were in the ≤10m height class, 53.05% of them were found within 10-15m height class whiled 41.22% of the trees were found in ≥15m height class. Soil characteristics where individual tree under different height classes were growing in this plantation were not significantly different. Hence the difference in growth traits, particularly tree height, observed in this Tectona grandis plantation was not as a result of the variation in soil characteristics but may be attributed to the differences in the genetic make-up of the trees. It is therefore recommended that seed collection should be done carefully from the tallest mother trees particularly if the objective of establishing the plantation is pole or timber production..*

**Key words**: Genetic make-up, Soil characteristics, Teak plantation, Height Trait

## INTRODUCTION

One of the most valuable forest plantation species in the world is *Tectona grandis* (Teak). The demand and interest in this species continues to grow every year as a result of its impressive rates of growth when optimal sites are chosen (Bermejo *et. al.,* 2004). It is a tropical tree species that belong to the family *Verbenaceae.* The tree could attain a height of 30 meters and girth of over one meter on good sites but on a poor site, it reaches 12 meters in height (Zanin, 2005). Although Teak is indigenous to India, it is one of the major plantation tree species in Nigeria (Pandey and Brown, 2000). Due to its high timber qualities, high durability of the wood, good dimensional stability, aesthetic qualities, high market demand, ease of cultivation, teak plantations have been widely established throughout the country (Nigeria). Though Teak plantations account for 5 - 8% of the total forest area in the tropics (Ball *et. al*., 1999), about 90% of the quality hardwood plantations for timber production are obtained from *Tectona grandis* (Granger, 1998). Plantation of *Tectona grandis* can be established under diverse conditions. Keogh (1996) and Enters (2000) pointed out that Teak can be planted on degraded lands. However, high productivity can only be expected on good sites. Wood from Teak is commonly used for ship building, furniture, cabinet and general carpentry.

Genetic information of trees are stored as a sequence of four bases or nucleotides: adenine, thymine, cytosine and quinine. This genetic information or genotype does not change throughout the life of the tree (Reiner and Finkeldey, 2007). According to Reiner and Finkeldey (2007), observed differences in any trait of interest among individual trees may be due to the differences in the gene coding for the trait or may be the result of the variation in environmental conditions. In many cases, it is a combination of the differences in genes coding for the trait and variation in environmental conditions. Although, Piotto (2007) reported height and diameter profile variations for every tree species from site to site, growth variation among trees is also common in most *Tectona grandis* plantations. The difference in tree growth characteristics usually observed in most *Tectona grandis* plantations may be due to dissimilarities in the characteristics of the soil where the individual trees were planted and/or the genetic make-up of individual trees or both. Regrettably, non-uniformity in the size of Teak trees in a plantation contributes to the poor returns in plantation investments. Nwoboshi (1972) highlighted some factors affecting the growth and growth pattern of *Tectona grandis* to include: soil, site, seed supply and seed quality, genetic composition and climate. Lack or short of important nutrients such phosphorus (P), potassium (K), calcium (Ca), zinc (Zn) and Nitrogen, high acidity and toxicity of aluminum (Al) and magnesium (Mg) may result in poor growth and other tree characters such as stem form, mode of branching and wood quality (Bermejo *et. al.,* 2004). The non-uniformity in growth traits of Teak trees in a plantation, if genetic, could be harnessed for selection and breeding for optimum yield, drought tolerance and disease resistance. This will go a long way to boosting the current supply of wood from *Tectona grandis* plantations in Nigeria and in the long run, give our economy a face lift.

One of the cardinal objectives for teak plantation establishment is to produce high quality wood for poles or timber. However, variation in growth characteristics that is normally associated with some Teak plantations often jeopardizes this objective. Therefore, this research was designed to investigate the disparity in growth traits in a teak plantation with the intention to finding out the cause of such growth dissimilarity and harnessing such potential for plus tree selection and subsequent teak plantation improvement.

## MATERIALS AND METHODS

### Study area

The study was carried out in a private teak plantation located at Itaogbolu, Ondo state. This one hectare plantation was established in the year 2000 at 2.5m espacement. The plantation was selected for this research work owing to the profound variation observed in height and diameter traits. Itaogbolu town is located within Akure North Local Government Area of Ondo State, Nigeria. The study area has a land mass of 2940.109km$^3$ with latitude 7$^0$22N and longitude 5$^0$15E. The area has a relatively high relief of between 950 and 1500m above sea level. The mean annual rainfall is 1500mm with bimodal rainfall pattern, relative humidity ranges between 85% and 100% during the raining season and less than 60% during dry season. Temperature ranges from about 20.6$^0$C to 33.5$^0$C. The monthly mean temperature is about 27$^0$C, a condition that is conducive to the development of tropical rainforest. The natural vegetation is the high forest, composed of many varieties of hardwood timber species. The soils are derived from the Basement complex rocks which are mostly well drained, with a medium texture.

### Data Collection

This one hectare plantation was divided into 25m x 25m plots and four (4) plots were randomly selected using random number generation. All trees within each sample plot were inventorized i.e diameter at the base, breast height, middle, top and height were measured using relaskop and girth diameter tape. Trees in each plot were grouped into three (3) different height classes namely: Upper Height Class "UHC" (Height >15m), Middle Height Class "MHC" (height between 10m and 15m) and Lowest Height Class "LHC" (height < 10m). Trees under each height class were identified and tagged. In each class, nine (9) trees were selected randomly to uncover the disparity in their height trait. Soil samples were collected at 0-20cm, 20-40cm and 40-60cm depths at three points around each of the selected trees using soil auger. Soil samples from the same depth were bulked to form a composite sample. These composite soil samples were labeled accordingly and taking to the laboratory for analysis.

### Data Analysis

#### *Basal Area Estimation*

The basal area of individual tree was estimated using equation (1):

$$BA = \frac{\pi D^2}{4} \quad \text{.........................................................................(1)}$$

Where: BA = Basal area (m$^2$), D = Diameter at breast height (cm) and $\pi$ = Pie (3.142).
Basal area for each plot was obtained by summing the BA of all the trees in that plot. Basal area per hectare was calculated by multiplying the mean basal area per plot with the number of plots in one hectare (i.e. 16).

#### *Volume Estimation*

The volume of individual tree was estimated using Newton's formula (Husch *et. al.,* 2003). This equation (2) is expressed as follows:

$$V = \frac{\pi h}{24}\left(D_b^2 + 4D_m^2 + D_t^2\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where:
V = Volume of tree ($m^3$); $D_b$ = Diameter at the base (cm); $D_m$ = Diameter at the middle (cm); $D_t$ = Diameter at the top (cm); h = height (m)
Total volume for each plot was obtained by summing the volumes of all the individual trees in that plot. Also, volume per hectare was calculated by multiplying the mean volume per plot with the number of plots in one hectare (i.e. 16).

Soil samples were air-dried and sieved using a 2mm wire mesh. Some important chemical elements commonly required for optimum Teak growth were analyzed. These include: Calcium (Ca), Phosphorus (P), Potassium (K), Nitrogen (N), Organic Matter (OM)) and Organic Carbon (OC). Total nitrogen (N) was determined by Kjeldal method, Organic Carbon (OC) was estimated using Walkely and Black method (Walkley and Black, 1934). Available Phosphorus (P) was analyzed using molybdenum-blue method. Soil physical properties, Soil texture and pH, were also determined. Soil texture was determined by hydrometric method (Black *et al.,* 1965) and soil pH was determined with a digital pH meter using suspension of 1:2.5 (soil/water solution). Organic carbon content was estimated using Walkley and Black method (Walkley and Black, 1934). Organic matter was obtained by multiplying organic carbon content by a conversion factor of 1.724. Samples for total N determination were digested using micro Kjeldahl method with selenium catalyst (Bremner, 1965). Available Ca and Mg were determined by atomic absorption spectrophotometer (AAS), while available Na and K were determined by digital flame photometry.
Correlation between soil characteristics and growth variables was carried out using Pearson correlation coefficient. The data was subjected to one way analyze of variance (ANOVA) using Statistical Package for Social Sciences (SPSS). Where significant differences occurred, mean separation was carried out with Duncan's New Multiple Range Test (DMRT) ($p < 0.05$).

## RESULTS

The results of *Tectona grandis* tree growth characteristics are presented in Table 1. The number of stem per hectare, Mean dbh and height were 132, 22.6cm and 11.51m respectively. Basal area and volume per hectare were estimated to be 6.25$m^2$ and 47.53$m^3$, respectively. The results indicated that about 5.73% of the trees in the plantation were ≤10m height class, 53.05% of the trees were found within the 10-15m height class while 41.22% were found in ≥15m height class as presented in Figure 1.

Generally, the characteristics of the soils where the trees in the three height classes were growing were not significantly different, except pH (Table 2).

**Table 1:** Tree growth variable in the study area

| Variables | Values |
|---|---|
| Number of Stem/ha | 132 |
| Mean DBH | 22.64cm |
| Mean Height | 11.51m |
| Basal Area/ha | 6.25$m^2$ |
| Volume/ha | 47.53$m^3$ |

Note: DBH – Diameter at Breast Height

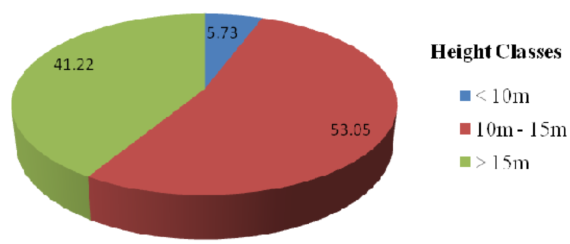


**Figure 1:** Height class distribution of individual trees in a 17 years old Teak plantation

**Table 2:** Characteristics of the soil of trees of the three height classes at 0-20cm depth

| Soil characteristics | Height classes | | |
|---|---|---|---|
| | UHC | MHC | LHC |
| OC | 2.10 ± 0.49[a] | 1.66 ± 0.74[a] | 2.14 ± 0.41[a] |
| OM | 3.62 ± 0.85[a] | 2.86 ± 1.27[a] | 3.69 ± 0.70[a] |
| P | 2.98 ± 4.04[a] | 1.38 ± 1.09[a] | 2.72 ± 2.99[a] |
| Ca | 2.94 ± 0.91[a] | 2.25 ± 1.02[a] | 2.59 ± 0.72[a] |
| Mg | 1.38 ± 0.63[a] | 1.46 ± 0.98[a] | 1.43 ± 0.61[a] |
| pH | 5.51 ± 0.19[b] | 5.72 ± 0.41[ab] | 5.86 ± 0.23[a] |
| N | 0.33 ± 0.07[a] | 0.34 ± 0.07[a] | 0.35 ± 0.03[a] |
| % Sand | 48.21 ± 1.53[a] | 49.71 ± 2.75[a] | 47.53 ± 3.37[a] |
| % Clay | 13.43 ± 2.42[a] | 11.02 ± 1.47[a] | 12.31 ± 2.73[a] |
| % Silt | 38.36 ± 1.62[a] | 39.36 ± 1.44[a] | 40.10 ± 2.52[a] |

Note: OC – Organic Carbon, OM – Organic Matter

For instance, at 0-20cm depth, the chemical and physical properties of the soils of the three height classes were not significantly different, except for pH which was found to be significantly higher in LHC (Table 2).

At 20-40cm depth, all the soil chemical and physical properties of the three height classes investigated in this study, except Ca and Mg, were not significantly different (Table 3). At 20-40cm depth, Calcium in soils of UHC was significantly higher while Magnesium (Mg) was found to be significantly higher in LHC (Table 3). The percentage silt, sand and clay were the same for the soils of the three height classes regardless of the soil depth. For 40-60cm depth, results revealed that there were no significant differences in all the characteristics of the soils of three tree height classes investigated in this study (Table 4).

**Table 3:** Characteristics of the soil of trees of the three height classes at 20-40cm depth

| Soil characteristics | Height classes | | |
|---|---|---|---|
| | UHC | MHC | LHC |
| OC | 1.86 ± 0.44[a] | 1.69 ± 0.52[a] | 1.77 ± 0.41[a] |
| OM | 3.62 ± 0.85[a] | 2.86 ± 1.27[a] | 3.69 ± 0.70[a] |
| P | 1.87 ± 2.86[a] | 1.92 ± 2.04[a] | 2.39 ± 2.63[a] |
| Ca | 3.25 ± 1.05[a] | 2.10 ± 0.87[b] | 2.05 ± 1.15[b] |
| Mg | 0.55 ± 0.46[b] | 0.89 ± 0.68[ab] | 1.25 ± 0.72[a] |
| pH | 5.38 ± 0.53[a] | 5.69 ± 0.18[a] | 5.75 ± 0.23[a] |
| N | 0.35 ± 0.04[a] | 0.34 ± 0.04[a] | 0.30 ± 0.08[a] |
| % Sand | 50.09 ± 1.53[a] | 49.75 ± 3.10[a] | 48.40 ± 4.81[a] |
| % Clay | 12.07 ± 1.97[a] | 12.92 ± 2.10[a] | 13.11 ± 3.56[a] |
| % Silt | 37.85 ± 1.74[a] | 37.33 ± 2.48[a] | 38.49 ± 2.13[a] |

Mean in the same column followed by the same letter(s) are not significantly different at 0.05 level of significance. *Note: UHC – Upper Height Class, MHC – Middle Height Class, LHC – Lowest height Class, OC – Organic Carbon, OM – Organic Matter.*

**Table 4:** Characteristics of the soil of trees of the tree height classes at 40-60cm depth

| Soil characteristics | Height Classes | | |
|---|---|---|---|
| | UHC | MHC | LHC |
| **OC** | 1.53 ± 0.18[a] | 2.12 ± 1.81[a] | 1.50 ± 0.47[a] |
| **OM** | 2.64 ± 0.30[a] | 3.66 ± 3.12[a] | 2.59 ± 0.81[a] |
| **P** | 2.00 ± 3.75[a] | 1.73 ± 2.90[a] | 1.38 ± 1.17[a] |
| **Ca** | 2.73 ± 0.76[a] | 1.93 ± 0.48[a] | 2.48 ± 1.27[a] |
| **Mg** | 0.98 ± 0.75[a] | 1.23 ± 0.51[a] | 1.23 ± 0.37[a] |
| **pH** | 5.60 ± 0.37[a] | 5.61 ± 0.37[a] | 5.80 ± 0.51[a] |
| **N** | 0.28 ± 0.07[a] | 0.29 ± 0.05[a] | 0.34 ± 0.08[a] |
| **% Sand** | 47.21 ± 2.94[a] | 48.15 ± 3.01[a] | 49.33 ± 4.02[a] |
| **% Clay** | 13.82 ± 3.47[a] | 13.71 ± 2.46[a] | 13.34 ± 3.90[a] |
| **% Silt** | 38.97 ± 1.71[a] | 38.15 ± 1.67[a] | 37.33 ± 2.41[a] |

Mean in the same column followed by the same letter(s) are not significantly different at 0.05 level of significance. *Note: UHC – Upper Height Class, MHC – Middle Height Class, LHC – Lowest height Class, OC – Organic Carbon, OM – Organic Matter.*

Though there was no significant difference in the percentage of Organic Carbon (OC), Organic Matter (OM), Phosphorus (P) and Calcium (Ca) among the three soil depths, it was observed that their values decreased as the soil depth increases (Table 5). The result also revealed that Magnesium (Mg), Nitrogen (N) and Silt content varied considerably among the depths. Magnesium was found to be significantly higher at 0-20cm depth compared to 20-40cm, which had the lowest Magnesium content. Similar trend were observed for Nitrogen and silt contents (Table 5). Soil physical properties examined in this study were statistically the same. However, their values assumed sinusoidal pattern across the depths except percentage clay, which increased with soil depth. For instance, the sand content increased from 48.48% at 0-20cm to 49.53 at 20-40cm and then reduced to 48.23 at 40-60cm depth. The results of correlation analysis between tree growth variables and soil characteristics (Table 6), indicated that strong relationships existed between height and organic carbon (0.85), height and organic matter (0.85, height and soil pH (0.90), height and %silt (0.84). Strong relationship was also recorded between basal area and calcium (70%) as well as between basal area and soil pH (0.71).

**Table 5:** Soil physical and chemical properties of Tectona grandis plantation across the three depths

| Soil characteristics | Soil Depths (cm) | | |
|---|---|---|---|
| | 0 - 20 | 20 – 40 | 40 – 60 |
| **OC (%)** | 1.97 ± 0.58[a] | 1.77 ± 0.45[a] | 1.72 ± 1.08[a] |
| **OM (%)** | 3.40 ± 1.00[a] | 3.05 ± 0.78[a] | 2.97 ± 1.86[a] |
| **P** | 2.36 ± 2.92[a] | 2.02 ± 2.38[a] | 1.70 ± 2.71[a] |
| **Ca** | 2.59 ± 0.90[a] | 2.47 ± 1.11[a] | 2.38 ± 0.92[a] |
| **Mg** | 1.43 ± 0.73[a] | 0.87 ± 0.66[b] | 1.14 ± 0.55[ab] |
| **pH** | 5.70 ± 0.32[a] | 5.60 ± 0.37[a] | 5.70 ± 0.36[a] |
| **N** | 0.34 ± 0.05[a] | 0.33 ± 0.05[ab] | 0.30 ± 0.07[b] |
| **%sand** | 48.48 ± 2.71[a] | 49.53 ± 3.16[a] | 48.23 ± 3.33[a] |
| **%clay** | 12.31 ± 2.40[a] | 12.68 ± 2.42[a] | 13.62 ± 3.19[a] |
| **%silt** | 39.21 ± 1.96[a] | 37.79 ± 2.13[b] | 38.15 ± 2.00[ab] |

Mean in the same column followed by the same letter(s) are not significantly different at 0.05 level of significance.

## DISCUSSION

In Nigeria, the impressive rates of growth of Teak when optimal sites are chosen made the species widely acceptable for plantation establishment and as such, collection of seeds is done without taking into consideration the existing intra-specific variation which when harnessed could further boast the productivity of a plantation project. It should be noted that in any breeding

**Table 6:** Correlation coefficient between tree growth variables soil characteristics of the Teak plantation

| | *Ht* | *BA* | *Vol* | *OC* | *OM* | *P* | *Ca* | *Mg* | *pH* | *N* | *% Sand* | *% Clay* | *% Silt* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ht | 1.000 | | | | | | | | | | | | |
| BA | 0.588 | 1.000 | | | | | | | | | | | |
| Vol | 0.927 | 0.694 | 1.000 | | | | | | | | | | |
| OC | 0.845 | 0.084 | 0.742 | 1.000 | | | | | | | | | |
| OM | 0.845 | 0.084 | 0.742 | 1.000 | 1.000 | | | | | | | | |
| P | -0.270 | 0.577 | 0.022 | -0.640 | -0.64 | 1.000 | | | | | | | |
| Ca | -0.107 | 0.702 | -0.026 | -0.622 | -0.622 | 0.791 | 1.000 | | | | | | |
| Mg | 0.083 | -0.010 | 0.390 | 0.269 | 0.269 | 0.226 | -0.385 | 1.000 | | | | | |
| pH | 0.895 | 0.713 | 0.997 | 0.700 | 0.700 | 0.090 | 0.005 | 0.438 | 1.000 | | | | |
| N | -0.783 | 0.029 | -0.566 | -0.946 | -0.946 | 0.807 | 0.610 | 0.036 | -0.505 | 1.000 | | | |
| % Sand | 0.541 | 0.199 | 0.746 | 0.666 | 0.666 | -0.017 | -0.452 | 0.879 | 0.767 | -0.391 | 1.000 | | |
| % Clay | -0.831 | -0.276 | -0.882 | -0.915 | -0.915 | 0.307 | 0.489 | -0.576 | -0.87 | 0.738 | -0.894 | 1.000 | |
| % Silt | 0.838 | 0.241 | 0.572 | 0.794 | 0.794 | -0.650 | -0.245 | -0.353 | 0.506 | -0.910 | 0.127 | -0.558 | 1.000 |

project with exotic tree species, one of the first steps is to understand the species pattern of provenance and intra-specific variation. Thereafter, efforts are then concentrated on selecting parent trees with desired traits.

Height and diameter variations usually observed in most Teak plantations may be influenced by many factors. As much as genetic make-up of individual Teak tree will affect its growth performance, edaphic characteristics can also affect the growth and yield of *Tectona grandis* which requires relatively fertile soil with high calcium (Ca), phosphorus (P), potassium (K), nitrogen (N) and organic matter (OM) contents (Reiner and Finkeldey, 2007). Findings from this research work agreed with the work of Adugna and Abegaz (2015), as chemical properties of the plantation soil decreased with increasing soil depth. This is expected as litters from the trees fall on the forest floor and as decomposition takes place, chemicals in the litter are released to the soil. Since the decomposition takes place on the forest floor, concentration of the chemicals are expected to be more on the upper part of the soil than in the lower part.

Generally, the success of forest planting programmes depends not only on the site quality but also on the genetic quality of the planting materials. In this study, the chemical and physical properties of the soils of trees in the three height classes were not significantly different. This suggests that the variations observed in the growth characteristics of the trees in the teak plantation may be as a result of the genetic make-up of the individual trees. According to Wellendorf and Kaosa-ard (1988), the growth and yield of forest plantations can largely be improved through selection of individual trees with good stem quality (i.e. straightness, persistence of stem axis, branching, flowering etc) which is strongly controlled by genetic make-up. They also reported that the use of seeds from plus trees is most essential in the improvement of growth, stem quality, and other characters of Teak plantation. They pointed out that by using such seeds, the growth and or volume production is increased by 5 to 20% depending on types of seed source and planting site. According to Keiding *et. al*., (1986), stem quality and growth of Teak can be improved to as high as 23% when selection of mother trees with desired trait is done carefully.

## CONCLUSION AND RECOMMENDATION

This research work revealed that the soil characteristics where individual trees in this teak plantation were growing, regardless their height classes, were not significantly different. Hence the difference in growth traits, particularly tree height, observed in this *Tectona grandis* plantation was not as a result of the variation in soil characteristics but may be attributed to the differences in the genetic constitution of the trees. Since there was no significant difference in the soil characteristics across the different height classes and the climatic conditions were the same, it is therefore recommended that seed collection should be done carefully from the tallest mother trees particularly if the plantation is meant for pole or timber production.

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