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Slenderness coefficients (SLC) and Growth rate (GR) of *Gmelina arborea* (Roxb.) plantation in Federal University of Agriculture Abeokuta arboretum, Ogun State, Nigeria

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ABSTRACT

The slenderness coefficients of trees, defined as the ratio of total height to diameter at 1.3 m above ground, have been widely used as an index of the resistance of trees to windthrow. For many of the trees in the natural forests, slenderness coefficients have been intensively studied, but very little information is available for the tree species in plantation stands. This study examined the growth rate and slenderness coefficient of *Gmelina arborea* plantation in the Federal University of Agriculture Abeokuta, arboretum in Ogun state with a view to providing information for improved management of the plantation through management decisions by the University. Ten (10) plots of size 20 m X 20 m each were established through two (2) transect lines of 200 m long and 50 m apart were used for the collection tree growth data. Total enumeration of all trees in the plots was carried out. Growth variables assessed included, the tree height, diameter at breast height, volume and basal area. Descriptive statistics of the growth characteristics of the tree species revealed a mean volume of $0.97 \pm 0.17 m^3/ha$ and $0.07 \pm 0.01 m^2/ha$ for basal area. The mean height and DBH observed were 12.24 ± 0.68 and 26.00 ± 2.25 respectively while the Mean Annual Increment was 1.73 ± 0.01 cm/yr. The result of slenderness coefficient showed that low slenderness coefficient (SLC) of < 70 showed that majority (89.2%) of the tree species are not susceptible to wind induced damage. Further research should be centered on tree form and growth variables needed to be encouraged for improved management of the plantation.

Keywords: *Gmelina arborea*, growth rate, tree plantation development, slenderness coefficient

Introduction

Depletion of tropical rainforest is geometrically on the increase despite efforts to tame the process. One major way that can act as a quick-fix measure is the establishment of forest plantation of exotic tree species (Ige and Akinyemi, 2015). Evidently, there has been a shift from tropical natural forest management to managements of plantation of mainly exotic species in Southern Nigeria (FORMECU, 1991; Onilude and Adesoye, 2007; Ige and Akinyemi, 2015). Forest plantations are usually established so that the desired size and volume are achieved in the shortest possible time to ensure continuous supply of wood to wood based industry (Akindele, 2003; Ige and Akinyemi, 2015). For the continued conservation and protection of Nigeriat ree species heritage, arboretum for conservation of both indigenous and exotic tree species was created. However, for this study emphasis was on *Gmelina arborea* stands in the arboretum.

Forest is a renewable natural resource which requires effective and scientific management. For this to be achieved, the forest manager like any other resources manager requires reliable information of the current state of the standing timber in the forest in terms of its yield, growth, quality, quantity, size and location of the forest resources available and how these resources are changing over time (Oniludeet *al*., 2017). This information will bring about the growth and development of the forest stand which is considered important in forestry as it provides clues to the future behaviour and guide to the management of a given stand and helps the manager in decision making about the sustainable management of the forest stand.

Meanwhile, sustainable forest management requires information on the growing stock (Onilude, 2019). Such information guides the resource manager in valuation and allocation of forest areas. In timber production, estimates of the growing stock are often expressed in terms of timber volume, which can be estimated from easily measured dimensions of the tree (Husch *et al.*, 2003; Akindele, 2005). Also, relevant information about forest resources provides forest managers with the necessary guides for rational decision making (Akindele, 2001) and management planning as well as its implementation. For example, the calculation and implementation of sustained yield harvest and long-term planning of forest management operations, such as planting, thinning, pruning and improvement cuttings, cannot be successful without reliable data on the growth rates of the trees.

Assessment of the diameter growth rate can be identified as one of the management tools used by forest managers and scientists in ensuring accurate assessment of the growth development of tree species. According to Wang *et al.* (1998), the susceptibility of a stand to wind throw or damage is largely influenced by the tree slenderness coefficient or taper of the tree and this vulnerability to wind most times is based on a combination of some tree growth characteristics such as stand conditions, site soil and site quality, topography and wind patterns (Ruel, 2000). These combinations generally substantiate the impact of both biological and physical factors on the individual tree or stand stability among exotic species (Byrne, 2011; Nivert, 2001; Navratil, 1996).

In silvicultural studies, the tree slenderness coefficient often serves as an index of tree stability, or the resistance to wind throw (Navratil *et al.*, 1996). According to Navratil *et al*. (1996), slenderness coefficient values can be classified into three categories.

SLC values > 99………High slenderness coefficient

70 < SLC values > 99….Moderate slenderness coefficient

SLC values < 70 ……Low slenderness coefficient

In general, a low slenderness coefficient value usually indicates a longer crown, lower centre of gravity and a better developed root system (Onilude and Adesoye, 2007). Trees with higher slenderness coefficient values (i.e. slender tree) are much more susceptible to wind damage and, therefore must be removed from the stand or area to avoid damaging other neighboring trees (Onilude and Adesoye, 2007).

Unfortunately, since the establishment of the *Gmelina arborea* plantations in the arboretum of the Federal University of Agriculture Abeokuta in Ogun State, the diameter growth rate and its slenderness coefficient havenot been assessed. Thus, there has not been data on these stand characteristics for rational decision making and sustainable management. Therefore, the objective of this study was to assess the mean annual diameter growth rates of thisspecies in the arboretum, with the view to providing the database necessary for their sustainable management. Onyekwelu (2001) reported that little emphasis has been given to growth characteristics of many exotic species in Nigeria and where silvicultural intervention had been adopted without good knowledge of growth characteristics, bad management decision are always made with attendance adverse effect on stand productivity. Thus, the reason for this study.

Gmelina arborea is a fast growing deciduous tree occurring naturally in India, Thailand, Cambodia and southern provinces of China but planted extensively in Nigeria, Sierra Leone and Malaysia (Ajayi, 2013). It is light demanding, tolerant of excessive drought but moderately frost hardy and has god capacity to recover in case of frost injury (Duke, 1983). In Nigeria, there is large investment of *Gmelina arborea* plantations and the tree is gaining momentum as avenue trees and also being planted in gardens and on agricultural land (Onilude, 2019).

Materials and Methods

Study Area

The Federal University of Agriculture, Abeokuta is located next to Ogun-Osun River Basin Development Authority (OORBDA), along Osiele-Abeokuta Road, off Abeokuta-Ibadan road in the north Eastern end of the city at Alabata and is from the city center of Abeokuta which lie approximately on latitude 7° 12' and 7° 23' N and longitude 3°20' and 3° 23' E. Itlies within the humid lowland rain forest region with two distinctive seasons. The wet season extends from March to October while dry season extends from November to February. The mean annual rainfall is 1113.1mm. The rainfall has a characteristic bimodal distribution with peaks in July and September and breaks in August. (Ufoegbune, and Fabiyi, 2016). The plantation was established in the year 2002 and the size of the arboretum is 2.5ha.

Data Collection

Data were collected from trees in all the plots established on transect lines (Figure 1) and direct enumeration of all trees in the plots were carried out. Two transect lines were established in the plantation at 50 m apart. Ten (10) 20 m X 20 m plots distanced 20 m to each other were obtained from the transect lines (Figure 1). All the trees in the plots were counted and measured. Growth variables measured and recorded included stem height, diameter at the base, middle and top. Also, diameter at breast height (dbh) using girthing tape at 1.3m above ground level was collected.

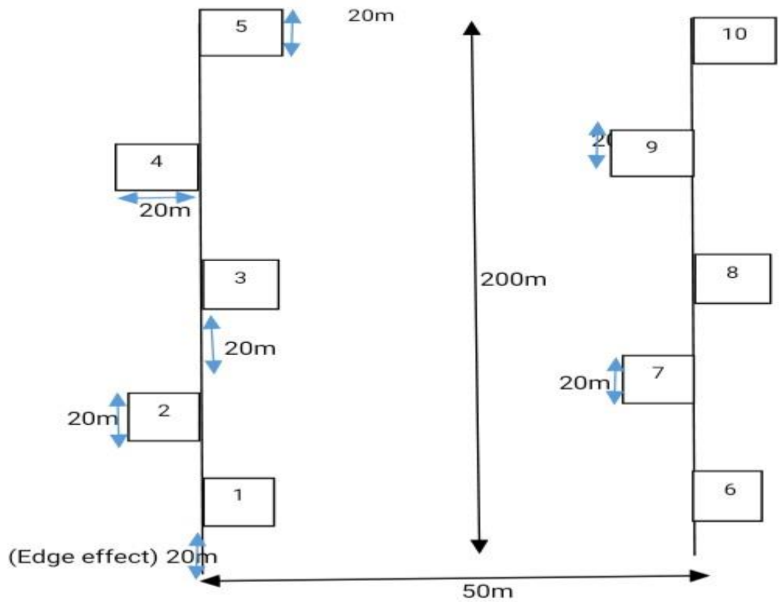

Fig. 1: Transect lines established for data collection

Data Analysis

Basal Area Estimation

The Basal Area (BA) of individual trees sampled will be estimated using the formula in equation given by Huschet *al.*(2003).

BA = $\frac{\pi d^2}{4}$……………..equation 1

Where:

BA = Basal area (m^2)
D = dbh (m)
Π = 3.142 (constant)

Slenderness coefficient (SLC)

$SLC = \frac{THT}{DBH}$ ………..equation 2

Where;

SLC = Slenderness coefficient
THT = Total height (m)
DBH = Diameter at breast height (m)

Diameter Growth Rate

The diameter growth rate for each tree species was estimated by calculating the Mean Annual Increment (MAI) in DBH using equation 3 as developed by Husch *et al.* (2003):

$MAI = \frac{DBH}{A}$………………..equation 3;

However, for the whole *Gmelina arborea* plantation in the arboretum, it was calculated by adding the MAIs of all the individual tree species and dividing the total by the number of individual tree species.

Where;

MAI = Mean Annual Increment (cm/yr),
A = Tree Age (years)
DBH =diameter at breast height (cm)

Results and Discussion

Table 1: Summary of growth variables for the tree species

Statistics	Volume (m^3/ha)	SLC	Height (m)	Basal area (m^2/ha)	DBH (cm)	MAI (cm/yr)
Mean	0.97 ± 0.17	53.07 ± 3.03	12.24± 0.68	0.07 ± 0.01	26.00 ± 2.25	1.73± 0.01
Min	0.02	16.44	3	0.01	7.00	0.47
Max	5.02	128.57	18	0.42	73.00	4.87
Sum	35.77	1963.54	453	2.53	962.00	64.13

Note: Min= Minimum; Max = Maximum; SLC = Slenderness coefficient; DBH =diameter at breast height;MAI = Mean Annual diameter increment

The *Gmelina arborea* plantation had 37 standing trees/ha with a total basal area of 2.53m^2/ha as shown in table 1. The mean dbh observed in the *Gmelina arborea* plot was 26.00±2.25cm (Table 1). However, this value was small when compared to the result obtained by Etigale *et al*.(2013). Also, the Mean Annual Increment (MAI) in DBH ranges between 0.47cm/yr^{-1} and 4.87cm/yr^{-1}. This MAI range is similar to result obtained by Etigale *et al*.(2013) for *Gmelina arborea* plot. Comparing the basal area/ha from this study to a standard provided by Holland *et al*. (1990) (9.18m^2ha^{-1} – 22.96m^2ha^{-1}), it showed that the *Gmelina arborea* plantation in this study was over stocked compare to the small area the plantation is covering. Therefore, competition among the trees will be a factor limiting the diameter growth of the trees.

When trees in a plantation competes for such resources as soil moisture, light and nutrients becomes so intense, height growth is emphasized rather than diameter growth (Nwoboshi, 1982; Holland *et al*., 1990). In such a competitions the weaker competitors is in a disadvantage position, whereby they gradually become stagnated in growth and may eventually be eliminated from the population. However, according to Holland *et al*. (1990), a stand needs thinning when its rate of growth begins to slow down as a result of competition.

The diameter tree distribution curve for the trees in the study area

The diameter distribution curve in Figure 2 showed that the plantations are still in its growing stage. The majority of the *Gmelina arborea* in the arboretum were found in Dbhsize class of 41- 50cm, followed by Dbh size class 31 – 40cm, while the least frequency was found in 0 -10cm Dbh size class (Fig. 2). Tropical rain forest tree species have been observed to grow above 80cm in diameter at breast heightin some instances (Hartshorn, 1980). This is in agreement with the result of this study as the highest diameter at breast height observed was 78 cm, almost close to the 80cm. In addition, some trees in the arboretum attained total heights above 10m because the arboretum enjoys adequate protection by law for conservation and academic purposes.

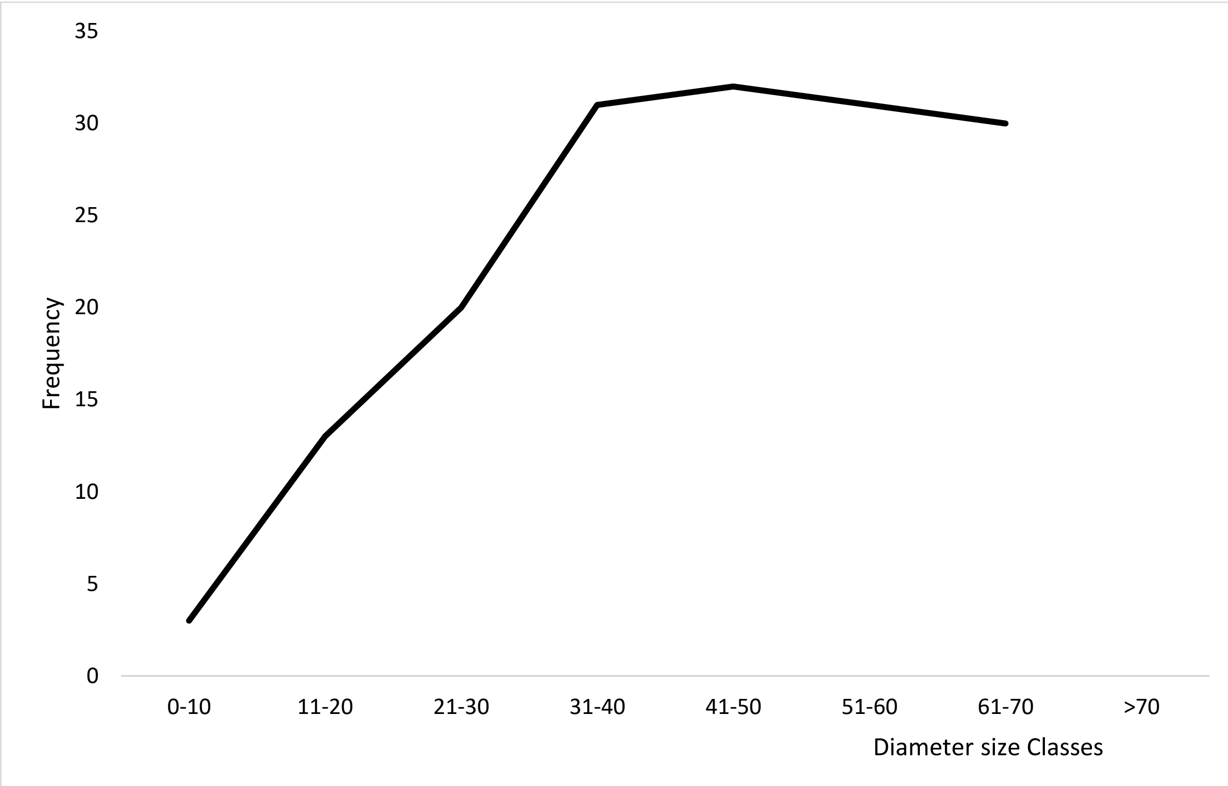

Fig. 2: Diameter distribution curve for the *Gmelinaarborea* Plantation

Implications of Slenderness coefficients on the tree stand

Navratil (1996) reported that certain percentage of slenderness coefficient reached within a stand can pose a high risk of wind throw. For this study however, only one tree was found to have a Slenderness coefficient value greater than 99 (2.7%), while 3 tree (8.1%) were found in moderate categories and 33 trees (89.2%)were found to fall below 70 slenderness coefficient values (Fig. 3). This result showed that one tree was susceptible to wind throw among the tree stands assessed. About 8.1% of the trees would partially resist wind throw as they were found in the moderate slenderness values while the remaining trees were of good stand because of their low slenderness values. However, this result compare favorably with the result presented by Aderounmu *et al.* (2017) in their study of diversity and growth characteristics of tree species in Botanical Garden, University of Ibadan.

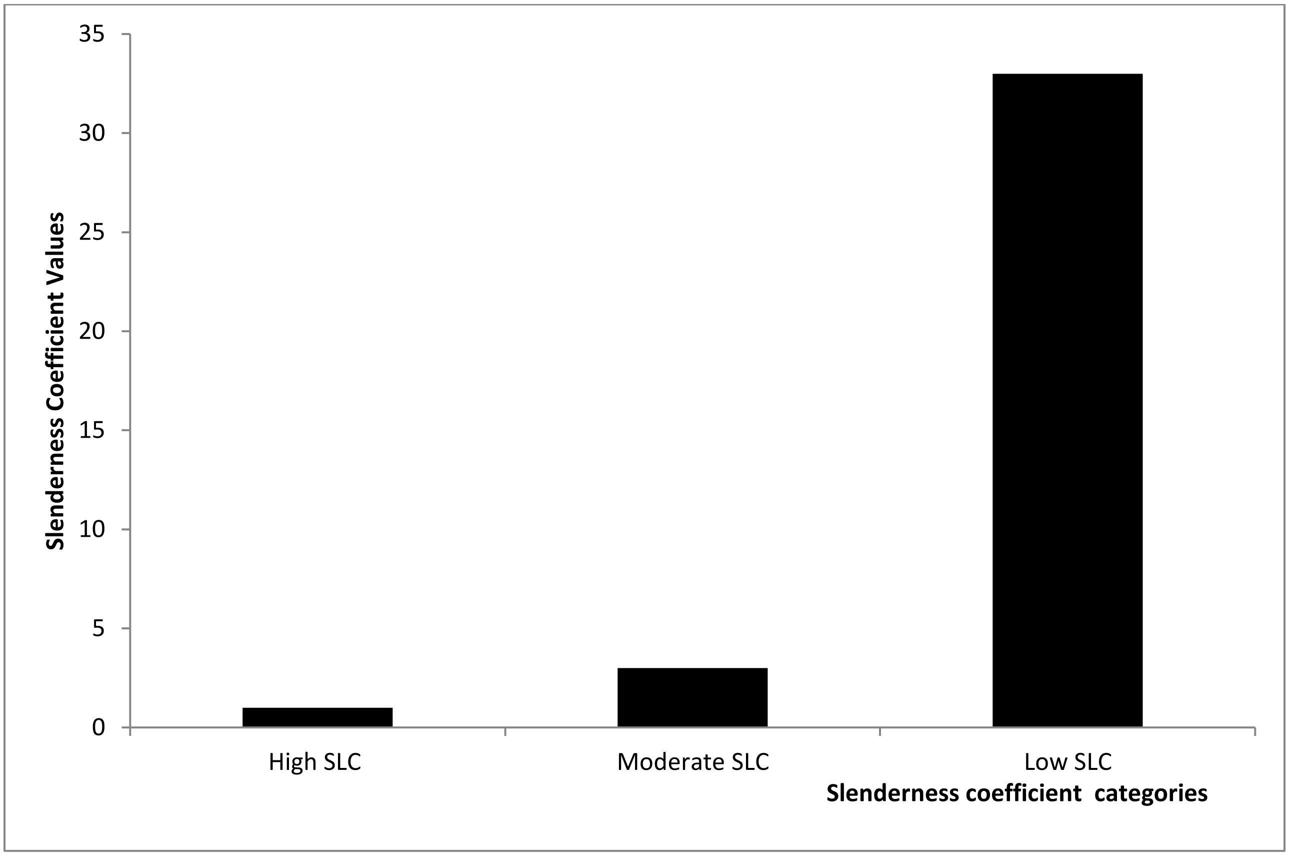

Fig 3: Graph of Slenderness Coefficient values of the tree species

Also, Adeyemi and Ugo-Mbonu (2017) had revealedin their study that the high percentage of trees with low SLC may be a result of adequate silvicultural treatments such as thinning at the early stage of stand development. According to Liu *et al*. (2003), when tree slenderness coefficient becomes very high, there is possibility of exposure of such trees to bending stress, leading to reaction wood, which may affect wood properties as well as the ultimate usage to which the wood can be put. *Gmelina arborea* stands in Federal University of Agriculture, Abeokuta appeared to be growing unhindered and with less stress. This result is also similar to the results of studies reported by Peltola (2006) and Teste and Lieffers (2011).

The result of Correlation Matrix Analysis

The results of correlation analysis among growth characteristics of *Gmelina arborea* and tree slenderness coefficient (SLC) is presented in Table 2. A low negative correlation value (0.162) was obtained between slenderness coefficient and tree stem height. This indicates low impact of this tree attribute on the tree slenderness coefficient which implies that there is no significant effect on the tapering of the *Gmelina arborea* in the study area. This trend was in agreement with the reports of several authors on the growth attributes and management scenarios for plantation species in Southwest, Nigeria (Onifade 1998; Onyekwelu, 2001; Onyekwelu *et al.*, 2003;Oyebade *et al.*, 2015 and Onilude *et al*., 2017). However, the negative coefficients of correlation (r) observed for Diameter at breast height (Dbh), Basal area

(BA) and volume (Vol)indicated inverse relationship, which indicated that as the individual trees of *Gmelina arborea* slender up the stem (decrease), the DBH, BA and Volume of the trees increases (Table 2).

A smaller slenderness coefficient is usually indicating a higher resistance to windthrow, the relationships suggest that silvicultural treatments, such as producing long-crowned trees, and maintaining appropriate stand density through spacing, thinning, or gradually harvesting overstory trees, can be helpful in reducing the risk of wind throw.

Table 2: Correlation Matrix of the Tree growth characteristics

Variables	DBH (cm)	THT(m)	BA (m^2)	Vol (m^3)	SLC
DBH (cm)	1				
THT (m)	0.678*	1			
Canopy (m)	0.525*	0.561*			
BA(m^2)	0.949*	0.468*	1		
Vol (m^3)	0.969*	0.626*	0.968*	1	
SLC	-0.633*	-0.162	-0.578*	-0.551*	1

Note: DBH- Diameter at breast height, THT- Total height, BA – Basal Area, Vol- Volume, SLC – Slenderness coefficient

Conclusion and Recommendation

Deforestation and degradation have been a major and crucial challenges in tree species growth monitoring in Nigeria. This study showed the capability of tree species in the Federal University of Agriculture Abeokuta arboretum to withstand wind throw during high velocity wind and the mean annual increment of the trees. Measured growth variables revealed average slenderness coefficient value (SLC) to be 53.07 $\pm$ 3.03 with the majority of the trees having low slenderness coefficient (ability to withstand wind throw). The mean annual increment (MAI) for the trees is 1.73 $\pm$ 0.01cm/yr. In addition, majority of the tree species are in higher diameter size classes indicating trees with high diameter at breast height are predominant of the *Gmelina arborea* in the arboretum. This shows restricted anthropogenic activities in the arboretum. Knowledge obtained from the study could be useful in the sustainable management of the garden and similar protected areas in tropical regions.Therefore, sustainable use through conservation and protection of this species will go a long way in making this species available on sustainable scale.

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