

Growth characteristics of *Nauclea diderrichii* (De Wild.) Merr. in unthinned plantations in south-western Nigeria

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1. Introduction

The area under forest plantation is increasing in the tropics, the rate of increase being dramatic, especially in the past two decades, during which the annual rate of establishment was between 2 to 3 million hectares (Evans 1998). This trend is expected to continue during the next decades.

Most plantations are managed to optimise yield of wood within a short time. This led to familiarise the use of fast growing trees species. In Africa, both exotic and indigenous species have been planted, with exotic species dominating (Pandey 1995). This is particularly true of Nigeria where exotic species account for over 80% of total plantations (Onyekwelu 2001). The dominance by exotic species is attributed to their ease of establishment, rapid growth rate and consequently short rotation length. However, there is empirical evidence that local consumers in Nigeria have higher preference for the products of indigenous species (Akindele and Fuwape 1998; Onyekwelu 2001). *Nauclea diderrichii* is the dominant indigenous plantation species in Nigeria. Although records indicate that until the 1960s, *Nauclea* was one of the dominant plantation in Nigeria (FAO 1981), the advent of large-scale plantations with exotic species led to a situation where *Nauclea* was neglected. Consequently, little emphasis was devoted to understand its growth characteristics and to develop thinning strategies for its plantations. To achieve positive and substantial response of residual trees to thinning, formulation of management strategies must be based on good understanding of individual trees and stand growth processes. Where silvicultural interventions have been administered without a good knowledge of growth characteristics, bad management decisions were made with some adverse effects on stand productivity and end products. The aim of the present study is to investigate the growth characteristics of unthinned *Nauclea* plantations in Omo forest reserve and therefrom derive silvicultural implications.

2. *Nauclea diderrichii* in Nigeria

2.1. *Distribution and site conditions*

Nauclea is indigenous to the moist tropical forest of West Africa (e.g. Nigeria, Ghana, Ivory coast, Liberia and Equatorial Guinea), Central Africa (Cameroon, Central African Republic, Congo and Gabon) and some parts of eastern Africa (Uganda and Mozambique) (Keay 1989, Leakey et al 1990, Hawthorne 1995a, Koch 1999, Wagenführ 2000). It grows well in the humid tropical rainforest forest, where annual rainfall ranges from 1600 to 3000 mm (Dupuy and Mille 1993, FORMECU 1999) and the soil is deep, shallow and well drained. Soil texture in these regions encompasses loamy sand, sandy loam, silty sand, sandy clay loam, sandy clay and clay. Soil pH ranges from 4.6 to 6.5, although wider range of 4.1 to 7.6 has been reported for its natural habitat (FORMECU 1999). *Nauclea* is rarely found outside its natural habitat.

2.2. *History of Nauclea diderrichii* in Nigeria

Nauclea diderrichii is indigenous to Nigeria. It was one of the 22 trees species identified in the early stage of forestry practice in Nigeria as a tree species of major economic importance (Redhead 1971). Thus, it has been under intense exploitation from the end of the 19th century till date. Today, *Nauclea* is rare in the natural forests. Consequently it has been rated as vulnerable and endangered tree species and its exploitation has been prohibited in some states in Nigeria (Hawthorne 1995b; Akindele and Fuwape 1998; FORMECU 1999). The history of *Nauclea* in Nigeria is purely that of series of silvicultural attempts that have been made towards regenerating it. Although its natural regeneration has been described as very good and easy (Dupuy and Mille 1993, FORMECU 1999), regeneration under the natural tropical forest in Nigeria has not been successful, due partly to the complexity of the tropical forest and the multiplicity of the species in it. Attempts to regenerate *Nauclea* systematically in the natural forests were completely given up in the 1960s and attention was subsequently shifted to regenerating it through artificial means. *Nauclea* was among the first indigenous plantation tree species to be planted on a large-scale in Nigeria and until the mid 1940s, was among the dominant plantation species in southern Nigeria (Horne 1966; Anon 1971; Lowe 1977; Ball 1979; FAO 1981). However, the evolution of fast growing exotic species (especially *Gmelina*) as the most preferred plantation tree species from the mid 1960s till date, resulted to a serious setback in further establishment of *Nauclea* plantations. Consequently, only very little plantations of the species were established in the 1970s and virtually non was established throughout the 1980s. However, in recent years, attention has been redirected towards the

indigenous plantation tree species. For example, the ADB Forestry IIB Project (1987 – 1996) in Oluwa and Omo forest reserves promoted small-scale plantation trials with indigenous tree species and *Nauclea* was one of the choice species. A total of about 1,354 ha of plantations of indigenous species was established by these trials, with *Nauclea* accounting for about 60% of this total.

2.3. Morphology

Nauclea diderrichii (De Wild.) Merr. belongs to the family of Rubiaceae. It is an evergreen tree species, native to moist evergreen forests and transitional to semi-deciduous forests (Dupuy and Mille 1993). Some of its local names are: Opepe in Nigeria, Badi in Ivory Cost, Kusia in Ghana and Bilinga in Gabon (Anon. 1997b; Wagenführ 2000). The stem is of good form, slender, straight, usually branchless and cylindrical (Figure 1a) up to a height of between 24 and 30 m and has low or no buttresses (Keay 1989; Hawthorne 1995a; Anon. 1997b; Wagenführ 2000). The branches are often horizontal and in whorls and are not very heavy. *Nauclea* has a broad spherical crown that is rounded, with a thick foliage (Keay 1989, Dupuy and Mille 1993). The leaves are glabrous and thin, 7.5 – 15 cm long and 3.5 – 10 cm broad. The flowers of *Nauclea* are yellowish-white, crowded in spherical heads and are 1 – 3 cm long. The species fruits between May and June as well as between November and January (Keay 1989). The fruits (Figure 1c), which are fleshy, fibrous cylindrical masses, are about 3 – 4 cm in diameter and are covered with polygonal honeycomb (Dupuy and Mille 1993) and orange in colour. The fruits are edible by both man and animals. Many small seeds are found in the fruit (WCMC 2000).

2.4. Regeneration

Nauclea is a light-demanding species (Dupuy and Mille 1993; FORMECU 1999; WCMC 2000). It is a pioneer species that requires abundant light to regenerate. Natural regeneration of *Nauclea* has not been studied much, thus information in this aspect is very scanty. It has been reported to regenerate well in large canopy gaps and openings in the forest, but in clear-felling, regeneration is virtually absent (Dupuy and Mille 1993; FORMECU 1999). Hawthorne (1995a) reported that seedlings of *Nauclea* are commonly found along the tracks of large animals e.g. Elephants. It is thought that the passage of the seeds through the animal's gut has effect on the germination of the seeds, but this effect has not been studied and thus unknown (Hawthorne 1995a; WCMC 2000). Efforts to regenerate *Nauclea* and other indigenous tree species in Nigeria through such regeneration methods as the Tropical

Shelterwood System (TSS) or enrichment planting did not yield encouraging results. However, this failure was not tree-species-specific but had to do with the regeneration method(s) and their implementation on the one hand and the complexity of the natural forests on the other. It regenerates easily from seeds and cuttings, which has contributed to its success in plantations (Abayomi 1983; Akindele and Abayomi 1993; Dupuy and Mille 1993). The species also coppices very well.

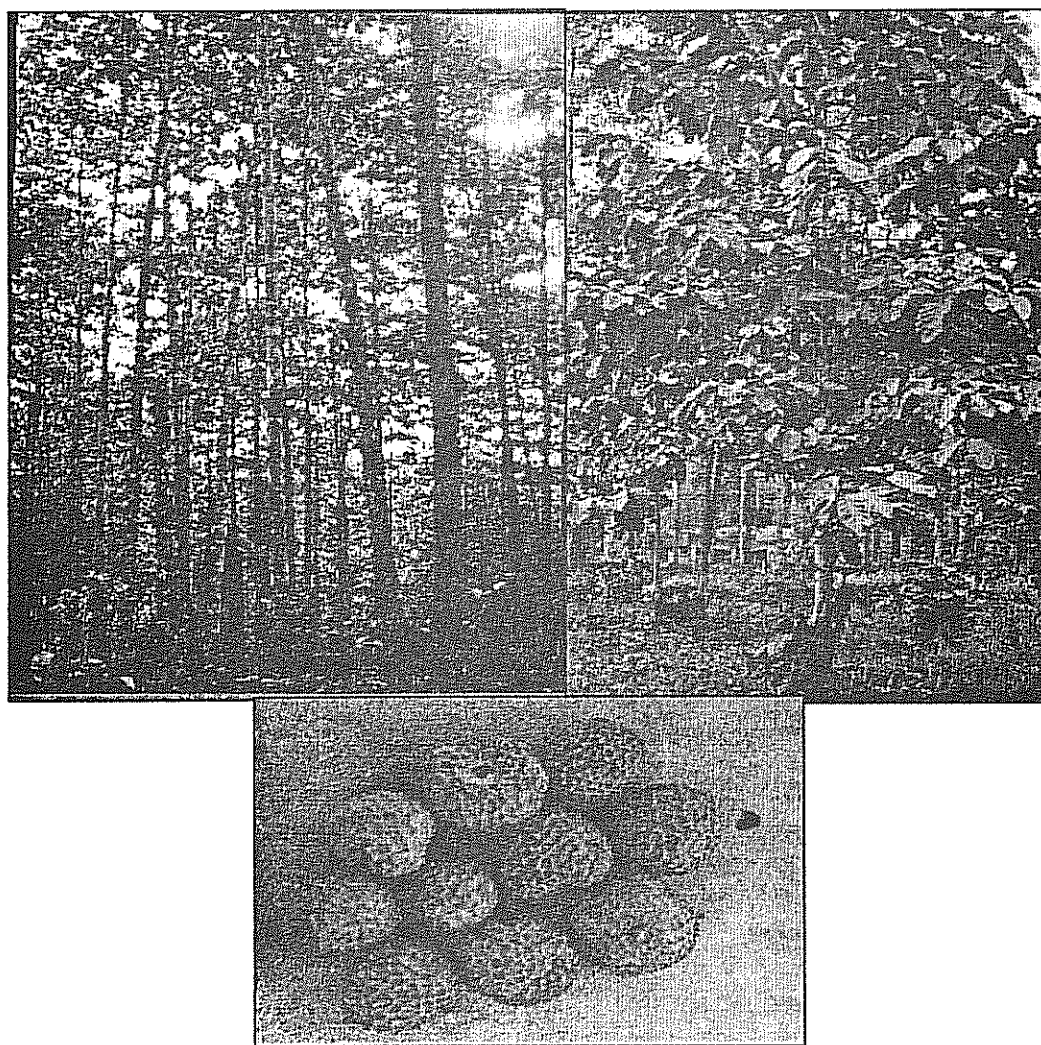


Figure 1: 9-year old *Nauclea* plantation (a), coppice growth of *Nauclea* (b), and fruits of *Nauclea* (c)

Artificial regeneration (plantations) of *Nauclea* has become very popular and necessary due to the difficulty of regenerating it naturally as well as the problem of extinction, which the species faces. Artificial regeneration is about the only hope of ensuring that the valuable timber of this species is available. The success of artificial regeneration of the species has been attributed to the following factors (Matin 1989; Leakey et al 1990; FORMECU 1999): yearly production of sufficient quantity and good quality seeds, easy propagation from seeds and cuttings (vegetative propagation), and good coppicing ability (see Figure 1b).

2.5. Properties of *Nauclea* wood

Nauclea wood is hard and very attractive. According to the classification of the Nigerian Standards Organisation, it is one of the strongest woods in Nigeria, having been classified into the strongest strength group (NCP 1973). Naturally, it is very durable, the heartwood being resistant to attack by marine borers and termites (NCP 1973; Wagenführ 2000). However, the sapwood may be liable to powder post beetle attack. The heartwood, which usually darkens on exposure, is orange to golden yellow in colour while the sapwood, which is clearly defined, is whitish to pale yellow in colour (Chudnoff 1984; Keay 1989). This striking colour of the wood, together with its figure, is reported to give *Nauclea* wood a very attractive appearance (Anon. 1997b). At between 12 and 18% moisture content, density of the wood ranges between 750 and 900 kg m⁻³, while at saturated moisture content, density could range from 950 to 1100 kg m⁻³ (NCP 1973; Koch 1999; Wagenführ 2000). Specific gravity of the wood is about 0.63. The texture of the wood is coarse, the grain is usually interlocked or irregular and produces an attractive ribbon or rope figure (Anon. 1997a). While the sapwood is permeable to impregnation, the heartwood is moderately resistant. *Nauclea* wood has a high dimensional stability and exhibits only small movement in service. Tangential, radial and volumetric shrinkage are small, being an average of 8.4, 4.5 and 12.6%, respectively (Chudnoff 1984; Anon 1997b; Wagenführ 2000). Manual and machine working of *Nauclea* wood is good. Gluing, nailing, planing, polishing, vanishing, moulding, carving, and sanding have been reported to be easy and satisfactory (Anon 1997b; Wagenführ 2000).

3. Study to assess the growth characteristics of *Nauclea diderrichii*

3.1. Methodology

A study was carried out to assess growth characteristics of *N. diderrichii* in unthinned even-aged plantations in Omo forest reserve in the humid tropical rainforest zone of south-western Nigeria. The reserve is situated between latitude 6° 35' and 7° 05'N and longitude 4° 05' and 4° 40'E, at 123 m above sea level. The climate is characterised by high temperatures and well distributed high annual rainfall (annual rainfall: 1,750 to 2,200 mm; mean annual temperature: 26.5°C; average daily relative humidity: 80%). Dry season begins in December and ends in February while rainy season spans from March to November. Soils were formed from crystalline rocks of undifferentiated basement complex of the pre-cambrian series (Anon. 1964). They are predominantly ferruginous tropical, typical of the variety found in rainforest regions of south-western Nigeria. The soils are well-drained, mature, red, stony and gravelly in

the upper parts of the sequence (Smyth and Montgomery 1962). The texture of the topsoil is loamy and sandy, subsoil consists of clay with gravel at 30-60 cm depth.

In Omo forest reserve, ten plantations of *Nauclea diderrichii* spanning from the youngest to the oldest over 25 years (from age 5 to age 30) were randomly selected. Each plantation was divided into sections of one-hectare equivalent, from which three were randomly selected, making a total of 30 sections of different ages. A 25 m x 25 m temporary sample plot was laid at the center of each section. Within each plot, measurements of various growth parameters (total height, crown height, and diameter at base, at breast height (dbh), and at crown point) were made on all trees. In addition, the crown class whether is free or suppressed and the stem form whether is single or forked below breast height were recorded for each tree.

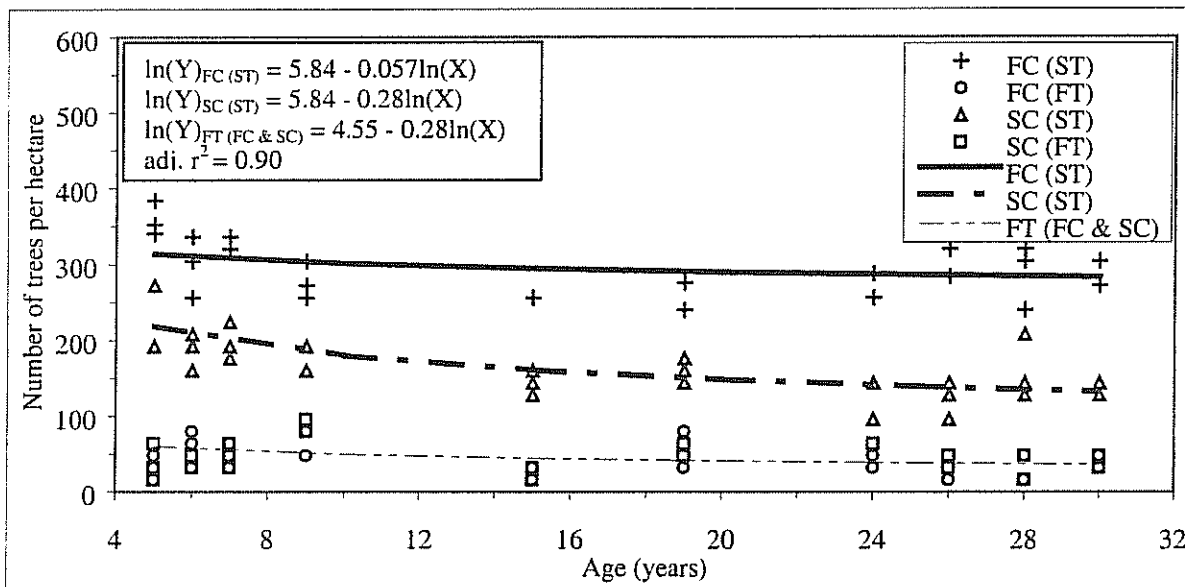
The statistical analysis of the data was based on the concept „Analyses for Evaluation of Silvicultural measures“ (El Kateb 2000) and the Programme „SaNaucleaGmelina_WBFE“ (Lehrstuhl für Waldbau und Forsteinrichtung 1999). Relationship(s) between important growth parameters were investigated for four strata including the two crown classes and the two stem forms. Different hypotheses to compare the regression equations of the four strata whether they are coincident or parallel were tested (for more details see Onyekwelu 2001).

3.2. Results and discussion

In even-aged stands, differences in seedling performance sort trees into crown classes, which could be a result of competition, genetic differences between seedlings, damage to seedlings and differences in initial size of seedlings (Evans 1992; von Euler et al 1992). Two distinct crown classes were encountered in *Nauclea* stands in Omo. This is in consonance with the observations of Evans (1992) for tropical plantations. The initiation of crown classes is affected by the productive capacity of a site, planting density, and growth rate and commences after canopy closure. In *Nauclea* stands in Omo, canopy closure would have occurred between 3 and 4 years. After crown canopy closure, growth and vigour of trees are strongly correlated with crown class as e.g. Xu and Harrington (1998) reported from loblolly pine stands.

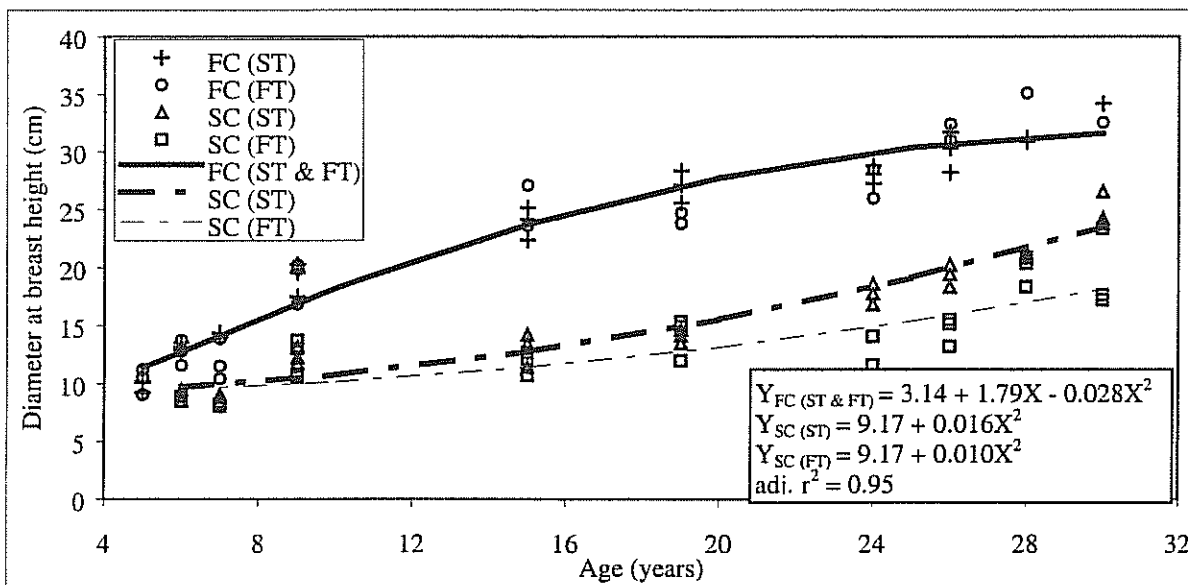
Survival rate of the *Nauclea* plantations in Omo forest reserve with initial number of 625 seedlings ha⁻¹ (spacing of 4 m x 4 m) ranged between 84 and 100% in young plantations between 5 and 9 years. Mortality was highest at the middle age (10 – 16 years) of stand development and survival rate stabilised in the older stands (over 19 years) and ranged between 70 and 80%. The trend of survival rate of *Nauclea* plantations in Omo agreed with

that published by Fonweban et al (1994) for *Nauclea* stands in Cameroon. **Density** in the strata was significantly different (Figure 2). In average about 62% of all trees were in the free crown class, of which about 4% were forked. Density of forked trees was approximately equal in both crown classes. Single trees in the understory made about 33% of all trees. In the course of stand development, more trees (four times) died in the understory and will probably continue to die, unless they are salvaged or released. High mortality in the understory was due to density-induced mortality or self-thinning in which suppressed trees die due to competition.



FC, SC, ST and FT = Free crown, Suppressed crown, Single trees and Forked trees, respectively

Figure 2: Nnumber of trees ha^{-1} in *Nauclea diderrichii* plantations of different age

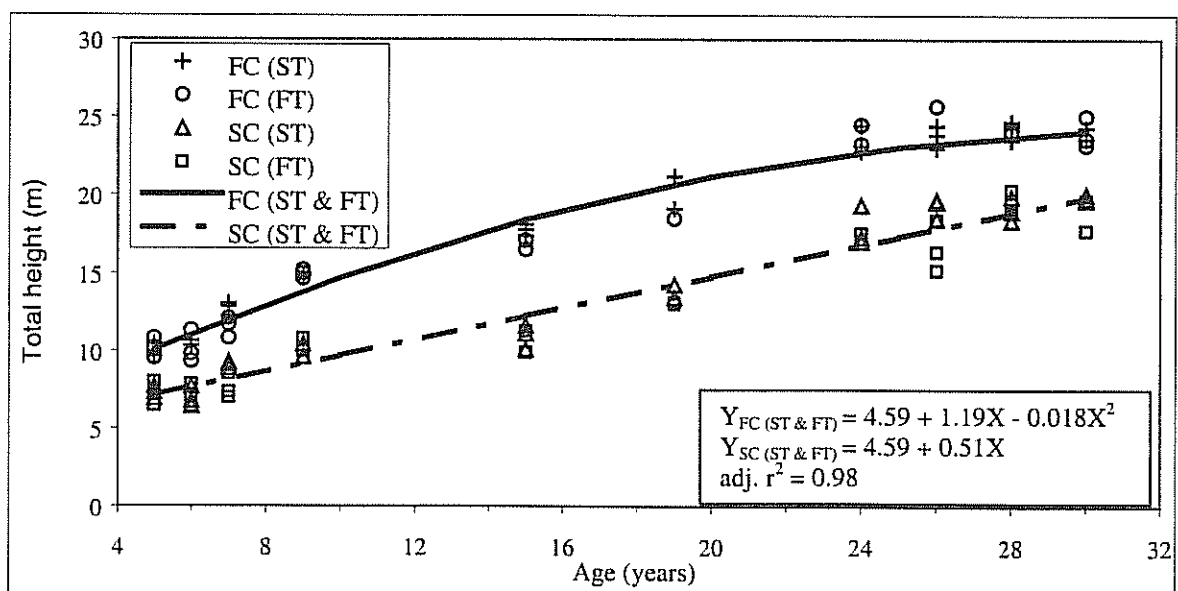


FC, SC, ST and FT = Free crown, Suppressed crown, Single trees and Forked trees, respectively

Figure 3: Stand dbh development in *Nauclea diderrichii* plantations

The average **forking** rate of all stands under investigation was over 8% and was lower in the older stands (trees forked into 2 to 4 stems but two forks were prevalent). However, as can be seen from Figure 2 forking persisted for a long time. Forking of stems is an undesirable characteristic in forest stands. The cause of forking as well as its effect on growth and yield is little known. It could be inherently controlled by a tree's genetic potentials, damage of terminal meristem of the initial trunk, disruption of growth pattern of the tree and water stress (Halle et al. 1978).

Maximum **diameter at breast height** (dbh) of individual trees was about 15 and 52 cm at 5 and 30 years, respectively. Mean stand dbh increased from 11 cm at 5 years to 29 cm at 30 years. While mean dbh in the study area is within the range reported by Dupuy and Mille 1993, it is a little lower than what was reported for the species by Fonweban et al 1994 and Akindele and Abayomi 1993. In the free crown class, stand dbh of single and forked trees were equal (Figure 3). On the contrary, in the suppressed crown class single trees had higher stand dbh (Figure 3). The 25-year periodic dbh increment (i.e. between 5 and 30 years) was 20 and 14 cm in the free and suppressed crown classes respectively. Mean annual dbh increment ranged from 0.5 to 2.3 cm year⁻¹. It culminated between ages six and nine years in both crown classes, after which it decreased with further increase in age.



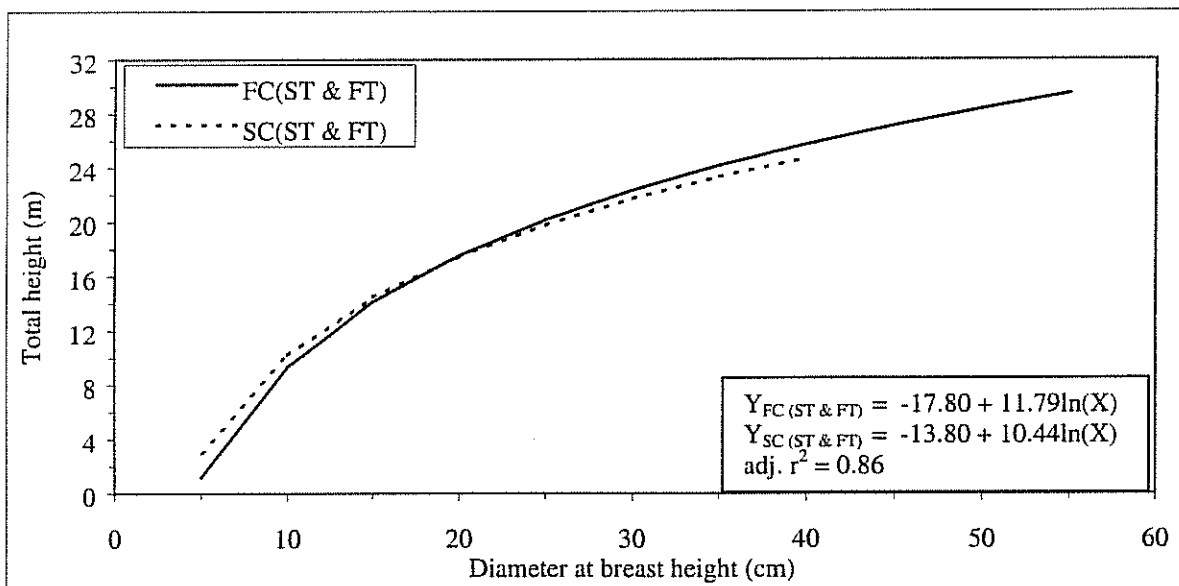
FC, SC, ST and FT = Free crown, Suppressed crown, Single trees and Forked trees, respectively

Figure 4: Stand height development in *Nauclea diderrichii* plantations

Maximum **height** of individual trees was 13 and 30 m at ages 5 and 30 years. The mean height of 6 and 9 m between ages 4 and 6 years and top height of 21 and 32 m at 12 and 33 years reported for the species (Akindele and Abayomi 1993; Dupuy and Mille 1993; Onifade

1998) is consistent with the result of the present study. Stand height development in the two crown classes differed significantly, with trees in the free crown class having higher height (Figure 4). While stand height growth tended to stabilise in the free crown class beyond 20 – 22 years, it appeared to be active in the suppressed crown class up to 30 years (Figure 4). Within each crown class, single and forked trees had equal stand height. In both crown classes, mean annual height increment (MAI_h) was highest at 5 years, after which it decreased with further increase in age. MAI_h tended towards becoming equal in both crown classes as the stands aged.

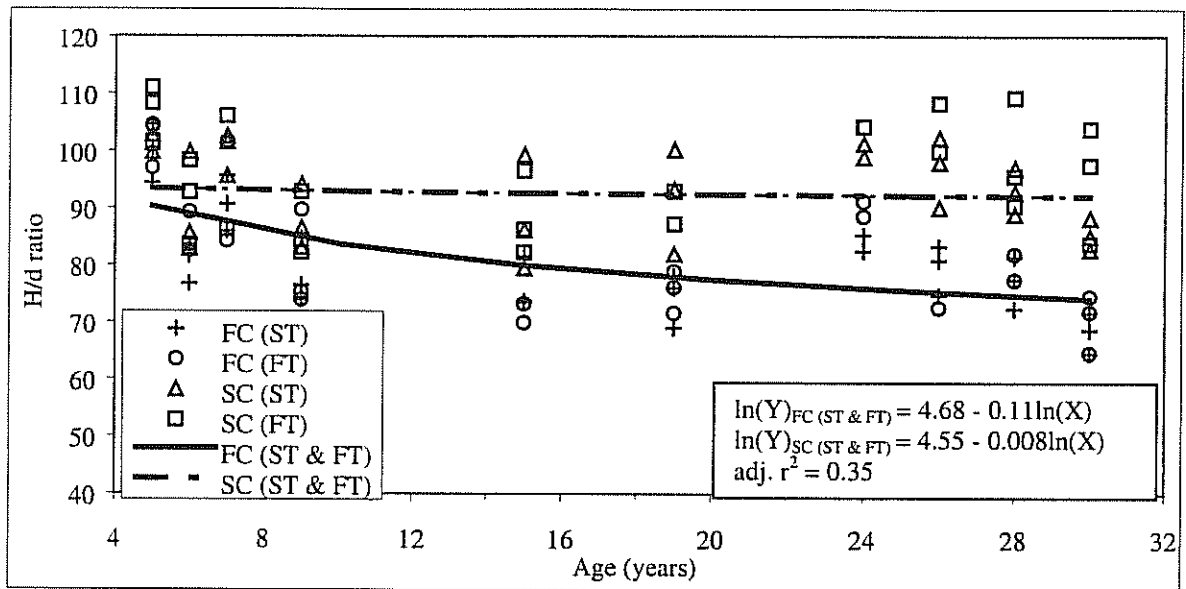
The height curve of individual trees is presented in Figure 5. Only slight but statistically significant difference existed between the height curve of individual trees in both crown classes. The difference is attributed to response of suppressed trees to competition (see Naidu et al 1998; Ishii et al 2000). In attempt to reach the canopy and avoid being overtopped, suppressed trees make investments in height growth a priority (Nilsson and Albrektson 1993).



FC, SC, ST and FT = Free crown, Suppressed crown, Single trees and Forked trees, respectively

Figure 5: Height curve of individual trees in *Nauclea diderrichii* plantations

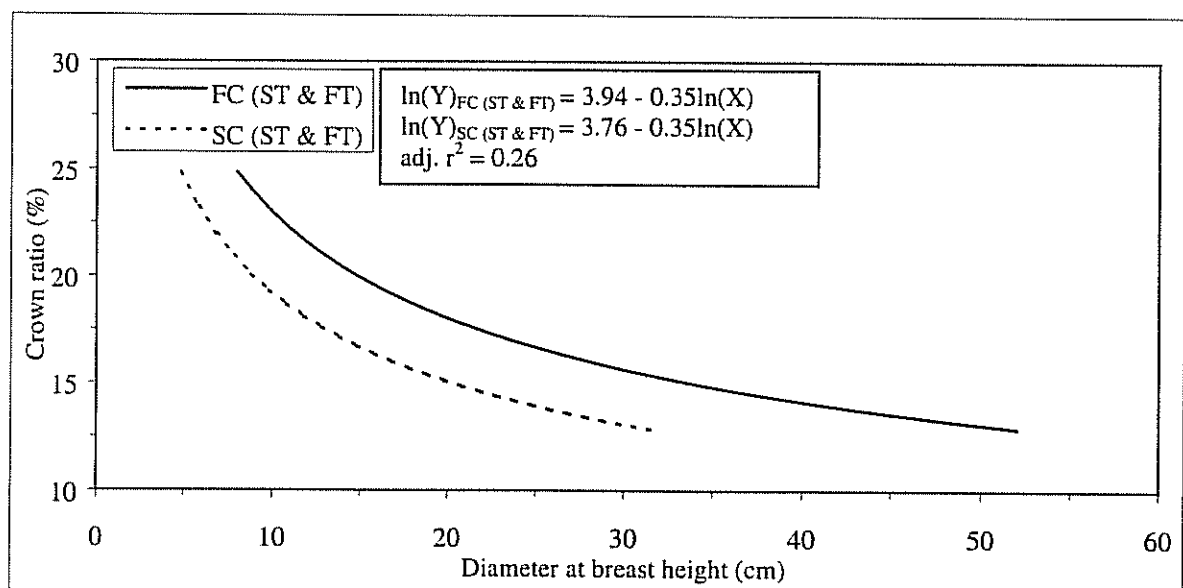
Height-diameter ratio (h/d) is a measure of slenderness, an indication of growth vigour and ability of trees to resist wind or snow damage (Navratil 1995; Wilson and Baker 2001), the lower the ratio, the more stable the tree. H/d ratio of individual trees ranged between 52 and 143 and was higher for small dimension trees and young stands, indicating that bigger and older trees are more stable than smaller and younger ones. Within each crown class, h/d ratio of single and forked trees were equal. In young stands (e.g. 5 years), h/d ratio in both crown classes were equal. While it decreased with increasing age in the free crown class, h/d ratio remained about the same by 93 in the suppressed crown class across all ages (Figure 6).



FC, SC, ST and FT = Free crown, Suppressed crown, Single trees and Forked trees, respectively

Figure 6: Stand h/d ratio development in *Nauclea diderrichii* plantations

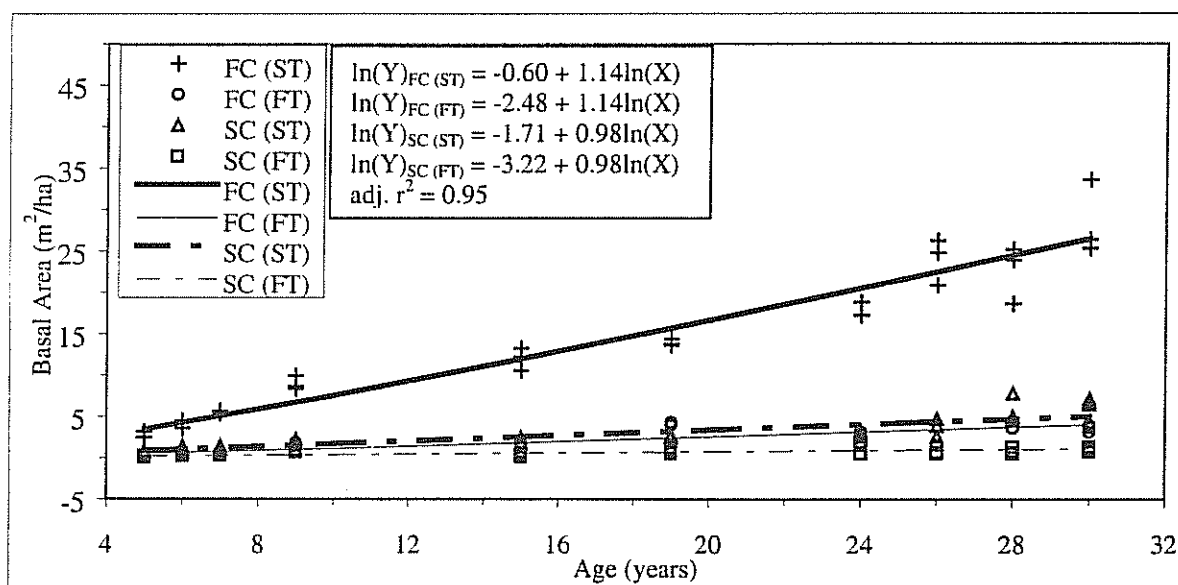
Stem taper ratio (ratio of diameter at crown point to diameter at base) increased with dbh in both crown classes. The tendency of *Nauclea* trees to become more cylindrical as their dimension (dbh) increased is in harmony with the results of Muhairwe (1994). Irrespective of crown class, single trees had the same taper ratios, which is also true for forked trees in both crown classes. Single trees had, however, higher taper ratios than forked trees. High stem taper ratio indicates a cylindrical stem and low ratio the reverse.



FC, SC, ST and FT = Free crown, Suppressed crown, Single trees and Forked trees, respectively

Figure 7: Relationship between crown ratio and dbh of individual trees in *Nauclea diderrichii* plantations

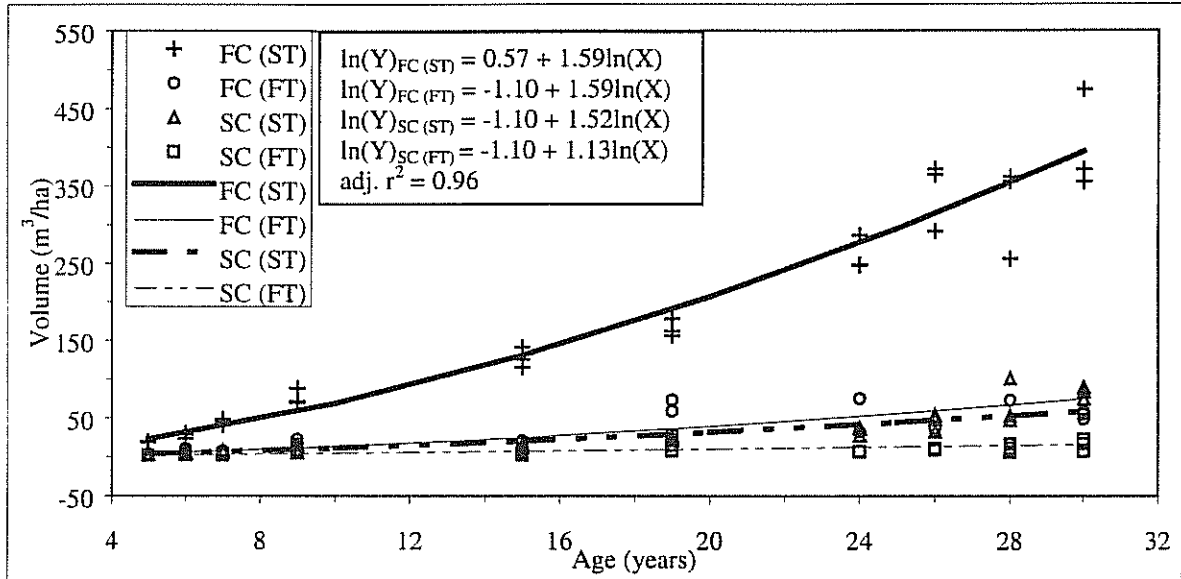
Crown ratio (ratio of crown height to total height) strongly influences light interception and tree growth (Assmann 1970). Crown ratio of individual trees decreased with increase in dbh (Figure 7). At any given dbh value, crown ratios of trees in the free crown class were higher than those of trees in the suppressed crown class. The higher crown ratio of trees in the free crown class indicates that they have greater ability to intercept light as well as greater biomass production. Within each crown class, crown ratios of single and forked trees were equal (Figure 7). Mean of stand crown ratio decreased from about 24% at 5 years to 14% at 30 years indicating that there was a necessity of early thinning.



FC, SC, ST and FT = Free crown, Suppressed crown, Single trees and Forked trees, respectively

Figure 8: Stand basal area development in *Nauclea diderrichii* plantations.

Standing **basal area** was about $5 \text{ m}^2 \text{ ha}^{-1}$ and $37 \text{ m}^2 \text{ ha}^{-1}$ in 5 and 30 years stands, respectively. While Dupuy and Mille 1993 published stand basal area for *Nauclea* similar to the results of the present study, other authors (Fonweban et al 1994; Onifade 1998) published higher figures, which can be attributed to different initial number of trees in their studies. As the free crown class included the higher number of trees with bigger individuals, a very high percentage of about 81% of total basal area was accounted for the free crown class (Figure 8). This pattern has been established in other stands, too. For example, Fuhr et al 2001 reported about 71% of total basal area in dominant tree class in *Aucoumea klaineana* plantations in Gabon. In both crown classes, a very high percentage (87 and 82% in the free and suppressed crown classes, respectively) of basal area was stored in single trees (Figure 8). Interestingly, single trees in the free crown class alone accounted for a remarkably high percentage of 71% of stand basal area.



FC, SC, ST and FT = Free crown, Suppressed crown, Single trees and Forked trees, respectively

Figure 9: Stand volume development in *Nauclea diderrichii* plantations

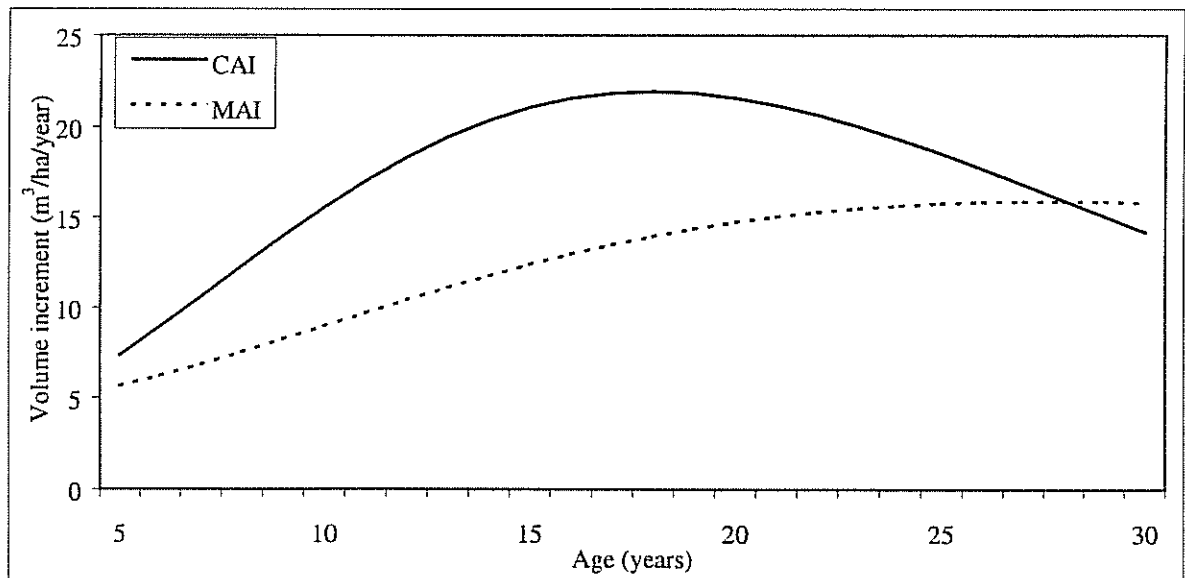


Figure 10: Current (CAI) and mean annual volume increment (MAI) in *Nauclea diderrichii* plantations

Most of the **volume** of individual trees was concentrated in the stem (range: 94.4 to 99.8% of total tree volume). Standing volume increased from 31 m³ ha⁻¹ at 5 years to 497 m³ ha⁻¹ at 30 years. Like basal area, a high percentage (average of 85%) of volume was accumulated in the free crown class (Figure 9). This is similar to the findings of Nilsson and Albrektson 1993, who reported about ten times higher volume in dominant trees. Within each crown class, most of the volume was stored in single trees (Figure 9). In the free crown class, single trees accounted for 84% of stand volume across all ages while in the suppressed crown class, between 65 and 79% of stand volume were accounted for by single trees. Mean annual

volume increment (MAI) ranged from 5.7 to 15.9 m³ ha⁻¹ year⁻¹. It culminated at about 28 years (Figure 10). After culmination, MAI decreased with further increase in age. However, MAI was approximately equal between the ages of 23 and 30 years (Figure 10).

3.3. *Silvicultural implications of the results*

In comparison to such tropical plantation species as *Gmelina*, *Eucalyptus* spp and *Terminalia ivorensis*, *Nauclea* has moderate growth rate. It has the potentials of attaining a total height of about 50 m and diameter of between 80 and 180 cm (Chudnoff 1984; ITTO 1986; Keay 1989; Koch 1999; Wagenführ 2000). However, this exceptional height and diameter growth has only been reported with regards to the species in natural forests. Information in literature on the growth characteristics of *Nauclea* in plantations are scanty. In plantations, *Nauclea* tree has been reported to grow to a height up to 1.7 and 7.0 m after 1 and 4 years of establishment, respectively (Dupuy and Mille 1993). *Nauclea* can attain mean dbh growth of about 10 and 35 cm after 6 and 33 years, respectively (Onifade 1998; Akindele and Abayomi 1993). Mean annual increment of between 3.7 and 15.4 m³ ha⁻¹ year⁻¹ has been reported (Onifade 1998).

The approximately equal MAI between 23 and 30 years implies that rotation age for timber production in *Nauclea* stands could lie within this age range, which is in agreement with what is in practice. Depending on site quality, Dupuy and Mille (1993) recommended rotation age of 30 to 40 years. FORMECU (1999) recommended 23 years for the best site. However, 23 years does not seem appropriate because trees that will be produced at this age will be small dimension logs, which are not currently processed in sawmills in Nigeria because the current processing technology is only suitable for large dimension logs (Onyekwelu 2001). With adequate silvicultural treatment, trees that will meet the timber size requirements of sawmills in Nigeria will be obtained during 30 years rotation.

The low stand crown ratio is an indication of crown recession, the need for more growing space and the necessity for thinning. Although a crown ratio threshold limit, below which *Nauclea* plantations are to be thinned is lacking, published information shows that generally stands should be thinned once crown ratio falls below 30%. Consequently, the low crown ratio in 5 years old plantations implies that early thinning is essential in *Nauclea* stands. Also, the drastic decrease in mean annual dbh increment beyond the age of 9 years indicates the necessity for early thinning operation, which is the view of other researchers (Dupuy and Mille 1993; FORMECU 1999). However, in administering early thinning, care must be taken not to remove high number of trees due to the high stand h/d ratio of young plantations, which suggests that young *Nauclea* stands are generally unstable. The removal of high number of

trees during a single operation will probably increase susceptibility of residual stands to damage by wind or rainstorm.

Since one of the aims of thinning is to improve the quality of residual trees, quality criteria should be used in choosing trees to be removed during thinning operations. Since results showed that single trees have better stem quality (more cylindrical stems) than forked trees, forked trees in the free crown class, which are the strongest competitors with single trees in the free crown class, should be removed first. The fact that single trees in the free crown class exhibited good growth potentials, good stem quality, good stability and accounted for higher portion of stand volume and basal area, implies that a large amount of volume will be harvested at the end of rotation, apart from the good quality end product that will be obtained at the end of rotation if their growth is promoted through thinning,. Thus, in the event of poor market for thinning products, the loss by the plantation owner will not be considerable.

4. Perspectives

At present the establishment of plantations with indigenous species is declining. As our study demonstrates there is a considerable potential in *N. diderrichii*. An extended cultivation of *N. diderrichii* in plantations is recommended, provided that proper thinning regimes, e.g. which aim to increase the production of valuable timber assortments, are applied.

5. Summary

Nauclea diderrichii is one of the most important indigenous species used in plantations in Nigeria. After a short description of *N. diderrichii* in Nigeria the results of a study concerning the growth characteristics of unthinned even-aged *N. diderrichii* plantations in south-western Nigeria are presented. Trees in plantations were stratified into free and suppressed crown classes and within each crown class, trees were grouped into single and forked stems, giving a total of four strata. Growth assessment was conducted for trees within the four strata. Generally, there were more single trees than forked trees. Mortality was about four times higher in the suppressed crown class. In average, stem forking was 8%. Forked trees were less cylindrical than single trees. *Nauclea* trees attained mean dbh of 29 cm and height of 23 m after 30 years of growth. Mean annual dbh and volume increments ranged from 0.5 to 2.3 cm year⁻¹ and 5.7 to 15.9 m³ ha⁻¹ year⁻¹, respectively. Growth of trees in the two crown classes differed significantly. Trees in the free crown class exhibited better growth characteristics than those in the suppressed crown. Results showed the necessity of early thinning of the plantations under investigations.

6. Zusammenfassung

Wachstum von *Nauclea diderrichii* (De Wild.) Merr. in undurchforsteten Plantagen Süd-West-Nigerias

Nauclea diderrichii ist eine der wichtigsten einheimischen Baumarten in nigerianischen Plantagen. Nach einer Kurzbeschreibung von *N. diderrichii* in Nigeria werden die Ergebnisse einer Studie zum Wachstum der Art in undurchforsteten, gleichaltrigen Plantagenbeständen Süd-West-Nigerias vorgestellt. Alle Bäume in den Plantagen wurden in zwei Kronenklassen eingeordnet, je nachdem, ob sie in der oberen, herrschenden Kronenschicht vertreten oder unterdrückt waren. Innerhalb jeder Kronenklasse wurden die Bäume in einstämmige oder zwieselige Individuen gruppiert. Damit wurden insgesamt vier Straten gebildet. Zur Beurteilung des Wachstums der Bäume wurden für jeden Baum innerhalb dieser Straten verschiedene ertragskundliche Kenngrößen ermittelt.

Im allgemeinen gab es mehr einstämmige als gezwieselte Individuen. Im Durchschnitt wiesen 8 % der Individuen Zwieselbildung auf; die gezwieselten Bäume waren weniger zylindrisch. Die Mortalität in der unterdrückten Kronenklasse war viermal so hoch als in der herrschenden. Im Alter von 30 Jahren erreichten *Nauclea*-Bäume einen mittleren BHD von 29 cm und eine mittlere Höhe von 23 m. Der durchschnittliche jährliche Dickenzuwachs (BHD) reichte von 0,5 bis 2,3 cm; der durchschnittliche jährliche Volumenzuwachs lag zwischen 5,7 und 15,9 m³. Das Wachstum der Bäume in den verschiedenen Kronenklassen war signifikant verschieden, wobei Bäume der herrschenden Klasse ein besseres Wachstumsverhalten aufwiesen. Die Resultate unterstreichen die Wichtigkeit von frühen und selektiven Durchforstungseingriffen in diesen Plantagen, besonders wenn es das Ziel ist, neben einer höheren Massenleistung auch eine Verbesserung der Wertleistung, entsprechend des Wachstumspotentials von *N. diderrichii*, zu erreichen.

7. References

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