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FAST GROWING TIMBER TREES
OF THE LOWLAND TROPICS

No. 2



CEDRELA ODORATA

Compiled by A. F. A. LAMB
Senior Research Officer

COMMONWEALTH FORESTRY INSTITUTE
DEPARTMENT OF FORESTRY
UNIVERSITY OF OXFORD

FEBRUARY 1968

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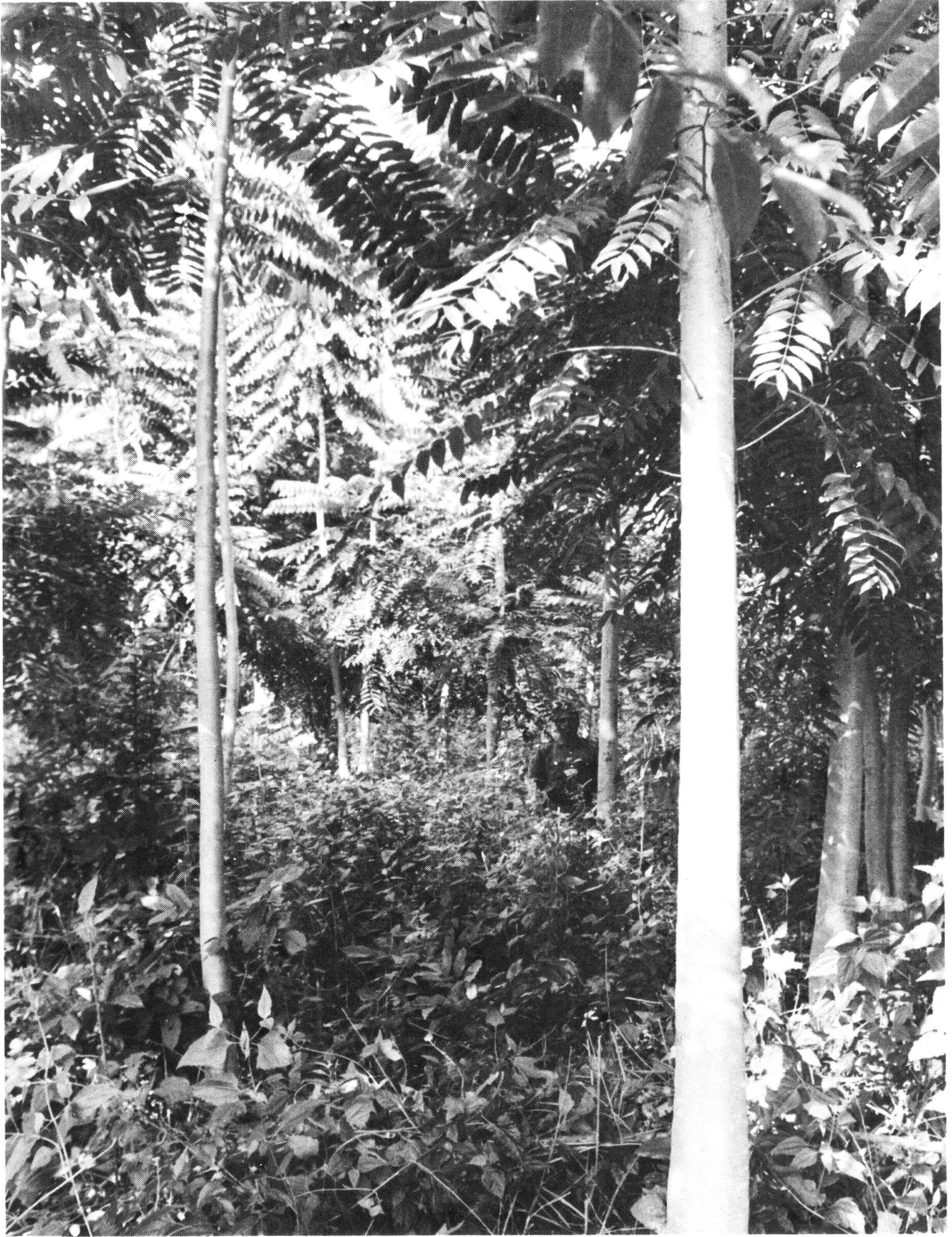


Photo by author.

Cedrela odorata L.

Okhessa Forest, Ubiaja, Nigeria, on Benin sand, 70 inch an. rainfall. Planted June 1964 as stump plants at 8 feet by 8 feet. Site clear felled and burned but not farmed. Photo taken 12/11/66 i.e. 2 years 5 months after planting.

Height 20—25 feet, (6.1 — 7.6 m).

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INTRODUCTION

Many tropical foresters are looking for suitable timber trees to grow in plantations in their countries especially species that will grow quickly and easily, that will provide the kinds of timber needed for their markets and that can be raised cheaply. Many of these timber trees are exotics, little is known about them except in the few countries where they are indigenous or have been introduced long ago, and seed is frequently difficult to obtain. Moreover, it is seldom that the kind of wood they produce when grown in plantations has been tested.

To fill this gap in knowledge of the silviculture and wood properties of these trees, to find out the best provenances of each species to grow and to assist tropical countries with their requirements of seed, a team of experienced tropical forest officers now based on the Commonwealth Forestry Institute, Oxford, have been travelling the tropics since September 1963 collecting data, wood samples and seed and are now in the process of compiling brief accounts of what is already known about those conifers and hardwoods which are showing promise in tropical plantations from both the silvicultural and timber properties points of view. Source-authenticated seed samples are being issued for species and provenance trials and the differences between provenances throughout the natural range of a species are being examined. This team is supported by the Ministry of Overseas Development, London, and is part of the United Kingdom's effort to supply centralised services in forestry of use to developing countries.

Much information was collected as short answers to a questionnaire about the species that are being tried in tropical countries and reports on this questionnaire (The Short Notes) and on visits to Africa, the Caribbean and the Australasian countries have been distributed to tropical forestry departments of the British Commonwealth. These were cyclostyled notes covering many species and forestry activities and were intended to form the equivalent of newsletters on current activities and techniques. In one of these, a prototype was included of full notes on a species - Terminalia superba, compiled by R. L. Willan and sent with a request for comments by field officers. The general trend of comment was that fuller coverage of each species is desirable so that working field officers may have in one booklet an up to date account of what is known about a species.

This booklet on Cedrela odorata is the second of these fuller compilations. (A booklet on Gmelina has already been issued.) The format has been changed from the earlier reports in foolscap size to the present quarto size in response to requests for a smaller self-contained format. It contains a review of published data and several unpublished writings together with first hand information collected by the compiler.

The Genus Cedrela is treated in the limited sense in which it covers only the New World trees belonging to this genus. The rest are placed by Smith (1960) in a separate genus Toona distinguished from Cedrela by two features, one in the flower and the other in the fruit. In the Cedrela flower there is a definite gynophore (stalk below the ovary on top of which the stamens are inserted); in Toona this is absent or rudimentary. In the Cedrela fruit, in each valve the two rows of seeds are attached by the unwinged end which is inserted nearest the tip of the columnella and the wings overlap towards the stalk; the reverse occurs in Toona, the wings overlap towards the tip and the attachment of the seed is nearest to the stalk of the capsule. Some species of Toona have double wings with the seed attached in the middle.

Our thanks go out with this booklet to all those who have cooperated in supplying information, samples of wood, seed and advice and have helped us in this compilation. Comments and additional information will be welcomed and included in revisions of this booklet when the need arises.

1.1 Nomenclature

<u>Latin Name</u>	Cedrela odorata L. Family Meliaceae
<u>Trade Names</u>	Spanish Cedar, Cigar box Cedar (English), Cedro (Spanish).
<u>Local Names</u>	Cedro Cebolla (Panama), Cedro Amargo (Venezuela), Cedar (Trinidad, Tobago and Jamaica), Red Cedar (British Honduras), Acajou Rouge (Guadelope and Martinique), Cedro macho (Cuba). For numerous other names see Record and Mell (1924).

1.11 The Genus Cedrela

The genus Cedrela was established by P. Browne in 1756 for the tree found in Jamaica Cedrela odorata described and published by Linnaeus in 1759 (Syst. Nat. ed. 10:490). Since then sixty-nine species have been allocated by botanists to this genus. These include trees growing in the Americas, India, S. E. Asia and Australasia; Bascope et. al. (1954), but the bases of the differentiation of these species have been unsatisfactory and unreliable, with the result that in the latest revision of the genus by Smith (1960), the Asian and Australasian species have been separated and placed in the genus Toona and the American species reduced to nine. Smith admits that not all the nine species retained are well established on the basis of adequate herbarium material. Smith found no evidence for the retention of the commonly used name C. mexicana.

White and Styles are now working on a revision of the family Meliaceae and consider that the nine species retained by Smith may be reduced still further but that subspecies may be necessary to differentiate local races.

Thus botanical classification within this genus is of little help, at the moment, in identifying seed obtained by foresters from countries in South and Central America, Mexico and the Caribbean. It is necessary to make exact records of the locality from which seed was obtained and to lay down replicated provenance trials in several countries which will form a basis for comparison of the provenances, species and subspecies within the genus. Such a provenance trial is being organized by the writer in 1968 and subsequent years if necessary. This will not include the genus Toona. It will cover the Americas from Misiones province of the Argentine in the South to Mexico in the North and include the species accepted by Earl Smith.

1.2 Distribution and Habitats

The distribution of the genus ranges from nearly sea level in several countries to 3,000 metres above sea level in Bolivia.

Ressini (1956) described Cedar at 3,000 m. a. s. l. in Bolivia at Sucre (19. 50° S. lat.) which he suggests is C. fissilis a species described also as occurring less than a hundred metres above sea level in the Amazon and Orinoco basins. The Sucre provenance is being grown experimentally in the forest district of Cochabamba at 2,750-3,000 m. a. s. l. along with Eucalyptus globulus. Further south and at lower altitudes the same species is reported from the foothills of the Andes near the Argentine border where it is a constituent of mixed hardwood forest in the district of Yacuiba.

Buchinger (1957) reported the presence of C. odorata as far South as 27° S. in Misiones, Argentine. This distribution is accepted by Smith (1960) who shows the range of the species on maps. The most northerly location of C. odorata is on the pacific coastal slopes of Mexico up to 24° N. latitude. All the island provenances of the Caribbean are considered by Smith to be C. odorata.

At various points along the mountains of Central America and South America the names C. oaxacensis C. DC, in Mexico and C. lilloi C. DC. in Peru have been given to hill varieties of Cedrela. There are undoubtedly considerable differences in appearance between hill and plain provenances and the important point of interest to foresters is that suitable provenances for a wide range of climates are available.

Herrera (1934), recorded two forms in Peru of one species; Atoccedro 15-20 m. high growing along streams and producing fibrous, light coloured, porous, slightly scented wood, and Cedro Virgen, 25-30 m. high, in hillside forests, supplying reddish compact, highly resinous timber having a pungent odour and much more highly valued for making furniture. The difference is thought to be due to the drier conditions on the hillside site.

All authors agree that Cedar is rare in evergreen forest types and prefers sites with a marked dry season. The amount of rain is less important than its distribution, but the tree becomes stunted where the total rainfall drops below 1,250 mm.

Lamprecht (1956) describes the distribution of Cedrela in Venezuela. Cedar is frequent in gallery forests along streams crossing the plain of the Orinoco. In these the soil is deep, fertile, moist and well aerated. The climate is seasonal. Ducke (1943) describing conditions in the Amazon basin adds the additional fact that Cedar is typical of river banks along

"white" (troubled) waters carrying much silt and states that an important source of commercial supplies are the islands of the estuary and the southern tributaries of the upper Amazon.

Martin (1946) describes C. fissilis Vell. in Misiones, Argentine, growing in a climate with an average temperature of 20-22°C and an annual rainfall of 1,200-1,500 mm. There is a risk of frost in June and July. Stocking over 20 cm. diameter in the natural forest ranged from 10 to 4.2 trees per hectare but considerable exploitation had already occurred. In these forests the tree reaches 60-70 cm. diameter and a height of 23-25 metres at 106 years old with 7-10 metres of clear bole.

Beard (1942) records the forest types where Cedrela occurs in the West Indies on Cuba, Jamaica, Antigua, Puerto Rico, Martinique, St. Lucia, Trinidad, Tobago and Guadeloupe. It was absent from montane, swamp, marsh and littoral forest and confined to inland lowland well-drained sites. In evergreen semi-monsoon forests with seasonal drought from January to April when 50-100 mm. of rain falls per month, it occurs on the driest sites, e. g. ridges at a stocking of one tree per five acres of all sizes. Cedrela reached its best development and greatest frequency on limestone hills covered with calcareous clay soils of high fertility in an annual rainfall of 1,500-2,500 mm. at Brigand Hill in Trinidad. Likewise in British Honduras it is a characteristic tree of deserted Mayan ruins in limestone country.

In forest clearings, secondary forest, hedgerows and cocoa plantations Cedar regenerates profusely if parent trees are present but does not thrive unless the drainage and nutrient conditions are both favourable.

1.3 General Description of Tree

A large deciduous tree varying greatly in size with environment from a maximum of 30 metres in Misiones subtropical deciduous forest to 40 metres in deciduous seasonal tropical forest and 50 metres in optimum conditions with a high rainfall in lowland rainforest. Girth above the buttresses in mature trees varies from 3 metres on drier less tropical sites to as much as 10 metres in the giants found in tropical rainforest.

The base of the stem is usually buttressed up to 3 or 4 metres in large trees and the buttresses run out into large surface roots. The root system is usually superficial except on deep sandy soils. Above the buttresses the stem is more or less cylindrical in well grown trees for 10 to 15 metres above which it breaks up into large ascending branches which support a spreading dome shaped crown of light green foliage.

1. 31 The Bark

The bark at the base of the stem in saplings is smooth, lustrous-grey tinged in the younger upper parts with dusty green. By the time the tree is six to eight years old the stem bark becomes fissured and these fissures deepen with age. In colour the bark is usually pale grey on both stem and branches bearing patches of lichen. Freshly cut bark has an unpleasant smell. The slash cut quickly turns red-brown and gum may exude from a wound.

1. 32 The Leaves

The leaves of all *Cedrela* species are alternate, pariprimate, clustered at the ends of the twigs, Smith (1960). While leaflet pairs vary considerably in their placement, usually they are oppositely arranged in mature foliage. In young trees branching seldom occurs till the stem is 5-10 metres high on favourable sites unless the leading shoot is attached by a shoot borer. The leaves radiate from the very straight stem of saplings and can reach 60 cm. long with 8-15 pairs of leaflets. Leaves on older trees are smaller up to 35 cm. long with 5-12 pairs of leaflets 6-17 cm. long and 2.5-5.5 cm. wide. The leaflets are oval lanceolate, generally acuminate, glabrous to densely pubescent or puberulent, margin entire, very variable in size and shape, usually acute to rounded at the base, often markedly oblique. The texture of the leaves is thin. The glaucous green colour characteristic of *C. odorata* changes to pale yellow before leaf fall giving the tree a striking appearance. The tree is deciduous for periods depending on the length of the dry season where it is growing.

1. 33 Flowering

Flowering occurs at the beginning of the rainy season (June-July in the Northern hemisphere and Sept.-October in Misiones, Argentine). The flowers are inconspicuous and are borne on paniculate racemes at the apex of the branches. They have a rank smell. *Cedrela* flowers are perfect and have a double floral envelope, Smith (1960). The calyx is variable within the genus, but general calyx forms are specifically distinct. *C. odorata* has a cup-shaped, usually glabrous calyx with an irregular toothed margin. Where *C. odorata* grows in proximity to *C. angustifolia* Sesse and Moc. ex DC. and *C. oaxacensis* C. DC. in Central America hybridization has masked flower differences.

Petals of all species of *Cedrela* are about three times as long as they are wide and densely pubescent or puberulent throughout. They are attached to the gynophore along the lower third of their length by a carina. Colour variations around the apical margin are not diagnostic.

The androecium consists of five stamens. The paired anthers are dehiscent throughout their length. The pollen is discharged towards the centre of the flower. Pollen grains of different species examined by Smith were so uniform throughout the genus that they have little diagnostic value.

1.34 The Fruit

The fruit is a septicidally dehiscent capsule 5-7 cm. long and borne near the ends of the branches of the inflorescence. The shiny green ovary is conical to subglobose puberulent without and bearing warts (lenticels) of varying size. It is usually divided into 5 locules within. The numerous hanging ovules are arranged in two rows in each locule and attached to the columnella with their wings overlapping towards the base of the fruit. A fruit may contain 30 to 40 fertile seeds. The slight specific differences in ovary and style shape are not of taxonomic value.

The capsule dehisces from the apex to the base exposing the many winged seeds which extend from the base to, or nearly to, the apex. The valve thickness of C. odorata is less than in C. fissilis.

From Smith's comment on the floral features of the range of variation within the genus it would appear that consistent differences within the genus Cedrela are difficult to quantify. Nevertheless the forester in the field can easily recognise the downy glaucous green upper surface of foliage and petiole of the West Indian Cedar and the glabrous upper surface and red tinted petiole of the upland Cedar of the Andes.

Marshall (1939) illustrates the seed and seedling and describes them. The seed is winged 2-3 cm. long including the wing which is of variable length. The seed is a flattened oval half a centimetre long and numbering about 16-25,000 per lb (35-55,000 per kilo). The two cotyledonary leaves are oval, about 1.25 cm. long and they open when the slender green stem is 2.5-3.75 cm. high. The winged seedcase is usually carried up. The cotyledons are succeeded by trifoliate leaves, about 4 cm. long including the stalk, merging gradually into the mature form of pinnate leaf.

2.0 HABITAT CONDITIONS

2.1 Climate

2.11 Trinidad

The rainfall varies from 1,250 to 2,500 mm., there being a dry season from January or February to May and a wet season for the

rest of the year with a short dry period about September. Rain falls on 235 days per year. This climate is very equable the mean maximum and minimum temperatures being 88° F and 67° F (32° C and 20° C) in the cool season (December to April) and slightly over 90° F and 71° F (32° C and 22° C) during the rest of the year. The minimum relative humidity is high (averaging 58 and upwards at 14 hours in March-April).

2.12 Central America

In the tropical forest zones the rainfall range is similar to that in Trinidad and so are the seasons but the temperature range is greater under more continental conditions (52° to 98° F, 11° to 38° C) and humidity is lower at the end of the dry season. Cedrela is found also in drier conditions in parts of Mexico especially on the Pacific slopes of the country.

2.13 South America

The climate of the lower Amazon basin near sea level resembles that of Trinidad, the mean temperature range is 88° to 73° F (32° to 23° C) and the minimum relative humidity is high (59 upwards). However, the same species (C. fissilis) occurs both in the Amazon and at Sucre, Bolivia, where the altitude is 9,344 feet (3,000 m.) and the mean maximum and minimum temperatures are 64° and 44° F (18° and 7° C) respectively. Frost occurs at Sucre but is not severe and the minimum relative humidity falls to an average of 32.5 for four months each year, May to August inclusive. The rainfall at Sucre averages 27.8 inches (689 mm.) falling on 97 days.

At the southern limit of its range on the plains of Misiones average maximum and minimum temperatures are 85° F and 63° F (30° and 17.5° C) and up to 3° F of frost occurs. Minimum relative humidity is high, being lowest (57) in August-September-October when the fruits ripen.

From this outline it is clear that Cedrela has become adapted to a great range of climate and may in past epochs have been dispersed in isolated populations which have become adapted to a range of sites and which have since merged in parts of the Amazon and Orinoco basins. More study in much greater detail of populations and distribution is needed. In the meantime the provenance of seed sources is all important.

2.2 Ecological and Edaphic Conditions

Several research workers, notably Marshall (1939) and Beard (1942) and Cater (1945) in Trinidad, Roig (1945) in Cuba, Duche (1943)

in the Amazon Basin and Lamprecht (1956) in Venezuela have studied the factors governing the growth of Cedrela and attempted to explain its needs. However none of them has been able to define exactly the causes of success and failure.

2. 21 Rainforest Conditions

Marshall and Beard found that under rainforest climatic conditions (annual rainfall 2,000-3,000 mm. 2-3 months dry), Cedrela was most frequent on the physiologically driest parts of sites within the wet climatic zone, e. g. Brigand Hill in Trinidad, a steep wet ridge composed of limestone with a highly fertile calcareous clay soil and excellent aeration of the limestone subsoil. Since these researches, Brigand Hill has been cleared and planted or sown with Cedrela under the taungya system and the vigorous saplings were able to overcome the attack of Hypsipyla grandella Zell shoot borer. This example probably highlights the two fundamental requirements of Cedar, complete absence of waterlogging of the root system and a plentiful supply of nutrients. Drought for considerable periods of the year does not affect the health of the tree adversely provided that in the growing season there is adequate moisture available. During drought periods the tree becomes deciduous and remains so till the rains return.

When Marshall studied the growth of Cedar in parts of the rainforest growing on grits and non-calcareous clays not overlying limestone his results were much less successful. On ridges in such forest some large old Cedar occurred naturally and each year a carpet of natural regeneration germinated round these parents. This was given a plentiful supply of light by drastic opening of the canopy and many grew to sapling size but after 18 months the trees over the 5 acre trial showed signs of distress. Trees, some of which had reached 20 feet in height in 2 years, showed signs of die-back, tended to drop leaves in the rainy season and a few developed curious thin sinuous leading shoots and very light crowns, the "weeping willow" form. Growth of other species was luxuriant and Marshall concluded in 1934 that the reaction of Cedar was not due to soil deterioration. Beard continued the research in co-operation with the soils branch of the Imperial College of Tropical Agriculture, Beard (1942). The reaction of Cedar trees to low and high rainfall regimes; soil variations of organic matter, the carbon/nitrogen ratio, low nutrient status, variations in the soil water-table level, the effect of liming the soil, and leaf analysis were all studied. Beard concluded that the Cedar problem appeared to be one of soil moisture relative to a sensitive root system. The most marked symptom exhibited by unhealthy young Cedar in plantations was the frequent intermittent loss of leaf during the rainy season when leaf activity is normally at its fullest. This would seem

to indicate physiological drought due to a damaged root system.

During the same period (1929) Cedar, probably of West Indian origin, was being planted in two plots at Sapoba in Benin Province, Nigeria by Kennedy. In the plot at Sapoba station several "weeping willow" trees were noted in 1933 by the writer but the rest grew vigorously. It is very unlikely that the "weeping willow" form was due to impeded drainage because the Benin sand formation consists of a red loamy sand hundreds of feet deep and excessively well drained. It is much more likely that, in the initially less fertile plot at Sapoba Station, the "weeping willow" form was due to rapid reduction of soil nutrients by leaching by the heavy rains (Sapoba rainfall is 2,500 mm with 2 - 3 months dry, altitude 50 m. a. s. l.). The surface layer of the soil under natural hardwood forest in Benin has a nearly neutral reaction but as soon as the high forest is cut and burned to clear the site a very rapid fall in nutrients takes place and the pH falls from a level of 6 - 7 to 4.3 in 2 years. The "weeping willow" trees occurred on the edge of the plantation adjacent to another younger plantation and may have been subjected to a second fire when the second area was cleared. Thus it would appear that lack of adequate nutrients either through the death of the root system as a result of poor aeration or due to an infertile soil can prevent the establishment of Cedrela and result in failure. The success of early sowing at stake prior to the break of the rains on suitable calcareous clay soils completely cleared of previous forest and burned over prior to sowing, is probably due to the adequate nutrient supply obtained by seedlings and saplings through a root system which ramified in the soil before competition of weeds and other vegetation established themselves in competition. The success in growing Cedar in West Africa is due to the good drainage of many West African soils, the legacy of nutrients accumulated in the surface layers and the failure of the local Hypsipyla species to thrive on Cedar as a host.

2. 22 Drier Closed Forest Conditions

In natural forests growing in a climate with a more marked dry season and a lower total annual rainfall of less than 2,000 mm the leaching of bases is slower and soils tend to have a greater accumulation of bases with accompanying better structure and aeration. In addition the forest leaf canopy is less dense. As a consequence under these conditions Cedar forms a higher proportion of the total stock and may occur as almost pure stands on limestone ridges or Mayan temple ruins in Central America. Under such climatic conditions plantations in East and West Africa have been established with success and have been extended in Nigeria into the rainforest of Benin because of the excellent soil aeration of the Benin sand formation.

Holdridge (1943) after considering Beard's views put forward conditions for the successful growth of Cedar which coincide very largely with those expressed above. In Latin America it is probable that Cedar should not be grown as a pure crop except on exceptionally favourable sites and these are likely to cover small areas only. In Africa, however, where Hypsipyla attack is not a major factor, large scale planting is possible.

2. 23 Savanna Woodland Conditions

At the dry end of the scale, Glover and Gwynne (1960) found that in Kenya Cedar (Cedrela mexicana) of unrecorded source, was less drought tolerant than Eucalyptus saligna. It reacted to drought by first showing erratic changes in the stomatal behaviour of the lowermost leaves which later dried and fell off leaving only a small tuft of younger leaves near the growing point. This underlines the need for adequate moisture in the atmosphere and soil during the growing season of this species, although it can survive a long annual drought period by remaining leafless.

3. 0 LIFE HISTORY AND DEVELOPMENT

3. 1 Life Span

Although Cedar is a fast growing light demander which colonises bare sites, hedgerows and abandoned farms, it is a long lived tree. There are few records of the age of large dominants of the natural forest. In British Honduras well grown Cedar of 11 - 12 feet (4 m.) in girth above the buttresses had 110 rings. As this is very definitely a deciduous tree it is almost certain that this gives an accurate figure of the age of the tree in years. The very much larger specimens recorded from Central America and Trinidad were probably two to three times as old. The Cedar photographed by Rellini (1956) in Sucre town (1950's, 3,000 m. a. s. l.) in Bolivia and thought to be C. fissilis may be even older.

3. 2 Growth Rate

Early growth may be up to 8 feet (2.3 m) per year in the absence of check due to insect attack or unfavourable conditions. Unbranched stems up to 30 feet high (10 m.) occur in young Nigerian crops and the stem is remarkably straight and cylindrical but in drier climates it tends to branch lower. Even so, well-formed straight stems are usual except in exposed open grown trees.

3. 3 Flowering

Flowering starts by the tenth year and it is usual for the trees to

bear fruit annually. The amount of fruiting is considerably influenced by competition and is usually plentiful on isolated trees. The drop-shaped capsules hang like loose bunches of grapes on the leafless tree in the dry season.

3.4 Fruiting

Fruits are glossy green in colour till ripe when the surface turns dull grey brown. When this happens a watch should be kept till the first capsule bursts open at the tip. Then all those already brown in colour should be harvested and spread in the sun to dry and shed their seed onto trays. Sunning of the seed to complete the ripening process is strongly recommended. It probably checks the development of surface moulds as well. Under natural conditions the winged seeds spin away from the opening capsule in the wind and may travel considerable distances. Those that land on bare ground and slopes are frequently washed by the first rains against obstacles and germinate quickly under hedges, logs and heaps of debris. Those that land in the leaf litter of the forest may be destroyed by insects and moulds before germination if the first rains do not fall for some time after dispersal. Therefore natural regeneration is most prolific in those years when the first rains fall soon after seed dispersal.

4.0 PLANTATION EXPERIENCE IN VARIOUS COUNTRIES

Experience in Trinidad and Nigeria has already been used to bring out the main factors governing success and failure in growing Cedar. (see also Streets 1962)

4.1 Latin America

4.11 Argentine and Brazil

Efforts to establish plantations in the Amazon basin and Misiones, Argentine, have not been successful because of the damage done by Hypsipyla grandella the shoot borer. Dubois (1967), recommends a trial of the French Recruitment Method ("Méthode du Recrut") proposed by Catinot (1965) but this retains considerable root competition and would succeed only on most favourable soils.

4.12 Cuba

In Cuba, Fors 1944 and Roig 1946 reviewed the results of planting 1,800,000 cedar trees issued from Cuban nurseries to private farmers. Survival was no more than 10 percent. Isolated groups or individuals were found thriving on a great variety of soils and sites. However, they concluded that Cedar grew best on fertile well drained sites and that

neutral or alkaline soils were not essential. Light side shade appeared to be beneficial and Roig suggested mixtures to supply side shade.

4.13 Ecuador

In Ecuador, (FAO Newsletter No. 14 of 1956 for Latin America) on Finca "La Mina" near Guayaquil, Cedar of Cuban provenance has been grown on land 25 metres above sea level in an annual rainfall of 1,200 mm. on soil of medium quality with a water table 5 - 6 metres below the surface. The 1930 plantation, when 26 years old, was 35 metres high and had a diameter o. b., b. h. of 112 cm. (44 inches). Timber has been used successfully from some of the trees for furniture. Since then plantations have been formed from the abundant natural regeneration round this plantation and from seed from these trees. The plantations were established without shade but they were not attacked by the shoot borer.

4.14 Mexico

However in Mexico Borlang (1957), had great difficulty in establishing potted plants in side shade when this was tried in the Yucatan peninsula south of Merida along lines cut through the natural mixed hardwood forest after exploitation. The plants suffered from sunscald of the bark and subsequent Buprestid damage. Even in the nursery the bark of seedlings was injured and had to be protected by sleeves. When planted out in competition with the established natural forest along opened lines, the plants had little chance of being successful under these adverse conditions.

In general, in Latin America, one must conclude that efforts over a long period and in many countries to grow Cedrela in pure plantations and in lines cut through exploited forest, has been a failure except on sites where the conditions of growth are the optimum for Cedar. Such sites usually cover small areas in most countries and consequently large scale planting of Cedar in them is unlikely. The main cause of the failure is shoot borer attack by Hypsipyla grandella Zell which finds the variety of Cedrela in its local environment a suitable host on which to feed.

4.2 Africa

The position in Africa is different probably because Cedar can be grown in pure plantations, large areas of fertile well drained soils are available and Hypsipyla there is not H. grandella but has been named H. robusta Moore by J. D. Bradley of the Commonwealth Institute of Entomology. This is the species reported from India by Beeson (1961). Although the African species can attack Cedrela, the attack is seldom

successful and does not control growth in the sapling stage.

4. 21 Ghana

Troup (1932) gives the date of introduction to Ghana as 1898 when it was planted as avenue trees. The origin is unknown. Plantations were started in 1922, using seed of Caribbean origin, at Dunkwa and in the Anwhiaso, Prah Anum and Essuboni Forest Reserves all within the high forest zone in annual rainfalls of 57 - 63 inches (1, 448 - 1, 600 mm.). Ghana soils in these forests are generally deep, fertile and well drained and there is a marked dry season. Growth has been less spectacular than in Benin, Nigeria, but Cedrela is gaining in popularity in Ghana and natural regeneration is prolific wherever good light conditions occur near plantations. A tree improvement programme has now been started and several superior phenotypes are being propagated. The die-back recorded in Nigeria and Trinidad has not been observed possibly because both soil and climate are optimum where it is being grown. (See also Streets, 1962.)

4. 22 Nigeria

Unwin (1920) mentions Cedar plantations at Ololemeji in 1905. In Nigeria the provenance trial at Ibadan indicates that there are two races in the country. The seed from Ololemeji has shown much poorer growth than the seed from Sapoba. The latter is reported by Kennedy to have come from Ghana. However, in the records of Sapoba arboretum Mackay (1953), notes that the seed for Plot No. 17 came from Trinidad. There is a tendency now to extend the planting of Cedrela especially in the Middle West State of Nigeria where the prevalent soil type is Benin sand. There is need, however, to find a suitable soil protecting species to mix with the Cedar in such plantations.

4. 23 Sierra Leone

Cedar has found conditions in Sierra Leone very well suited to it. The severe monsoon climate, long dry season, well drained soils and basic igneous rocks over much of the forest belt produce soil conditions under which Cedar can grow successfully especially when in taungya plantations. Where Cedrela and Toona are growing as mature trees side by side in the environment of Freetown the form of the former is much superior to the latter. Both regenerate freely. Thus the conditions in much of West Africa suit extensive growth of this valuable species.

4. 24 Tanzania

In Tanzania, it was introduced in 1914 and planted on the steep slopes of the Usambara Mountains, Bryce (1966). The trees are now

85 - 110 feet high (26 - 33.5 m.) and 4 to 5 feet (1.2 - 1.5 m.) in girth above the buttresses with a bole length of 45 to 70 feet (13.7 - 21.3 m.). Rainfall in Tanzania in regions suitable for the West Indian provenances is low compared with West Africa but on sites formerly occupied by closed forest on the Ronda Plateau and in Longusa Valley recent trials show great promise.

4.3 Other Countries

4.31 Fiji

Fiji has the advantage of not having any Hypsipyla. On well drained parts of its volcanic soils growth has been good in trials but it has not been extensively planted and has failed in the wet zone. Hurricanes have tended to break its branches (see Streets).

4.32 Malaya

Trials have been a failure in Malaya and it is not considered to be a potential timber species.

5.0 SILVICULTURE

5.1 Natural Regeneration

5.11 Trinidad

Marshall (1939) makes it clear that regeneration of Cedrela odorata in Trinidad usually fails completely under rainforest conditions in spite of the carpet of seedlings which germinate near parent trees each year and opening of the upper canopy. On the other hand he quotes cases in forests with lower rainfalls (less than 2,000 mm. per an.) where plentiful regeneration occurred after the extensive forest fire of 1912 and the hurricane of 1933. A similar case occurred in British Honduras after the fire of 1947 when 450 square miles of hardwood forest on limestone soils were damaged by a creeping fire in March, April and May which left a considerable number of Mahogany and Cedar parent trees alive in unburnt islands of forest. There is little doubt that the main reasons for the successful regeneration noted above are the very open light conditions produced, the desiccation of the soil and litter surface between seedfall and the first rains, the sudden reduction of root competition and the increase in available nutrients especially potash due to the burning of the leaf litter. Under these conditions damping off and insect attack of the seed between dispersal and the first rainfall are at a minimum, seedling growth is rapid and the sapling builds up the vigour necessary to carry it through the susceptible stage when Hypsipyla attack can be limiting. In British Honduras funds were made available for creeper cutting and

thinning of weed species in favour of the Cedar and Mahogany. As a result a stocking of 70 trees of these two species per acre (154 per ha.) were brought through the sapling stage over considerable areas of calcareous clay soils.

Marshall gives the results of inventories in two Trinidad forests over 1,000 acres (405 hectares) in each. These show the larger amount of natural regeneration in the drier forest and the larger size of the trees in the rainforest type. (Girth classes converted to centimetres.)

Rain-fall per an. mm.	Girth Classes in Centimetres									
	30-61	61-91	91-122	122-152	152-183	183-213	213-244	244-274	274-305	305+
2540	13	7	10	6	12	5	4	1	5	10
1524	585	323	154	92	38	100	62	15	-	-

Workers in other Latin American countries have confirmed Marshall's results.

5.12 Ghana

In Ghana natural regeneration is prolific. In Sierra Leone it is common in hedgerows near Freetown where large parent trees are frequent.

5.2 Artificial Regeneration

5.21 Seed

5.211 Weight

The number of seed per kilo has been given as 45-50,000 (20-23,000 per lb) from exotic trees grown in French West Africa and Tanzania. In Puerto Rico seed weight is given as 18,500 per lb, and 14,000 per lb with wings on is quoted by Beard 1942. Seed should be collected when the first capsules burst on the tree and before the majority open, not from the ground.

5. 212

Storage

Cedar seed quickly loses its viability if not thoroughly dried. Capsules and seed should be sunned daily to open and dry them. A dry atmosphere and a temperature of 3° to 5° C during storage ensures much higher germination after periods of storage beyond two weeks and is recommended.

Marrero (1943) working in Puerto Rico found that seed kept at 35 - 40° F (2 - 4° C) in open bags and in sealed containers gave 31 - 34 percent germination after four months storage whereas seed at 77° F (25° C) gave 0 and 2 percent.

In Trinidad, Anon (1953) Cedar seed stored in a desiccator for 76 weeks gave 60% germination and similar seed stored in a refrigerator (temperature unstated) gave 70% germination.

A note by Acuña (1938) for the Philippines records results of germination of seed kept at room temperature in sealed bottles as follows:-

After 21 days 97.4%, after 63 days 80%, after 119 days 27%, after 140 days 2.0% and after 161 days 0%.

5. 22

Germination

Epigeous germination takes 2 - 4 weeks. The radicle emerges from one end of the seed, the hypocotyl arches slightly and usually carries the testa above the ground but the testa quickly drops. The stem of the young seedling is erect, delicate at first and green. Under favourable conditions, rapid growth starts within three months of germination and the seedling can reach 3 - 5 feet in height in the first season.

5. 23

Direct Sowing

In 1952 - 54 at Mount Hope Estate and at Brigand Hill, Trinidad, about twenty to thirty seeds were sown at stake in a cleared and burned taungya farm on a 10 to 20 percent slope where the soil was a calcareous clay and the climate markedly seasonal in the 60 - 70 inches (1524 - 1778 mm.) annual rainfall bracket. The sowing was done in May before the rains started when the soil was hard and dry and had to be pulverised in the small sown patches. The first storms swept some of the seed from the patches and it germinated among debris against logs and the sides of paths. By August signs of dominance by individuals showed up in the patches which were then thinned to one or two trees per site. Results were uneven but by January 1955 vigorous poles 20 feet high had been produced over considerable areas of the lower slopes with dominants

30 feet (9.1 m.) tall. Where ample seed is available this method is cheaper than the use of nursery stock and it avoids the check which reduces tree vigour when saplings are transplanted from the nursery to the field. Two essentials for success are very early sowing on completely cleared sites and a soil having adequate aeration, fertility and depth. There was no shade above these seedlings until the farm crops, sown later, grew up.

Direct sowing has seldom been employed in Africa so far because planted trees have succeeded and seed supplies are seldom abundant. It is unlikely to give as even a crop as planting but under Latin American conditions it and natural regeneration may be the only possible ways of establishing this species. This is confirmed by James (1960) from his experience in Mexico, who found that such saplings were less susceptible to Hypsipyla grandella.

5.24 Nursery Technique

Nursery soil should be a fertile sandy loam, well aerated and well cultivated prior to sowing. Beds should be level to reduce the risk of the seed being washed into hollows or off the bed. A light covering of charcoal, sand or sawdust over the broadcast or line sown seed is needed to prevent the seed from being blown or washed away.

The heat in the dry soil before the first rains probably improves the conditions of the seed and results in quick germination if the seed is sown prior to the break of the rains. Where adequate moisture is available, shade would appear to be unnecessary and may increase the risk of damping off. Beard (1942), found that the burning of brushwood on the nursery bed before sowing had a beneficial effect on germination, survival and growth.

Belanger and Briscoe (1963) working in Puerto Rico grew Cedrela in a sterile matrix of firmly packed vermiculite and applied subsurface irrigation with solutions of fertilizers containing the amounts in the table which follows.

Fertilizer	Grams per gallon			Total	Remarks
	Nitrogen N	Phosphorus P	Potassium K		
Tap water	0	0	.0	0	x Numbers refer to percent on N. P. and K. respectively
1. 18-18-18 ^x	1.57	1.57	1.57	4.71	
2. 15- 5- 5	1.76	0.59	0.59	2.94	
3. 7- 6-19	0.49	0.46	1.46	2.41	

Contrary to expectations, high nitrogen and high phosphorus did not promote rapid growth, high potassium, (3), gave the maximum shoot growth, (2), gave the poorest development. Cedrela produced excellent leaf growth and vigour in solutions, (1) and (3). Shoot growth was stimulated more by high potassium than root growth. The greatest ratio of root to shoot, on a fresh weight basis, was obtained by irrigating with plain tap water.

In the lowland tropics it is usual to sow at the beginning of the rains, transplant if necessary in August or thin out the seedlings to 6 inches by 12 inches (15x30 cm.) and leave the crop unwatered in the dry season. Plants should be 3 to 5 feet high by the beginning of the planting season the following year. Stump plants are not so satisfactory as saplings (Marshall 1939); in Trinidad but have given good crops in Nigeria.

5. 25

Establishment

Troup (1921) working at Dehra Dun in India on Toona and Marshall (1939) working on Cedrela in Trinidad both found it possible to transplant saplings in the dry cool season when they were leafless or at the beginning of the rains if new growth had been trimmed off. Cool season transplanting is more suited to the subtropics of Dehra Dun than the West African tropics where temperatures are higher in winter. It is not the practice there to put out Cedrela in the field in December, January. Planting should be done when rains break in May-June before the heavy later rains leach the mineral nutrients from the soil surface layers.

Several pure plantations of Cedar have been created in African countries and grown satisfactorily to timber size. Those at Sapoba, Nigeria and in Ghana have already been mentioned.

Oseni (1963), working at Ibadan in Nigeria has tried stumps, striplings, cuttings, wildings and potted seedlings. He now favours polypot plants but records that the early plantations were established using stumps and striplings. Stumps were used also in Ghana, Streets (1962), but see comment above by Marshall on stumps.

Oseni records numerous trials of this species all over Nigeria and it seems more probable that polypots were used because they could be transported long distances than that they give better results than striplings. During a recent visit to Nigeria the writer did not see successful Cedar grown from cuttings. The new Sapoba and Benin plantations were being established with striplings one season old. The small polypot plant may have a place in the future if the nursery period can be shortened nearly a whole season by sowing seed whenever it is

collected in March, transplanting to small polythene pots $1\frac{1}{2}$ to 2 inches diameter whenever large enough to handle and putting out the plants in the field in June. This is being tried in Nigeria with other species, notably Terminalia and Teak as a substitute for stump planting.

5. 251 Preparation of Site and Planting

The taungya system gives the best early growth in African countries and should be employed wherever possible. However, Mesa (1946) considered the taungya system and all pure plantations unsuitable for Cedar in Cuba.

Clear felling burning off of the debris and planting is a more costly second best and subsequent tending is more costly, (see frontispiece).

Line planting through degraded forest and the close line planting for use where human populations are too low to operate the taungya system (Méthode de Recru), advocated by Catinot (1965), does not completely remove root competition of the remaining vegetation; as a result there is a reduction in early growth of the Cedar and a risk of a reduction in vigour in the sapling stage when Hypsipyla attack may reduce height growth to nil and prolong the tending period and cost.

5. 252 Mixed Plantations

Mesa (1946) in Cuba and some of the Nigerian forest officers have advocated mixing Cedar in plantations. In the sapling stage in Benin, Nigeria, it has a very narrow crown of little effect in the suppression of weed growth (see frontispiece) and creeper tangle and would therefore benefit from a "filler" species in mixture. Its rate of growth is slightly less than Gmelina but faster than Nauclea. Other possible filler species are Cordia alliodora and Anthocephalus cadamba both of which have suitable branching habit in youth. Mixtures are more necessary in the rainforest sites than in drier forests where weed growth is less rampant. Such mixtures should be as alternate trees in rows not as pure rows. This will reduce the risk of Hypsipyla attack becoming prevalent.

Mesa (1946) states that pure plantations in the open have failed on all suitable soil types in Cuba regardless of the spacing and planting methods employed. This may be as much a result of unfavourable climatic conditions in Cuba as of failure in silvicultural technique although isolated Cedar occur naturally. Cuba is near the northern limit of the range of Cedrela. Where successful plantations have been created in Trinidad, both climate and soil were optimum. On Brigand

Hill, Trinidad, Cedar and Cordia alliodora were grown in mixture and as pure crops with success.

Planting should be carried out at the beginning of the rainy season. Once the soil has been moistened, early planting has given the best results. Two to four foot high striplings stripped of their leaves are recommended as planting stock.

5. 253 Spacing

Mesa advocated a spacing of not less than 4 metres (13 feet x 13 feet) with alternating rows of other trees. Spacings used in Ghana have been $16\frac{1}{2}$ feet x $16\frac{1}{2}$ feet (5 m. x 5 m.) and 9 x 9 feet (2.74 x 2.74 m.). In Nigeria the 10 ac. (2.5 ha.) 1929 plantation at Sapoba was planted 16 feet x 16 feet (4.9 x 4.9 m.) as a result many of the trees carry heavy branches low on the stem. In mixed and pure plantations of fast growing hardwoods in Nigerian rainforest a spacing of 12 feet x 12 feet (3.7 x 3.7 m.) is now in favour. In drier forests a closer spacing of 9 feet x 9 feet (3 x 3 m.) is preferred but much will depend on markets for thinnings in the future.

5. 254 Tending

Clean weeding in the first year to reduce root competition is considered essential. Thereafter full overhead light should be maintained by removal of overtopping weeds and creepers till the canopy closes. When Hypsipyla attack causes more than one leader to grow all but one should be removed during tending.

5. 255 Thinning and Pruning

There is very little data on this subject and much depends on the carrying capacity of the site and the composition of the crop, i. e. whether it is pure Cedar or a mixture of species.

At Sapoba, Nigeria, in the 1929 plantation the stocking per acre in 1954 (25 years old) was 116 per acre (290 per ha.). This was reduced to 85 per acre (212 per ha.) at 32 years old. A further thinning is being carried out in December 1967. Horne (1962) comments on the relatively dense stocking for this age and the continued maintenance of a high increment. This is undoubtedly due to the high rainfall and the great rooting depth of the well aerated soil and indicates that under such conditions Cedar is not a surface rooting species. In an adjacent less heavily thinned plot of the same age, there were 167 trees per acre (417 per ha.) with a basal area of 280 square feet per acre (65 m² per ha.).

6.0

MENSURATION

6.1 Girth Increment

In Trinidad, Cedar-trees of large size grown in open sites on the alluvial banks of streams issuing from the Northern Range and in 60-70 inch (1,524-1,778 mm.) annual rainfall, maintain a girth increment o. b., b. h. of 3 inches per annum (7.62 cm.) when 8 to 12 feet (2.44 to 3.66 m.) in girth. From ring counts such open grown trees are about 40 years old, they have large crowns and if well grown about 10 to 12 metres of clean bole to the first branch. In Nigeria the mean annual girth increment of the 40 largest trees per ac. (100 per ha.) in the 1929 Sapoba plantation, (100 inch, 2,500 mm. rainfall) has been 2.15 inches (5.46 cm.) up to 32 years old. This is considerably less than open grown trees in Trinidad but rapid nevertheless. In the Nigerian deciduous forest zone at Olokemeji, (48 inches, 1,219 mm. rainfall per an.) growth rates have been much lower. The mean annual girth increment o. b., b. h. in a stand planted about 1918 and measured in 1960 was 1.7 inches (4.3 cm.) when the basal area per acre was 128 sq. feet per acre (29 m² per ha.).

6.2 Height Increment

Oseni obtained measurements of the average height increment in six young Cedar plantations at Ibadan, Nigeria (49 inch, 1,245 mm. per an. rainfall, 800 feet, 244 m. a. s. l.) and correlated this with rainfall. After planting in June 1962 there was an initial period of very slow growth till April 1963, the end of the dry season; indicating a period of settling and root development, thereafter almost continuous growth occurred as follows.

Period	Year	Ht. Incr. inches	Rainfall inches	Remarks
Jan. -Apr.	1963	3	7.77	November to March are the driest months and average less than 2 inches rainfall per month.
May-Aug.	1963	11	39.27	
Sept. -Dec.	1963	14	16.17	
Jan. -Apr.	1964	15	9.58	The six trees averaged 20 inches high when planted.
May-Aug.	1964	47	27.93	
Sept. -Dec.	1964	22	11.35	
Jan. -Apr.	1965	28	10.24	
May-Aug.	1965	67	43.18	
Sept. -Dec.	1965	15	10.67	

Height growth was strongly influenced in this plantation by the sloping ground in the plantation. Height at the drier upper side of the compartment was much less than at the bottom of the slope.

In the Sapoba 1929 plantation the mean height of the 40 largest trees per acre at 32 years old was 127 feet (38.7 m.) or an annual increment of four feet (1.22 m.).

In Misiones, Argentine, Martin (1946) records a height of 23 to 25 metres at 106 years old in natural forest.

The Ghana sample plot figures quoted by Streets (1962) compare closely with those for height and girth given for Sapoba, Nigeria.

6.3 Volume Increment

Horne (1962) gives true volume data for the 1929 Sapoba plantation for the main crop only ignoring thinnings.

Year	Age	Mean Height feet	Mean G. B. H. inches	True Vol. per acre u. b.	M. A. I. u. b. Cu. ft. per ac.	Remarks
1954	25	105	50	4500	180	No adequate data for thinnings are available
1961	32	120	56	5368	167	

Horne estimated a yield at 40 years old of 6,500 cu. ft. per acre (455 m³ per ha) with a mean girth of about 7 feet o. b., b. h. (2.13 m.). Lest these figures be thought exceptional, figures for a half acre plot in the adjacent arboretum in the thirty-second year of growth were higher. This plot was originally planted closer and thinning was light. There were 167 trees per acre (twice the density of the other plots) and the basal area was 280 square feet). This is equivalent to 10,000 cubic feet per acre (680 m³ per ha).

PRINCIPAL ENEMIES

7.0

7.1 Wind

In Fiji the branches have been extensively broken by hurricane winds but the trees were not blown down. These trees were beyond the sapling stage when stem breakage occurs and had rigid trunks.

Likewise in Cuba, Roig (1946), described the 1944 hurricane which destroyed all woodlands in the provinces of the west but Cedar trees remained with only the loss of some branches. In this respect Cedar is excelled only by Mahogany (*Swietenia* spp.).

7.2 Sun

Miller et al (1957) investigated "sunscald" in the Yucatan peninsula of eastern Mexico on Cedar raised in a nursery in pots and planted out in groups or lines through exploited natural forest when 2 - 3 feet high.

In the lightly shaded nursery 5 percent of the plants showed yellowing of the bark just above soil level. The stem became constricted and on seven percent of the plants the damaged plants were attacked by a Buprestid beetle (*Chrysobothris yucatanensis*). The bark split like a canker and the tree became moribund.

Along the lines cut through the exploited and rather dry type of forest, the incidence of damaged plants was 91 to 95 percent and the experiment was a failure.

The conditions in Northern Yucatan are adverse and planting of Cedrela is unlikely to succeed.

7.3 Frost

At the extremities of its extensive range the provenances of Cedrela have become adapted to withstand several degrees of frost. (See Habitat Conditions.) This resistance is greatest in the leafless resting period and is unlikely to be effective if frost should occur during the growth period.

7.4 Animals

In Sabah, Malaysia, the 1964 plot suffered severely from debarking in the young sapling stage by snails. This ceased as the trees grew larger and produced more resistant bark. Large snails about half the size of the Giant African Snail were responsible for the damage.

7.5 Insect Pests

7.51 Bark Beetles

The Buprestid attacking plants in the Yucatan, Mexico, has been mentioned under Sunscald above.

A scolytid beetle attacked Cedar seedlings in the nursery in Fiji and was controlled by uprooting and destroying the affected plants, Anon, Fiji (1953).

Roberts (1965,b) working in Nigeria found Apate (Bostrychidae) beetles which bore into the sapwood of vigorous trees which are planted under severe savanna-woodland conditions. The Powder Post Beetles (Apate monachus), as newly emerged adults attack the stems of growing trees more than 3 cm. in diameter in the dry season, especially the most vigorous individuals which have the largest food reserves (starch) under the bark. After a short period within the tree they emerge and fly away to attack and breed in dead wood. They allow the entry of staining fungi.

Two longhorn beetles Tragocephala and Tragiscoschema have been classed as major shoot boring pests of Cedrela by Prosser et al (1965) in East Africa. However, since 1962-63 when extensive damage occurred in trial plots on the Usambara Mountains and at Kimboza, Tanzania, the attack has shown a marked decline. The Tragocephala parent girdles the fleshy leading shoot and deposits one egg in a slit above the girdle. The larva burrows in the shoot pith first upwards and then downwards for several feet and pupates, at the same time severing the life supporting tissues of the stem from the inside above the pupal cell. It is thought that the adult emerges from the shoot at the point of severance above the pupal cell after clearing away the fibre plug left by the larva to discourage intruders. Tragiscoschema appears to have a similar life history except that it partially severs the stem above and below the pupal cell.

Attack by either longhorn beetle may cause forking or a kink in the stem of saplings of 0.4 to 0.7 inch diameter (1 - 1.8 cm. diam.) at the point of attack. Many other hardwoods are attacked by these beetles in Tanzania.

7.52 Hypsipyla

7.521 General

The success achieved by foresters in growing Cedrela in Africa and the contrasting widespread lack of similar success in Latin America

now appears to be due mainly to the failure of the African and Indian moth (Hypsipyla robusta, Moore) to be attracted by the smell of Cedrela and the attractiveness of Cedar to the American moth (H. grandella Zell).

Much work has been done in recent years by Roberts, (1965) and Beeson, (1961) on this group of insect pests which is summarised here for ease of reference.

7. 522

Life History

The female moth in India produces on the average 472 eggs which are laid as a rule on the unexpanded leaves and glued in position, (Beeson 1961). In Nigeria the larvae feed on the flowers of Khaya ivorensis from September to November, on the fruits from November till February and on the new shoots from March till August. In addition attack on the inner bark can occur in any month of the year and control by insecticides is not considered feasible, Roberts (1965).

In Nigeria the larvae of H. robusta are able to feed, moult and pupate within the shoots of Cedrela odorata and have been successfully bred from this host at Ibadan, Roberts (1965). However, Roberts suggests that extensive attack may not occur because female moths are not attracted to Cedrela to lay eggs. Another possibility is mentioned by Beeson: in India, on Toona, the larva after hatching descends on the surface to the stouter portions of the growing shoot and feeds by removing the epidermis in irregular patches at the same time testing the shoot for suitable spots to bore into the interior. If too vigorous tissue is selected as the site of entry, the attack is unsuccessful because a flow of sap or gum ensues which may entrap and drown the larva. This confirms the thinking used by the writer in Trinidad which resulted in the decision to concentrate plantations of Cedar on the optimum sites where the shoots would have maximum vigour and tend to exude sufficient gum to entrap invading larvae.

These eggs laid on shoots are from the third, fourth and fifth generations of the year; eggs of the first and second generations are laid on the flowers and young fruits of mature trees and they pupate in bark crevices whereas the later generations pupate in the hollowed out shoots and emerge in the following March (Northern Hemisphere). The length of time taken for the development of each generation gets longer as the year progresses from one month in the first and second to four months in the fifth.

In the second generation each larva is capable of destroying 5-6 fruits before pupating and rapid development is related to a good food supply in the fruits. The slow later growth reflects the poorer

nourishment provided by shoots. All five generations of the borer are found only on vigorously growing middle aged trees.

In India and Australia, in some years, the complete seed crop has been ruined by this insect. In the West Indies and Africa such an occurrence has not been recorded. However, young plantations near Mahogany parent trees are more likely to be attacked than those that are isolated. Control by physical means of the first two generations may be possible by tying bands of sacking a foot wide with cord round the trunks of Cedrela and other Meliaceous parent trees above the buttresses and folding over half the width of the band. Sacking impregnated with insecticide is recommended by Beeson (1961).

No data on the distance the moth can fly is available. No predators have been found in Nigeria. Roberts suggests that the nutrients obtained from the Cedrela shoots by H. robusta in Nigeria may upset the larva's digestion. The fresh frass from larvae living on Cedrela is bright green in colour instead of the usual brown colour when Khaya is eaten. Roberts could find no H. robusta feeding on the flowers of Cedrela in Nigeria but they were found on Khaya flowers.

These summaries of existing knowledge on the Hypsipyla moths in the old and new tropics have been given at considerable length because of the importance of these insects in the success or failure of Cedrela plantations. More detailed study is needed in Latin America of the success or failure of the larvae of H. grandella when it attempts to enter very vigorous shoots.

7.523

Control

Sanchez (1966) who worked at Barinitas in the lowlands of Venezuela on H. grandella found that three applications of insecticide were required during the 6 weeks of oviposition because heavy rains as well as high evapotranspiration shortened the duration of the protective film of the insecticide to four days. The insecticides used were D. D. T., 25% E, D. D. T., 50 % P, Fosferno Telodrin 15, Parathion, Metasystax and Endrin, and the plants were 3 metres high. No insecticide showed marked superiority. This kind of treatment is costly and if H. grandella behaves like H. robusta in Nigeria it would have to be continued throughout the season of production of new leaves in sapling trees. However, Marcano (1963) also working in Venezuela found that Hypsipyla attack on Cedrela plantations always coincided with the beginning of the rainy season (May-June), but the shoot borer did not attack plantations established later in areas adjacent to those initially affected. More work in Venezuela is necessary to confirm this.

than from trees grown more slowly. The pale to red-brown colour of the wood darkens on exposure and the scent fades with time. Some samples have an oily exudation which gives a sticky surface to the wood and can discolour the paper of cigar boxes and any metal or glass objects stored in Cedar wood. Some specimens taste bitter, others have no taste.

Record and Mell (1924), found it impossible to distinguish between the woods of the different species for, although they exhibit a considerable variation in their structure and physical properties, it remains to be determined to what extent these variations are attributable to the age and environment of the trees on the one hand and to hereditary factors on the other. The wood of young trees, especially those of very rapid growth under open conditions, is less fragrant, of lighter colour and softer, though tougher than that of old forest grown trees. In this Cedrela differs from Gmelina.

8.11 Density

The heartwood is pink to reddish brown, sometimes with a purplish tinge, fairly uniform in a given specimen; sharply to rather poorly demarcated from the pinkish to white sapwood. Luster is medium to high and golden; it is lowest on light coloured wood. Density is very variable; specific gravity (air-dry) is 0.37 to 0.75. Martin (1946) recorded an air-dry density of 0.550 for C. fissilis from Misiones, Argentine. The densest provenance, tested by Record, comes from San Salvador. The air-dry weight range is 23 to 47 lbs per cu. ft. averaging about 35 lbs; the texture range is rather fine and uniform to coarse and uneven; grain usually straight; some specimens are crisp under tools others tough and fibrous.

8.12 Figure

The characteristic figure consists of a series of dark lines on a red-brown background, sometimes the wood shows roe figure. Wood from the buttresses and curls is frequently attractively figured.

8.2 Anatomy

8.21 Macroscopic Features

Record (1941) described the wood anatomy. Growth rings are usually poorly defined. The cell structure ranges from virtually diffuse-porous to decidedly ring-porous. Dark-coloured woods from drier regions may be coarser than light coloured woods. The grain is generally straight but sometimes interlocked. A characteristic growth ring pattern is visible on the tangential surface. Bryce (1966), working

on plantation grown Cedar, grown at Anami in Tanzania, found distinct growth rings marked by bands of terminal parenchyma and a tendency to ring-porousness.

8. 22 Microscopic Features

The vessels (pores) are variable in size; large ones exceed 200 microns tangential diameter and contain abundant gum deposits, tyloses are absent or not abundant. Vessels are rather few except in early wood of distinctly ring porous specimens.

8. 221 Wood parenchyma is both terminal and surrounding vessels, the former distinct to the naked eye, the latter indistinct. Parenchyma is coarse-celled, sparingly paratracheal and diffuse, also in distinct, concentric bands few to 15 cells wide usually rather widely spaced and apparently terminal or initial, sometimes crowded together locally; gum abundant. Crystalliferous strands are common but not composing whole strands.

8. 222 Rays of Tanzanian samples were uniseriate or locally biseriate, few to 30 cells high, the larger measuring 0.35 mm. high and 0.054 mm. wide, very distinct on radial section where they appear either lighter or darker than the background. Pits to the vessels are small. In American samples they were 1-5 cells wide, up to 25 cells high, heterogenous, the marginal tiers low; gum and crystals were common.

8. 223 Vessels are septate, walls medium to thick, pits very small; length, minimum 0.70 mm., maximum 1.754 mm. average of 100 measurements 1.287 mm.

8. 224 Gum ducts were occasionally present in the Tanzanian wood and filled with a dark red deposit. They are very distinct in longitudinal section especially the tangential and sometimes present in compact peripheral rows.

8. 3 Pulp Properties

Coursey and Ogunle (1964) found that plantation grown Cedrela tested in Nigeria was unsuitable for pulpwood. In this it compares unfavourably with Gmelina and Eucalyptus grandis. Cedar pulp made indifferent paper, difficult to bleach, but perhaps suitable for low-grade wrapping paper if sulphate pulp is used. The neutral sulphite semi-chemical process gave low yields of low quality unbleachable pulp.

8. 4 Physical and Mechanical Properties

The Madison report compares the average mechanical properties of Cedrela with Swietenia macrophylla and these are compared below with the results from Tanzania.

Property	Madison U. S. A. Cedrela	Moshi Tanzania Cedrela	Swietenia
Moisture content air dry percent	12	12	12
Specific gravity air dry (lb. per cu. ft.)	-	28	-
Specific gravity (based on volume green and weight oven dry)	0.38 (24 lbs per cu. ft.)	0.388 (24 lbs per cu. ft.)	0.45
<u>Static Bending</u>			
Fibre stress at proportional limit			
Air dry in p. s. i.	7390	8400	7830
Modulus of rupture			
Air dry in p. s. i.	10,230	-	11,410
Modulus of elasticity			
Air dry in 1000 p. s. i.	1360	1090	1430
Work to maximum load			
Air dry in lb. per cu. in.	9.8	8.7	8.0
<u>Compression parallel to grain</u>			
Maximum crushing strength			
Air dry in p. s. i.	5600	5200	6550
<u>Hardness</u>			
Air dry			
End in lb.	830	-	1030
Side in lb.	570	460	840
<u>Compression perpendicular to grain</u>			
Stress at proportional limit			
Air dry in p. s. i.	690	-	1040
<u>Shear</u>			
Air dry in p. s. i.	1140	1390	1330
<u>Resistance to splitting</u>			
(lb. f/in. width) radial	-	280	-
" " " tangential	-	320	-
<u>Impact Resistance to suddenly applied loads</u>			
Max. drop of 50 lb. hammer, inches	-	19	-

These data indicate that Cedrela is low in all strength properties even for its density and is not suitable for any structural or load bearing purposes. Tanzanian plantation grown wood is somewhat weaker than the average of samples of commercial wood from natural forest tested in the U. S. A.

8.5 Comparison of Wood Properties of Cedrela and Gmelina

Cedrela varies greatly in its mechanical properties according to its density but taking average samples it would appear that Gmelina is weaker in bending and compression parallel to the grain, both have similar hardness and shear, but Gmelina has slightly higher resistance to suddenly applied loads. Cedrela shrinks more than Gmelina and is therefore less stable. Gmelina does not have the repellent smell which makes Cedar particularly suitable for clothing chests and wardrobes and Cedrela is available in much larger sizes.

8.6 Seasoning and Shrinkage

Anon (Madison, U. S. A.) 1957 gives the revised data for American grown Cedrela and Bryce (1966) gives data for Tanzania grown plantation samples.

The American samples were easy to season either by air or kiln drying. Surface checking was slight. Some samples had a tendency to collapse during drying; such wood should be dried at a low temperature. The Madison Laboratory recommend their schedule No. T 10-D4, Torgeson (1951) for 4/4 stock.

Bryce obtained well shaped logs from the Anami plantations in the Usambara Mountains. These trees were 52 years old, 85-100 feet (26 - 33.5 m.) tall and 4 - 5 feet (1.2 - 1.5 m.) girth o. b. , b. h. with bole lengths of 45 to 70 feet (13.7 - 21.3 m.). Owing to the steeply sloping ground all the logs had eccentric pith. Star shakes developed very rapidly in storage extending to a length of 6 feet (2 m.) and opening as wide as 3½ inches at the end of the log. Tension wood had developed on the side of the longer radius.

Shrinkage from green to 12 percent m. c. , measured only on samples free from reaction wood, was:-

radial 2.8 percent; tangential 3.9 percent

The movement of sawn wood in varying atmospheric conditions of moisture content was small. However pieces containing tension wood suffer from severe spring and usually collapse even in air drying. This type of collapse cannot be cured by steaming.

One inch boards air-dried from 83 percent m. c. to air-dry (14 percent) in two months at Moshi with slight distortion and end splitting.

In kiln drying on the fairly severe Schedule H. one inch boards dried from 77 % to 12 % m. c. in 12 days with slight distortion and splitting comparable to that in air-drying.

Dutch kiln schedules are reported by Noerkamal, (1952). Boards 4 cm. and 2 cm. thick were kiln dried from 95 % moisture content to 15 % moisture in 8 and 2 days respectively without serious degrade.

Shrinkage was:

	<u>4 cm boards</u>	<u>2.2 cm boards</u>
Tang.	6.03 percent	6.65 percent
Longitud.	4.75 "	5.75 "
Radial	1.89 "	3.20 "
Specific gravity	0.445	0.415

8.7 Durability and Preservation Treatment

8.71 Durability

Slow grown, harder wood from dry sites is more durable and contains more volatile oil than wood grown faster on humid sites, Noerkamal (1952). In recent tests the heartwood of several samples from different sources ranged from "durable" to "non-durable" in resistance to White-Rot fungus (Polyporus versicolor (L.) Fr. and from "durable" to "moderately durable" when exposed to Brown-Rot fungus (Poria monticola Murr.).

Bryce found some damage to heartwood by Ambrosia beetles but the wood resisted termite attack in Africa after a short period of exposure. It is classed as naturally durable in Latin America.

Edmondson (1949) working in Brazil found that the wood had little resistance to marine borers in tropical waters. It contains little silica.

8.72 Effect of Volatile Oil of Wood on Insects

Laudani and Clark (1954) tested the effect of the scented volatile oil on the various stages of the larva of the Webbing Clothes

Moth (Tineola bisselliella Hummel) and the Black Carpet Beetle (Attagenus piceus Oliv.). They used two white Pine chests as controls and two Cedar chests. The older the Cedar chest the less effective it proved in controlling insect development. The eggs of beetles laid in 4 months old Cedar chests gave 15 percent hatch compared with 64 percent hatch in the Pine chests. The corresponding figures for the moth eggs were 30 percent and 82 percent. The young moth larvae mortality was 77 percent in the 4 month old Cedar chests and nil percent in the Pine chests. However, after 16 months it had fallen almost to nil in the Cedar chest for both moth and beetle larvae. Older larvae were less affected, pupae were little affected and few adults died, nor were their reproductive functions greatly reduced.

8.73 Preservation Treatment

The heartwood is untreatable with preservative solutions using normal pressure impregnation equipment. Sapwood can be impregnated when dry.

Diffusion methods do not appear to have been tried to treat wet sawn timber of this species.

8.8 Utilization of the Wood

8.81 Working Properties

8.811 Sawing and Machining

The green timber from plantations in Tanzania can be cut exceptionally easily with all standard 36 inch plate saws, Bryce (1966). Some gumming of the blade occurs. Overheating is common when tension wood is sawn.

The dry wood is very easy to machine, requiring little power and having a negligible blunting effect on cutters. The standard 30^o planer knives give a clean finish, provided they are really sharp, even to pieces containing tension wood. In mortising and boring, it is difficult to make a clean hole, as the wood is soft and exits must be adequately supported. Sanding must be done lightly with fine paper to avoid score marks, and a filler is needed before polishing.

The nailing properties are good. There is no tendency to split and nails (of diameters suitable for the thickness of the piece) can be driven safely at the extreme ends and edges. The nail holding power on the other hand is very low: 12 gauge nails driven to a depth of one inch (2.5 cm.) have an average withdrawal resistance of only 43 lbs (19.5 kilograms) in the end grain and 57 lbs (25.85 kg) in the side grain (c. f. 100 to 140 lb for Pinus radiata).

Bryce was testing wood from trees grown on steep hillsides which contained considerable amounts of tension wood. Smith (1960) confirms that in Central America trees from natural forest grown on steep hillsides are less desirable for lumber because they are liable to contain a large amount of tension wood.

8.812 Peeling and Steam Bending

Cedrela has been used for many years in Latin America as the source of veneers. Veneer plants using little else have been set up in Mexico. Figured trees are highly valued for surface veneers. It is particularly suitable as veneers for making light-weight racing boats.

The wood can be rotary peeled or sliced. Its most troublesome feature is the presence of gum which may build up on cutters and adhere to machine tables and feed rollers. The gum may also cause some trouble if surfaces are polished. Nigerian plantation grown logs were peeled at a commercial plant at Sapele and gave satisfactory veneers from 18 inch diameter samples.

The bending properties, cold or steamed, are reported to be good by Bryce.

The Ghana report, Anon (1955-56), covers tests of all working properties of plantation grown trees, from level and undulating sites. It is concluded this species can be more extensively planted with the assurance that its timber quality will be high. In Hawaii, tests have found the wood quality to be excellent.

8.82 Uses and Trade

Perhaps the best known use till recently was for cigar boxes. Its strength for weight and durability made it a favourite for boat construction (the Oxford and Cambridge boats were made from specially selected Cedar from British Honduras). However, on the basis of volume, by far the largest quantities have been used in Latin America for building, furniture, veneers, panelling, chests and cupboards. In British Honduras it is used for water vats replacing swamp cypress formerly imported. However Browne, (1756), records that the lumber, "cannot be made into casks for spirituous liquors because spirits dissolve a great quantity of its natural resin and acquire a strong bitter taste from thence".

9.0

TREE IMPROVEMENT PROGRAMME

Nigeria has laid down a provenance trial at Ibadan of the local varieties of Cedrela drawn from the plantations at Sapoba and Olokemeji. In this there are considerable differences in vigour and growth rate between the two provenances, the Sapoba source is much superior but its origin is uncertain. A provenance trial on an international scale is being organised at the time of writing by the Commonwealth Forestry Institute, Oxford, which, it is hoped will lead to much data on which further tree improvement of Cedrela can be based.

Norman Jones and his colleagues in Ghana have started to select superior phenotypes throughout the 312 acres (125 ha) planted prior to 1966. The technique of budding and grafting clonal material onto seedling root stocks is being studied.

No work of this kind has been reported to the compiler by other countries.

10.0

CONCLUSIONS

1. Throughout Latin America and the Caribbean Cedrela has been severely overcut and is in short supply almost everywhere. There is no longer enough for the cigar box industry and other species and materials have had to be used instead.
Only in remote parts of the Amazon and Orinoco basins are there virgin forests which contain mature trees.
2. The removal of the rare mature Cedar trees from the high forest of the new-world tropics has removed the source of seed and virtually eliminated the species over large areas.
3. Natural regeneration can be adequate in the drier seasonal high forests but growth is much slower than in plantations especially those formed by clearing rainforest on suitable soils.
4. Nevertheless throughout Latin America, except on optimum sites, pure plantations of all the Cedrela varieties and provenances are likely to fail because of the severity of attack by Hypsipyla grandella Zell.
5. Much more care is required in site selection and in experimenting with species mixtures which may reduce the effectiveness of Hypsipyla attack. From existing experience there appears to be little hope of control of the larval stage by insecticides or predators.

6. In the African tropics experience over the past seventy to eighty years indicates that Cedrela may become a major plantation species where soils of adequate depth, fertility and aeration occur under seasonal climatic conditions in the 1250-2500 mm. annual rainfall zone. This is because large optimum planting sites exist and Cedrela odorata appears to be not very attractive to the indigenous Hypsipyla. Greater use of mixtures in Cedar plantations is advocated so as to maintain soil fertility where such a light canopied species forms a major part of the stocking.
7. With well planned management, natural regeneration of such plantation mixtures may well be possible in future rotations.
8. In the Australasian tropics many of the soils are volcanic and too poorly aerated for Cedrela. In Malaya it has been a failure after limited trials. Where Teak will grow well it will grow if the Hypsipyla present is not attracted by it. Much will depend on market demand. In India and Burma it is unlikely to oust Teak.
9. In uses, it is complementary to Teak and pine providing a light durable hardwood with many uses where pine is not quite good enough and Teak or Mahogany is too valuable. This applies especially to furniture and panels.
10. Unlike Gmelina its growth continues till large trees are produced on a relatively short rotation. It is, however, a less satisfactory source of pulp than Gmelina and does not coppice. It appears to be more exacting than Gmelina under Savanna woodland conditions and does not produce a satisfactory building pole.
11. Much remains to be done to find the best varieties and provenances suitable to the sites where Cedrela is likely to be extensively planted. Most of these lie in West Africa and the West African equatorial zone south of the Equator but some parts of the limited lowland closed forest sites of East Africa are suitable and high level provenances from Bolivia may succeed on inland sites with drier climate conditions, e. g. in parts of Uganda.
12. If cocoa continues to be grown under shade, Cedar can provide light shade and very profitable returns to cocoa plantation owners wherever cocoa is being replanted but especially on the

best calcareous cocoa soils of Latin America and the West Indies. Once established, natural regeneration replaces the trees cut. The West African cocoa farmers of Ghana and Nigeria may come to value it as much as Trinidadians do.

13. Cedrela can be cheap to establish and to regenerate subsequently and gives a high return if conditions are optimum but the silviculturist should think deeply before using it in a plantation programme and weigh up its potentialities in comparison with its rivals in tropical plantations or enrichment planting.
14. Before more extensive planting of Cedrela in high rainfall areas is started, much more timber testing of plantation grown Cedar is advocated especially wood grown under rainforest conditions where the fast growth rate may have produced light-weight timber of low strength properties, less durability and woolly texture. A major test of Sapoba samples is being organised and carried out by the Forest Products Research Laboratory, England.
15. The tree improvement programmes should take into account variation in wood quality within stands as well as tree form, growth rate and resistance to insect attack.
16. If Cedrela is resistant to Hypsipyla robusta attack in Africa, Tbona may be resistant to H. grandella in Latin America. Has this been tested?

11.0

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