FAST GROWING TIMBER TREES
OF THE LOWLAND TROPICS

No. 1

GMELINA ARBOREA

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

COMMONWEALTH FORESTRY INSTITUTE
DEPARTMENT OF FORESTRY
UNIVERSITY OF OXFORD

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Photo A. F. A. Lamb.

Gmelina arborea

Oluwa Forest, Ondo Province, Nigeria. Planted June 1963 at 10 feet x 10 feet. Altitude 300 feet a.s.l. ; annual rainfall 80 inches. Photo taken 24/11/66 ; crop 3 years 5 months old.

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Name Gmelina arborea Linn.

Family Verbenaceae

Vernacular names Gumhar, Sewan (Hind.), Gomari (Assam), Shivan (Mar.), Shivani (Kan.), Gumadi (Tamil), Yemani (Burma).

Name used in Exotic Plantations Gmelina or Yemane

1.0 INTRODUCTION

As a result of the greater interest during recent years in plantations of fast growing trees within the lowland tropical zone, Gmelina is now on trial in a great many countries. There are few countries however where it has been tried for long enough and on a large enough scale to assess its potentialities and limitations. Streets (1962) summarised experience up to 1962, giving most detail for Nigeria and Sierra Leone where commercial plantations have been made. It promises to be an important species in Malawi and Malaya but less so in the sub-tropical climates of Rhodesia and Zambia. Recently detailed timber and pulp tests have revealed its many valuable properties and stimulated interest in large scale plantations.

Enthusiasm for the species is further stimulated by its rapid early growth, ease of establishment, cheapness of establishment and early returns. Its limitations are a tendency to die at a young age except under most favourable soil and climatic conditions, a relatively small maximum size and the rapid reduction in increment after the seventh year. Its poor form in the open can be controlled by good silviculture in plantations.

Many have helped in this compilation besides the authors quoted. I wish to thank, especially, Professor Laurie and my colleagues of the Commonwealth Forestry Institute for their assistance and advice.

1. 1 Distribution

The species extends from the lower Himalayan course of the River Chenab (West Pakistan) south east and south through India, Nepal, Sikkim, Assam, East Pakistan, Ceylon, throughout Burma to Thailand, Laos, Cambodia, Vietnam and the southern provinces of China (Yunnam and Kwangsi Chuang). Although Rodger (1913) states that it occurs naturally in Malaya and the Philippines, Corner (1940) and Merrill (1923) say that it is an introduction in these countries.

The tree is usually very scattered in occurrence becoming frequent only in moist localities in Burma and Chittagong. In drier regions such as the Punjab it is rare. It is most frequent in the mixed deciduous forests of Burma associated with Teak (Tectona grandis), Terminalia tomentosa and various species of bamboo Rodger (1913). It is occasionally found in evergreen forest, is not uncommon in Sal (Shorea robusta) forest and extends into comparatively dry regions of Central India. In the Western Himalayas it ascends the outer hills and valleys to 4000 feet, where it may occasionally be seen in stunted form even in somewhat dry situations, Troup (1921).

1. 2 General Description of Tree

A moderate-sized to large unbuttressed, deciduous tree with opposite, broadly ovate, acuminate, usually cordate leaves, glaucous beneath, or stellately hairy or tomentose beneath in one variety, Troup (1921). The bark on young trees and on the crown and the upper part of the stem in older trees, is smooth, corky, pale brown to grey in colour. It exfoliates near the swollen base of the stem in trees over five to eight years old exposing smooth paler coloured bark beneath. Form varies greatly with varying conditions of growth. If grown in the open, heavy branches and a wide crown develop and the stem is short, seldom straight, swollen at ground level and markedly tapered; if grown in well thinned plantations on high quality sites, the tree attains a height of 100 feet in 20 years, a girth of 6 to 8 feet at breast height, a clean nearly straight stem, with much less taper

1. 3 and a domed crown. Trees of this form have been reported in natural forest in Burma, Rodgers (1913). The leaves fall as a rule about January - February in its natural habitat; the new leaves appear in March - April. The panicles of flowers appear from February to April when the tree is more or less leafless, or with the young leaves, and the irregular tubular corollas about one inch long, which are dull chestnut in colour with a yellow tip and throat, quickly fall from the trees and cover the ground in their neighbour-

1. 4 hood. The root system varies in depth of penetration with soil depth and texture. Roots have the same pale corky bark at the ground surface as the branches. They cannot penetrate concretionary gravel easily. Roots in the gravel layer are often misshapen because they cannot push aside the stones and so attain normal diameter growth, Tinsley (1966).

2.0 Habitat Conditions

2.1 Climate

In its natural habitat the absolute maximum shade temperature varies from under 100° to 118° F, (37° c to 48° c), the absolute minimum from 30° to 60° F (- 1° c to 16° c) and the normal rainfall from 30 to 180 inches (762 - 2032 mm). Its best development occurs where the extremes of temperature range from 65° to 95° F, where there is a distinct dry season but the atmospheric humidity never drops below 40 per cent. In these climates the total rainfall exceeds 60 inches (1524 mm) per annum and is optimum from 70 to 90 inches (1778 - 2286 mm) per annum. Above this most of the rainfall is ineffective owing to excess run off and may cause soil deterioration by leaching. Provenances at the extreme upper altitudinal limit of its range have some tolerance to frost; the leaves are often touched, the shoots escaping. However, in grass the seedlings may be entirely killed down, though their power of recovery from the base is good.

2.2 Edaphic

The evaporation rate and rainfall influence the aeration of the soil and moisture availability. Gmelina is a short lived tree everywhere but lives longer and grows larger where deep moist soil amply supplied with nutrient occurs. It must therefore be classed as a transitory species in rain forest, springing up where a hole occurs in the canopy and growing rapidly on the accumulated fertility occurring in such gaps. It will grow equally well in deciduous high forest on the deep river alluvia and will start to grow on quite dry shallow soils provided they are well aerated but will soon check in the absence of sufficient depth, sufficient nutrients and sufficient moisture during the growing season. In India on dry sandy or otherwise poor soil, it remains stunted and is apt to assume little more than a shrubby form owing to its being repeatedly killed back by drought, Troup (1921). It is sensitive under these conditions to competition from weed species, especially grasses, and fails to suppress them; the leaves turn yellow, the canopy lightens and tree growth slows down. However, in savanna woodland on the sites of abandoned villages and old cattle kraals in Africa, the stimulus from the residue of nutrients in the soil causes vigorous growth, a dense closed canopy and clean forest floor, and produces stems useful for poles.

Charlton (1934) examined the effect of the soil composition on the growth of Yemane in Burma and concluded that growth is favoured by increasing acidity from the surface of the soil downwards and by high acidity at a depth of 3 to 4 feet. This conclusion is not confirmed by more recent experience in Trinidad and British Honduras, where the best growth occurred on calcareous loams in moist alluvial valleys. Like Cedrela, Gmelina will grow vigorously where the surface layers are alkaline or slightly acid, provided

ample nutrients are available but will fail on very leached acid soils where pine will thrive.

It would appear from Sierra Leone experience that Gmelina cannot survive more than 15 years in plantations where stony or concretionary subsoils restrict downward root development. This may be purely physical or the result also of the chemical composition of the soil. In the same country, in plots on young alluvium over river gravel and in the Eastern Nigerian plantations on deep sandy loam without a concretionary horizon Yemane has survived much longer although growth rates at breast height have fallen off after the eighth to tenth year in all cases.

It is evident therefore that soil conditions are of paramount importance wherever this tree is to be planted for timber production.

2.3 Physiographic (Topography)

In so far as the soil depth and the moisture retaining ability of the soil are influenced by slope, topography plays an important part in choice of site. For this reason growth on deep alluvium in valleys far exceeds growth on steep slopes. Plantations for timber production should be confined to lower slopes and valley floors.

2.4 Ecological Associations

In Burma Gmelina attains best development in mixture with Teak (Tectona grandis L.) Anogeissus acuminata and Careya arborea on a deep alluvial plain in Mohnyin forest situated in the Katha district of Upper Burma Troup (1921, figure 264). This forest is situated on flat or nearly flat ground on deep alluvial soil. A peculiarity of this forest apart from the high percentage of Teak it contains is that the Yemane trees are mainly of large dimensions and regeneration almost entirely absent. Bamboos do not occur over much of the area.

The mixed deciduous forests of the Central Provinces of India contain Gmelina mixed with Teak, Terminalia tomentosa, T. belerica, Lagerstroemia parviflora, Ougeinia dalbergioides, Anogeissus latifolia, Dalbergia sissoo, D. paniculata, Pterocarpus marsupium, Diospyros melanoxylon, Acacia catechu, Chloroxylon swietenia, Soymida febrifuga, Schleichera trijuga, Schrebera swietenioides, Cleistanthus collinus, Odina wodier, Cassia fistula, Bridelia retusa, Adina cordifolia, Stephegyne parvifolia, Butea frondosa, Bassia latifolia, Phyllanthus emblica, Buchanania latifolia, Xylia xylocarpa. In this forest the prevailing bamboo is Dendrocalamus strictus but occasionally Bambusa arundinacea is found on alluvial flats by rivers.

A similar mixed deciduous forest on the Western Ghats of South India contains Gmelina up to 3000 feet altitude.

3.0 Life History and Development.

3.1 Longevity and Growth Pattern

Yemane grows very rapidly during the first six years of its life with the production of heavy branches where the trees are widely separated and a very tapered bole. With competition from neighbours the branches are kept small and the taper of the stem is greatly reduced. By the seventh year rapid height growth slows down. The life span of the tree is affected by the suitability of the site. On adverse sites it may succumb by the twelth year without being attacked by a primary pathogen but on the best alluvial sites in a monsoon climate it may live to be at least 30 or 40 years old. It is however a short lived tree.

3.2 Flowering and Fruiting

The panicles of flowers appear from February to April in India and Burma when the tree is more or less leafless. The irregular tubular corollas are about one inch long, dull chestnut coloured, with a yellow lip and throat. The fruit ripens from the end of April (Burma) to July. The fruit is a succulent ovoid or oblong drupe 0.9 - 1.2 inches long, yellow when ripe, with a leathery shining pericarp, a sweetish pulp, and a hard bony stone. The stone is 0.6 - 0.9 inches long, ovoid, pointed at one end, usually two celled and two seeded, but sometimes one or three celled and seeded.

3.3 Seed Production

Trees as young as 3 - 4 years have started to fruit in plantations. Fruiting is regular and usually plentiful each year. There are about 640 stones per lb. (1408 per kg.)

3.4 Seed Quality

The germinative power of fresh seed is high but if stored for a year a considerable proportion of the seed loses its viability. A sample of fruit-stones tested at Dehra Dun, Troup (1921), gave 90 per cent germination when fresh and only 30 per cent after being kept for one year. Sometimes three seedling emerge from one stone. In Nigeria, Ogbe (1960), recorded 500 fresh fruits per gallon container which when rotted reduced to a quarter of a gallon. In Malaya the germination percentages of Burmese and local seed varied from 25 to 91 per cent, the best results being obtained from local seed.

Seed is usually stored in atmospheric conditions. Research is needed to discover the temperature and humidity at which high viability will be prolonged as much as possible. The new technique of storage in an atmosphere of nitrogen or carbon dioxide may prove useful with this seed. It is essential to remove the pulpy pericarp at the time of collection of the seed as

the fermentation which occurs if the fruits arestored in a heap reduces viability.

3.5 Seed Dissemination

The fleshy fruits are eagerly devoured by cattle and deer in India, they are attractive to birds and bats and the nuts are eaten and distributed by these animals and rodents. Insects sometimes eat the pulp of fruits lying under the trees.

3.6 Causes of Damage to Seed

The animals that distribute the fruits destroy many of them in the process. It would appear also that in humid hot climates, the lower germination after storage is related to fungal development causing loss of viability.

4.0 Silviculture

4.1 Natural Regeneration

On sandy soils in the open, around Gmelina plantations in Eastern Nigeria and Sierra Leone, natural regeneration is prolific and has been used as a source of planting stock with success. In Sierra Leone at Kasewe where the 15 year old plantation suddenly died out profuse natural regeneration appeared. The seed will germinate under the thinned out canopy of a plantation.

A considerable amount of alternating heat and moisture is necessary to stimulate germination; for which reason fruit stones lying under shade which is at all heavy fail to germinate for want of the sun's heat. Secondly, it is of great importance that the stones should become buried to some extent, otherwise there is a strong risk of failure to germinate. Want of sufficiently continuous moisture appears to be the explanation of this. The required conditions occur in Burma on abandoned taungya lands (temporary cultivation) where plentiful natural reproduction has been observed.

4.2 Artificial Regeneration

4.21 Germination of Seed

Epigeous, resembling that of Teak. The stone of the drupe opens by means of one or two lateral valves, the radicle emerging first, the cotyledons issuing shortly after. The stone is either left on the ground, or is carried up over the cotyledons, falling with their expansion.

4.22 The Seedling (from Troup)

Roots: primary root long, at first thin, afterwards thickening

considerably, terete, tapering: lateral roots moderate in number and length, fibrous, distributed down the main root or more plentiful in its upper part. Hypocotyl distinct from and thicker than the root, 0.3 - 0.7 inch long, terete or obscurely quadrangular, white turning green, finely pubescent. Cotyledons: petiole 0.1 - 0.2 inch long, channelled or flattened above, finely pubescent with capitate hairs: lamina 0.5 - 0.7 inch by 0.3 - 0.4 inch elliptical or ovate, emarginate, entire somewhat fleshy, yellow turning green, finely pubescent with capitate hairs, midrib deeply impressed on upper surface, lateral veins less distinct. Stem erect more or less quadrangular near the nodes, green, finely pubescent with capitate hairs; internodes 0.5 - 3 inches long. Leaves simple, opposite, ex-stipulate. Petiole 0.3 - 1.5 inches long, channelled above, green glabrous or finely tomentose. Lamina 1.5 - 3 inches by 1.2 - 3 inches, broadly ovate, acute or acuminate, widely dentate or sinuate, base cordate, cuneate or obtuse, with glands near the petiole, green above, glaucous beneath, glabrous or lower surface glabrescent or finely pubescent with capitate hairs on the principal veins; lateral veins 3 - 5 pairs, including two prominent basal lateral veins.

4.23 Sowing

Sowing at stake was possible in Sierra Leone, Fox (1967), because the stones are relatively large, the seedling robust and rapid growing and the percentage germination of fresh seed high. Best results will be obtained in well cleared and burned plantation sites, using fresh seed and sowing 2 to 3 stones per peg just below the soil surface. The date of sowing should be before the rains break and during the first rains so as to permit the seedling to establish itself before leaching removes the readily available nutrients released by the fire and before weed growth or farm crops establish themselves.

4.24 Nursery Practice

Alternate wetting and drying under hot sunlight stimulates germination. Consequently before sowing the fleshy covering of the fruit should be removed and the seed sown broadcast in a thin layer and covered lightly with soil or preferably compost litter. It should be copiously watered and the bed should not be shaded. Seed sown in this way in Eastern Nigeria in January and February germinated in 2 - 4 weeks. The seedlings were transplanted and produced in 6 months woody seedlings of pencil thickness which may be stumped and planted out in the field.

A different technique quoted by Ogbe (1960) is to slit the fruit open, the seed is picked out and thoroughly dried by spreading thinly in the sun. Such seed is reported to retain its viability for more than a year.

Where nursery soils are not highly fertile and rainfall is below 50 inches, the seed may be sown in drills, one foot apart, during the rainy

season in July/August. It will germinate in 2 - 4 weeks and thereafter the plants in the drills should be thinned out to leave them 8 inches apart. This time of sowing dispenses with the need for watering and so long as the soil is not freshly-exposed high-forest soil of high natural fertility, the plants may still not be too large to use as stump plants in the following June.

In all nursery practice no shading is necessary except for a short time immediately after transplanting. The time of sowing must be regulated to produce stumps not larger than two inches in diameter, at time of planting. A uniform crop of stump plants one inch in diameter at the root collar should be aimed at.

The technique developed in Malawi up to 1964 takes into account the lower rainfall and more adverse site conditions on private farmlands and Government forests where this tree is grown for poles and fuel in a 35 inch annual rainfall with 6 - 7 months dry season. The tubes used are 6" long by 3" wide and they are not removed during planting but are slit. Soaked seed stored since the previous November is sown direct in the tubes in October in a rich soil mixture. If more than one seedling appears the surplus ones are transplanted. Root pruning is necessary until December when stock 6 - 9 inches high is transferred in tubes to the field. Stump plants are grown for issue to remote villages and are 13 months in the nursery. Anon. (1964).

In Assam, India, Rajkhowa (1964), experimented with the spacing of seed in germination beds and related this to the yield of stump plants after one year. His spacings varied from 1 inch by 1 inch to 4 inches by 4 inches. Close spacing gave lower yield of stump plants. The minimum should be 9 fruits per square foot (90 fruits per sq. metre). For a 6 foot by 6 foot spacing he recommends sowing 34 lbs (39 kg. per ha.) of seed to produce 1, 260 plants (1 acre stock).

The use of wildings in Eastern Nigeria gave as good results as nursery grown stock and is advocated. A mulch of rice bran in newly planted poor grassland areas nearly doubled tree growth, Forest Administration Report 1955/56. A similar result was obtained in a mulching trial in Gambia in 1954, Forest Admin. Report 1954.

4. 25 Plants

Dibbling and broadcasting of seed and transplanting of nursery stock have all been tried in Burma with varying success. Troup reported excellent results from direct sowing in lines at Dehra Dun in experiments. Ogbe (1960) does not recommend direct sowing under Nigerian conditions and there is little doubt that when large scale planting schemes develop, the high survival and reliability of establishment by well grown stump plants justifies the extra cost of this type of stock. Stump plants $\frac{1}{2}$ to $1\frac{1}{2}$ inches diameter are extremely tough, can stand rough handling and a week in transit; they grow much faster

than seedlings and can more easily overcome weeds and unfavourable climatic conditions after planting. Stumps are usually trimmed to leave 1 - 2 inches of stem and a foot of taproot.

4.26 Preparation of Site and Planting

In the Amazon region on fertile alluvial soils where the burn was intense, no weed growth followed. The growth of Gmelina from stumps or striplings was excellent and no weeding was required. Judging from Nigerian research, this good growth of the planted trees was due more to the heat effect of the burn on the soil than to the presence of ash. The better the burn the better the growth of the planted tree crop.

Cuttings have been successfully used on a field scale in Sierra Leone taungya plantations, Fox (1967).

Experience in Burma, Malaya and Nigeria confirms that the taungya system should be used in the establishment of Gmelina plantations, wherever possible. On unfarmed and degraded high forest sites carrying Imperata grass and other tall grasses, Yemane is less successful in the initial years than pine. However, its very fast growth enables it to overcome woody weed growth and creepers on high-forest sites which have been newly clear felled and burned. Even at a spacing of 10 feet by 10 feet, cleaning of weed growth is necessary for the first year only, after which the dense canopy of Gmelina suppresses the weeds.

Planting should be carried out whenever the first rains have fallen in high forest climates. Under the drier conditions in savanna woodland sites early planting gives the best results after a sufficient build up of moisture in the soil.

4.27 Tending

Double leaders, bent stems and heavy low branches should be removed in the cleaning and tending operations during the first and second years. Weeding is seldom necessary after the second year except on dry sites where grass competition must be eliminated.

In the drier savanna woodland climates of Zambia and Rhodesia (annual rainfall 45 - 50 inches (1000 - 1250 mm) per year with 6 months dry) form is frequently poor in the original crop. It can be improved by early pruning in the 2nd and 3rd years but a still better procedure is to coppice the whole crop in the 3rd to 4th year. This gives poles from coppice stems which are of much better form than the original single trees and an early return from the sale of firewood and some poles. This system deserves wider trial. It is being used for Teak with success at Ibadan, Nigeria.

4.28 Espacement in Plantations

The spacings used in Malaya in 1947 were 6 ft. x 6 ft. and 4 ft. by 4 ft. where the plantation was for fuel, Mitchell (1963); but this was increased to 10 ft. x 10 ft. in the 1956 and 1958 tobacco taungya plantations, Freezaillah (1966).

In recent plantations, grown on high forest sites, spacings have been wider than those quoted by Troup. The usual spacing in Sierra Leone is 8 ft. x 8 ft. or 9 ft. x 9 ft. on degraded high forest sites but in the Western Nigerian and the Benin taungya plantations 10 ft. x 10 ft. or 12 ft. x 12 ft. have been employed with success and are justified where the growth is extremely rapid on newly cleared high forest sites. At 10 ft. x 10 ft. the canopy closed in the second year after planting, suppressing weed growth. However, the original spacing is influenced by the market to be supplied. The object in view in these Western Nigerian schemes is to grow Gmelina to timber size. If a pulp or chipboard market develops, a return to a closer spacing would be justified. In Sierra Leone grasslands the normal spacing is 7 ft. x 7 ft. ; 12 ft. x 12 ft. was not too wide on good high forest sites Fox (1967), but 15 ft. x 15 ft. provided too few well formed trees to form a satisfactory final crop. Spacing in Malawi is influenced by mechanical cultivation; where this is possible a spacing of 9 ft. x 6 ft. is used. Elsewhere in fuel and pole plantations 6 ft. x 6 ft. spacing is usual so as to obtain a closed canopy as soon as possible, Anon. 1964.

4.29 Cost of Establishment

Nursery stock in Nigeria costs about 1.7 pence per plant or £7 per 1,000 stump plants delivered on planting site. The cost of removal of the original forest on contract by clear felling and burning varies from £14 - £17 per acre where exploited high forest is being converted to plantations. Planting and clearing until canopy closure is estimated to cost £10 to £12 per acre, making a total establishment cost of £25 to £30 (75 - 90 mandays) where labour rates are six shillings and sixpence per day. The incidence of overheads is excluded from these figures as it varies so greatly with the cost of road making, the cost of fire protection, if any, and the size of the operation. The wide crown, quick canopy closure and rapid growth make this one of the cheapest species to establish under cleared high forest conditions. On derived savanna sites, the closer spacing used to ensure early closing of the canopy, the need for thorough removal of woody stems and competing grass before and after planting, and the longer period before canopy closure, make costs of establishment as high as under newly cleared high forest conditions and yields are lower.

4.30 Nutrient Requirement

Growth after canopy closure shows up every variation in the fertility and rooting depth of the site. This is strikingly revealed in several of the derived savanna plantations in Kabba and Northern Benin, Nigeria. The presence

under the canopy of the mud walls of an old village site is reflected in the dark green vigorous growth and dense canopy whereas a few yards away outside the former village site the canopy may be open, the grass competing and the leaves of the Gmelina yellow. In Sierra Leone near Kabala the edge of a flourishing plantation, now surrounded by a sea of 10 foot high grass all of which has been planted with Gmelina, marks the precise line of the cattle kraal used for several years ten years before. Gmelina requires not only good drainage in the soil but high base status also; pine needs good drainage only. Ample available nitrogen is probably essential to vigorous growth of Yemane whereas pine can flourish where the supply of nitrogen is deficient.

4.40 Thinning and Pruning

There is little information on thinning schedules in the literature of this species because many of the plantations have been grown for fuel, poles and mining timber on a coppice rotation and left unthinned. However, correct thinning is essential if the species is to be grown as a source of timber and peeler logs.

In Sierra Leone, very heavy thinning schedules were introduced in an effort to produce timber-size trees 5 ft. - 6 ft. girth b.h.o.b. before the trees died at 15 - 18 years old. Equally heavy thinning will be necessary in the new large scale plantations now being created in Western Nigeria and Benin Province. Permanent sample plots are being laid down in 3 year old crops to study this, Esan (1966). Each productivity class will require a separate schedule designed to reduce the stocking to nearly final spacing by the tenth or twelth year, e.g. original stocking 680 per acre; 3rd/4th year reduce to 300; 5th/6th year reduce to 175 per acre; 7th/8th year reduce to 100 per acre; 10th year reduce to 70 per acre; 13th year reduce to 50 per acre. Such treatment will provide large intermediate yields for which markets are required. It is justified on high quality sites because the wood so produced is equal in quality to slower grown timber, Esan (1966), and short rotations are possible on the best sites which will improve the economic returns.

Thinning of coppice crops to one stem per stool is practised in Malawi to supply good building poles. Standards left to reach timber size, if this proves possible, are pruned to 20 feet above ground. Pruning ir high forest plantations in wetter climates is not usual as the heavy thinning programmes effectively remove most dead branches.

5.0 Mensuration

5.1 Growth and Yield

Malaya has produced growth data, Freezaillah and Sandrasegaran, (1966), and a yield table Sandrasegaran, (1966). These give total volume including branchwood in the 7 - 11 year old plots in the Bintang Hijan Forest Reserve.

These plots were established after a long period of farming and were very lightly thinned by Sierra Leone standards; consequently the size of the trees is less and the basal area high. The following data is extracted from Table 2 of the first reference:

Plot. No.	Spacing (ft.)	Age (yrs.)	Height (feet)	Stems per acre when cut	Total basal area in sq. feet.	Vol. of stem & branchwood u.b. to 3" diam. cu. ft. (true)	M.A.I. cu. ft.
1	2	3	4	5	6	7	8
1	10 x 10	7	77	403	117	3,657	522
2	10 x 10	8	78	387	132	4,472	559
3	10 x 10	9	80	370	137	3,993	444
4	20 x 10	11	84	226	145	4,478	407

It will be noted that even at 7 years old the height growth was already no more than 1 - 2 ft. per year. The high total volume increment which includes branchwood would require little reduction to give utilizable volume if there is a market for pulpwood. The need for heavy thinning is obvious where it is planned to produce sawn timber or peeler logs. Freezaillah points out that the total volume increment down to 3 inches diameter in these plots exceeds that of pines and of Eucalyptus robusta Sm. grown in Malayan highlands at 5,000 feet a.s.l. and is comparable to Nigerian yields from Gmelina published by Chittenden et al, 1964. These yields of Gmelina greatly exceed the mean annual increments quoted by Setten 1953 and Mitchell 1963 for 4 - 5 year old plantations on a less well drained and, probably, more degraded site near Kepong.

Actual figures for sample plots on reasonably good sites in the 120 inch annual rainfall zone of S.E. Sierra Leone are quoted by Fox (1967).

Plot	Age	Stocking No. of stem per acre	Mean girth inches	Basal area per acre sq. ft.	M A I Girth inches	M A I Girth largest 40 per acre inches	Mean height feet	M A I height feet
31/3	3	340	14.0	37.4	4.66	5.93	24	8
45/9	6	140	28.1	60.2	4.68	5.75	44	7.3
45/10	6	170	21.6	44.2	3.60	4.45	42	7
45/11	6	120	26.0	44.4	4.33	4.95	44	7.3
45/5	7	50	39.6	43.0	5.65	5.96	46	6.6
45/2	10	60	40.8	55.2	4.08	4.66	50	5.0

Fox concludes that under these conditions, with adequate and timely thinning, Yemane can reach 4 feet in girth o.b.b.h. in 10 years, 5 feet in 13 years and 5 feet 5 inches in 15 years with a maximum girth in plantations on a much longer rotation of 6 to 7 feet.

In Malawi at Bunda, (3,800 feet a.s.l., 35 inches annual rainfall, 6 - 7 months dry season) on a good site a ten-year old plantation planted at 9 feet by 6 feet had a mean height of 51 feet and a mean diameter b.h.o.b. of 8.9 inches. The mean annual increment to the tenth year was 435 cu. feet per acre, including branchwood, (30.4m^3 per ha). On poor sites one third of this increment was produced. With mechanical cultivation double the Bunda yield is anticipated, Anon, 1964. At five years of age a conservative estimate of the yield of fuelwood would be 50 to 75 cubic yards per acre (117m^3 per ha.)

Nigerian estimates of yield quoted by Chittenden et al, 1964, were supplied by the Federal Director of Research, Ibadan.

In the Derived Savanna Zone:

1) On poor sandy soils 1,200 cu. ft./acre after 12 years growth

2) On good clay or laterite soils 3,000 cu. ft./acre after 12 years growth

3) On the most favourable savanna sites, 3,600 cu. ft./acre after 10 years growth

In the Rain Forest Zone; little information is available but the figure of 3,600 cu. ft./acre after 8 years growth is quoted.

These data give M.A.I.'s of 100 to 360 cu. ft. for the range of savanna sites and 450 cu. ft. for high forest. The last figure may well be greatly exceeded by the new plantations now being created in Ondo and Benin provinces.

6.0 Principal Enemies

6.1 Parasites

In Chittagong, Pakistan, Yemane was destroyed by a mistletoe (Loranthus scurrula L.) Trevor (1935) and at Dehra Dun by a combination of fungoid and insect pests.

6.2 Insect Pests

Throughout Central and South tropical America it is subject to constant attack by leaf cutter ants (Atta sp.) which have so reduced the vitality of a plot in Arena Forest, Trinidad, that the trees succumbed. This pest can be controlled by insecticides or poisonous gases provided the expenditure and constant vigilance are justified. Control is necessary for a considerable distance outside the plantation area.

Another method of control is to use explosives. First it is necessary to find the fungal garden by using a soil auger, then a small explosive charge is inserted into this cavity. All exit holes are closed as the object is to kill the ants by the poisonous gases rather than to kill them by the explosion. The size of the charge will depend on the size of the nest and must be based on experience, Pitt (1967).

Plantations in India have been reported to be severely defoliated by Calapepla leayana (quoted by Ogbe, 1960). The insect attacked the leaves, buds and twigs so severely that two years were sufficient to bring about the death of trees 4 to 6 years old growing in an area with an annual rainfall of about 55 inches. The insects seemed to concentrate their attack in small areas from which they spread only when the trees had died. Several methods of control were tried - hand picking of the insects and collection from white sheets proved to be the most successful. Chemicals were a failure. Control was not attained and the affected plantations had to be abandoned.

Termites do little damage to growing Gmelina in India or Burma. In Malawi and Nigeria it is very free from damage by termites or any other insects. However, in Malaya the heartwood of growing trees near the ground has been hollowed out by termites.

6.3 Fungal Diseases

In the eastern states of India and Pakistan (Chittagong) in shady, unfavourable and waterlogged localities on clayey soil the tree has been attacked and practically girdled when 16 years old by the fungus Poria rhizomorpha Bagchee. The attack starts in the lateral roots (C.f. Sierra Leone). The bark of attacked trees is infested for 3 feet to 5 feet above ground and appears white. In the final stages the sap and heartwood turn a cinnamon brown. The sapwood becomes weak and brittle and breaks away in blocks when pulled by the fingers. All stages are completed within 12 months. This infection spread over an area of 5 to 6 acres where Gmelina was growing about 30 ft. - 40 ft. apart on well drained, sloping sandy loam. The affected trees were 70 ft. - 80 ft. high and up to 3 ft. 6 inches in girth. The fungus spread by bands of white threads in the surface soil and in the leaf litter. Bamboos (Melocanna bambusoides) which form an understorey 35 ft. high were killed also. The fungus follows damage to the roots by animals such as field rats, porcupines and pigs gnawing the roots. Fungus spread is confined to the monsoon period when the substratum is saturated with moisture and root aeration is defective.

Ganoderma colossum syn. (Phaeolus manihotis) causes root rot in Mamu River area of Eastern Nigeria but is not extensive.

Root rot in small groups in Nigeria during 1966 has been attributed to Fomes lignosus, Momoh (1966). So far death from this cause is not extensive.

Armillaria mellea is suspected as the cause of death of some trees in Sierra Leone and Malawi but this has not been confirmed, Tinsley & Barrett, 1966.

Root suffocation is to be expected in waterlogged areas of a site.

6.4 Frost Damage

Gmelina is frost tender in parts of India. In Malawi, Anon (1964), trees up to 20 feet high may be severely injured by frost though when cut back at the base the power of recovery is good. Frost limits the use of this species in plantations in parts of Zambia and Rhodesia.

6.5 Fire Damage

The tree is seldom killed by ground fires but the damage to the base

of the stem admits rot and termites. Most trees in a 4 year old plantation in derived savanna at Urho near Ubiaja, Nigeria, had exposed wood showing on scars a year after a ground fire.

The mechanical cultivation used where possible in Malawi, effectively reduces the danger of fire until canopy closure, but the carpet of dead leaves in the dry season forms a perpetual fire hazard with the risk of soil erosion and damage to the trees at ground level.

6.6 Wind Hurricane Damage

Mauritius has reported that Gmelina is moderately resistant to hurricanes.

7.0 Wood Properties

7.1 General Properties

In general appearance the wood is straw yellow to creamy white. The heartwood may be tinged with pink and the sapwood may appear slightly greyer than the heartwood but there is little difference in appearance between heartwood and sapwood. Selected samples show fiddleback mottling, and a fine sheen on quarter sawn boards. The wood is very wet when freshly cut. It air dries slowly with remarkably little degrade such as distortion, splitting, change of colour or pinhole attack. Its excellent behaviour when sawn and stability when dried are related to its low radial and tangential shrinkage. Data from India, Malaya, Gambia and Nigeria show that in spite of very varied growing conditions in these countries the density averages 30 to 31 lbs. per cubic foot in all of them, which is close to Baltic Redwood (Pinus sylvestris) and puts it in the right weight category for very many uses. Unlike pine, fast growth does not change the density of Gmelina wood, Esan 1966, making it ideal for rapid production of large quantities of stable utility timber. Its pulping properties are excellent. The heartwood is moderately durable except where particular species of termite are prevalent (as in Malaya) but is very resistant to impregnation with preservatives. The sapwood can be impregnated and averages 2 to $2\frac{1}{2}$ inches in width.

7.2 Anatomy

A very full description is given by Pearson and Brown (1932).

Chowdhury, 1947, found that the wood produced by Gmelina was ring porous when conditions of growth were adverse (shallow rooting soils in a monsoon climate) but became more and more diffuse porous as rooting, nutrient and climatic conditions became more favourable. When the wood is diffuse porous, the initial parenchyma cells may be altogether absent although the

growth rings are visible due to differences in the thickness of the cell walls of the early wood and the late wood of the previous year. Brittlewood was not observed in the Gambian samples sent to England but some tension wood was present.

7.21 Macroscopic Features (taken from Nigeria F. P. Res. Rep. 2)

The vessels are visible to the naked eye and are not arranged in any regular or definite pattern. They are however mostly associated with the parenchyma which are sometimes wing-like in arrangement. The rays are small and only just visible to the naked eye. The timber has no diagnostic smell or taste but growth rings are visible and are usually annual. In some trees the grain may be interlocked giving a broken, stripe figure on quartered surfaces. The texture is moderately course.

7.22 Microscopic Features and Density

Vessels are more than 200 microns in diameter, with tyloses and other deposits included within. Fibres are septate, perforations simple. Rays are commonly heterogenous (Kribs' type III) but sometimes homogenous, 4 - 10 cells wide. Pits of vessels are mostly small, but sometimes large and rounded. Presence of Acicular crystals is a reliable identification characteristic. Parenchyma is para-tracheal and vasicentric but sometimes aliform. Terminal and initial parenchyma are present.

Esan, 1966, investigated fibre length and density patterns within three randomly chosen, 8 year old Nigerian grown Gmelina trees (from Arakanga near Abeokuta. These trees were sampled at 10%, 30%, 50% and 70% of total height. The conditions of growth were adverse (rainfall 46.72 inches per annum with five dry months, site degraded to grassland and subject to periodic ground fires, mean annual temperature 80° F). Growth rings were separated by bands of terminal parenchyma which may be laid down when starch is withdrawn from the leaves before leaf fall. The number of rings appeared to fit the known age of the trees.

Density tends to increase very gradually from the pith outwards and ranges from 25 to 34 lbs per cubic foot, averaging 30 lbs. A slight fall off in density close to the bark may have been due to the time of felling of the trees (August). There is a very slight fall in density up the tree from 10% of height to 30% of height (0.41 to 0.39).

Fibre length of both early and late wood increases rapidly from the pith to the end of the third year, after which fibre length increases very gradually. The increase is from about 0.6 mm at the pith to 1.2 mm in the third year. The fibre length varies also with increasing height in the tree. Considering only the ring nearest the pith, the fibre length increased from 0.75 mm at 10% of height

to 0.88 mm at 50% of height in tree A, after which it fell off. In the middle ring and the outer ring, the peak of fibre elongation occurred at the 10% level, after which the fibre lengths decreased gradually up the tree. This means that Gmelina pulpwood (unlike Pinus caribaea which does not emerge from the juvenile stage until it is 8 - 16 years old) will not contain a high proportion of short fibres even when grown on a short rotation of 8 years.

Esan concludes that fast grown Gmelina would not necessarily have lower density than slower grown trees, and could be grown on the most fertile soils to produce timber of uniformly high density and length of fibres. Thinnings from the plantation when three years old would contain many short fibres undesirable for pulp but satisfactory for particle board. Thinnings from older trees and final crops from 7 - 8 year old trees would give sufficient long fibres in the mixed pulp for printing papers, although the paper would be too weak for use alone in newsprint or wrapping papers.

7.3 Pulping Properties

Nigerian Gmelina from 4 year old coppice growth in a fuel plantation near Ibadan was tested by Chittenden et al (1964) who had already studied the work of Petroff & Doat (1960) on samples from the Ivory Coast.

Pulping trials were carried out using both the sulphate chemical process and the neutral sulphite semi-chemical process. The former process may be expected to give pulps suitable for wrapping, writing and printing papers; the latter process should give higher yields of pulp from which lower-quality writing or printing papers or carton boards may be made. Optimum processing conditions resulting in maximum yield of the strongest pulp were determined.

The chemical analyses indicated that there is nothing particularly abnormal about the timber of this species. The "resin" content is rather high but the effect of this was completely eradicated by the use of the anti-foaming agent, turpentine. There was a high holocellulose content (total carbohydrate fraction excluding lignin).

Bark formed only 7% of the raw material (a low figure because of the age of the material).

The mean ovendry density was 23.5 lbs per cu.ft.

Ultimate fibre dimensions of the wood were:-

Mean fibre length	1.01	$\pm$ 0.002 mm
Mean fibre diameter	0.0278	$\pm$ 0.0006 mm
Cell wall thickness	0.003 mm	
Lumen diameter	0.02 mm	

By calculation from these figures the co-efficient of suppleness was 72. These figures for Nigerian material agree closely with those previously reported by Guha (1961) for Indian material. The co-efficient of suppleness indicates that this wood should yield a paper of fair quality with a reasonable degree of surface contact and interfibre bonding. The fibre dimensions are of the same order as are observed in Aspen (Populus tremuloides) and Birch (Betula alba) and various species of Eucalypts, all of which have recently been used successfully for the manufacture of paper pulp.

A satisfactory yield of sulphate chemical pulp can be produced from the timber of this species without excessive chemical consumption under moderate pulping conditions. The physical test results of paper prepared from unbleached sulphate pulp are excellent, with the exception of tear and fold strength which are only moderately good as is normal in most hardwood pulps. The loss of yield on bleaching is satisfactorily low; the consumption of bleaching agent extremely low and a paper of high brightness is produced. No loss of physical strength is associated with the bleaching process. In general the results obtained in these trials are more favourable than those reported by Guha and Saxena, 1961, the strength of Nigerial pulps being greater in most respects. The bleaching behaviour also is much better in the case of the Nigerian material. The yields per cent of the two best neutral sulphite semi-chemical pulping trials (screened pulp + screenings) were 75.7 and 66.5. Of this, screenings amount to 2.6 and 1.2. The quality of paper produced was normal in comparison with other semi-chemical hardwood pulps.

Pulping trials of more mature timber of this species (7 - 8 years) grown in the Gambia have been carried out. This material gave very similar results when pulped by the sulphate process but the yields obtained by the neutral sulphite semi-chemical process were lower and the pulp obtained was more difficult to bleach.

The quality of Gmelina papers was found to be substantially improved by blending with small quantities of coniferous (i.e. long-fibred) sulphate pulp (10 - 20%).

Malayan experience was reported by Peh (1964). Samples were obtained from three different localities. The logs varied in size from 14 inches to 7 inches diameter and in age; two samples were 30 and 31 years old and the third 10 years old. Thus all were much older than the Nigerial samples (4 years).

Difference in some chemical characteristics expressed as percentages of oven dry material were:

	Ash	Alkali sol. 1% of NaOH	Holo-cellulose	Alpha cellulose
Nigeria	1.2	15.1	81.0	46.4
Malaya	1.0	10.4	69.0	42.7

Fibre dimensions of the Malayan samples were obtained from samples 2 cm. from pith, half way from pith and 2 cm. from bark. The length of wet fibres increased from the centre of the tree to the pith averaging 1.19 mm, 1.30 mm and 1.36 mm respectively. There was also a range from 1.29 mm for the 10 year old tree to 1.41 mm for the 31 year old tree in the outer sample further confirming increase in length with age. The overall strength of pulp prepared from this material was superior to commercial Eucalypt sulphate pulp. Suppleness decreased from pith to bark.

Using the mean of the Malayan figures for comparison with those of Nigeria and the Ivory Coast, gives the following:

	Malaya (wet fibres) 31 yrs	10 yrs.	Nigeria 4 yrs.	Ivory Coast 12 yrs.
Mean fibre length	1.29 mm	1.24 mm	1.01 mm	1.150 mm
Mean fibre diameter	33.9 μ	30.5 μ	27.8 μ	34.5 μ
Cell wall thickness	4.78 μ	4.37 μ	3.0 μ	3.38 μ
Lumen diameter	24.3 μ	21.7 μ	20.0 μ	28 μ
Coefficient of suppleness	71.8	70.7	72	80.5

Petroff & Doat (1960) who worked on the three log samples from plantations on the Ivory Coast compared the species to Poplar and Birch. However, they conclude that this species would be unsatisfactory as a source of dissolving pulp.

Crossley and Ogunle (1964) working on the Nigerian material conclude that unbleached sulphate pulp could be dried without deterioration of its paper making properties.

None of the reports on its pulping properties refer to its potentialities as a source of ground wood pulp. Its pale colour and the ease with which it can be bleached would justify trials in the production of newsprint from this species by the refiner process.

7.4 Physical and Mechanical Properties

Gmelina timber has been tested in India, Burma, Malaya, Ivory Coast and Nigeria and wood from Gambian plantations has been examined recently in the United Kingdom.

Thomas (1939) compared Malayan, Burman and Indian wood with Teak. More extensive tests in Malaya, Nigeria and the U.K. are compared in Table A.

TABLE A

In comparing the Gambia samples with tests carried out in other countries the Forest Products Research Laboratory of England comments as follows:- "The Gambia timber is appreciably less stiff and slightly less strong in bending than the average but is well up to the average in compression, resistance to impact toughness and hardness; it is somewhat above average in resistance to shear".

(Where no figure for the other countries that corresponded to the units given in the U.K. Report could be found the statistic is omitted in the table.)

Country	No. of trees tested	M.C.	Nominal specific gravity	Weight per cu. ft.		Static Bending				Impact Bending	Compression parallel to grain	Hardness (Janka)	Shear	Cleavage		Remarks
Plantation Grown Trees		Moisture Content %	Nominal	At 50% Moisture Content (lb.)	At 12% Moisture Content (lb.)	Equivalent Fibre Stress at Maximum Load (lb.f/in^2)	Modulus of Elasticity (1000 lb. f/in^2)	Work to Maximum Load (in lb. f/in^3)	Total Work (in lb. f/in^3)	Maximum Drop (inches)	Maximum Crushing Strength (lb. f/in^2)	On Side Grain Indenting Load (lb.)	Shear Strength (lb. f/in^2)	Splitting Strength Radial (lb. f/in width)	Splitting Strength Tangential (lb.f/in width)	
India U.P.				41.7	31		1070			30	3230	905				Mal. For. 8 : 84-85
Nigeria	7	115.4		39		8200	950	14.5	36.8	30	3860	800	1280 (Radial)	60	61	Extracted from Nigeria For. Prod. Res. Lab. Report No. 2 of 1965
4 trees Ibadan 3 trees Enugu	7	12		-	31	10200	1100	12.4	23.7	27	5360	690	1600 (Radial)	74	82	
Gambia (U.K. Report)	5	113	0.407	38	-	6870	750	12.5	36.4	28	3230	680	1130			
			0.0425	-	-	1267	117.5	4.96	11.10	7.85	577	152.4	222.3			Standard deviation of individual results
	5	11.6	0.427	-	30	8650	800	-	-	17	4900	720	1720			
			0.0427	-	-	1489	142.6	-	-	6.39	714	179.4	280.4			Standard deviation of individual results
			35			35	35			34	35	35	70			Number of tests
Malaya	5	15	0.42	42.5	30	-	1393	7.33	13.86	35	4725	599	1184 (Radial)	278	303	Mal. For. 27 : 370-374
Burma	5	12		39.4	31	-	1250			28	3300	760				Mal. For. 8 : 84 - 85

7.5 Seasoning and Shrinkage

The Gambia samples cut from dominant trees 12 years old contained large knots which are a defect that could be greatly reduced by good silviculture. The unbarked logs were still very wet after three and a half months on the journey to the United Kingdom research laboratory but showed no insect attack or rot in the sapwood and no staining or splitting such as would normally be expected after such a delayed journey. Both in England and Malaya the wood dried unusually slowly. In Malaya after 11 months air-drying 1 1/4 inch thick boards were dry but $1\frac{1}{2}$ inch boards were still losing weight and half inch boards cut from wet logs took $3\frac{1}{2}$ months to air dry, Lee (1964). Kiln drying was satisfactory under schedule K (U.K. schedules); a starting temperature of 160° F (71° C) is recommended for boards up to $1\frac{1}{2}$ inches (3.75 cm); higher temperature schedules were needed for thicker boards but these caused appreciable general darkening of the timber on the surface. This could probably be removed by planing or sanding. One inch material dried in $1\frac{1}{2}$ to 2 weeks from 110 per cent to 12% moisture content, 2 inch stock took 6 weeks. Distortion was negligible and there was little tendency for end shakes to extend during drying.

Shrinkage from green to 12% moisture content was:

	Gambia	Movement	Nigeria	Vol. shrinkage	Classification
Tangential	3.5%	small	2.4%	15%	Very stable
Radial	1.5%		1.2%		

Weight at 11.6 moisture content was 27 to 32 lbs. per cu. ft. in U.K. tests, which compares closely with results reported from India, Burma, Malaya, Nigeria and with Scots pine.

Slight warping of a few boards was recorded in Malaya.

7.6 Durability and Preservation Treatment

Sapwood on freshly cut logs contained a large starch content as measured by the iodine test but the amount of starch was undetectable after some months storage under water. This loss of starch during storage is thought to be connected with the effect of respiration of living tissues within the log which reduces the stored carbohydrates.

Sapwood is classed as perishable but like Teak is not very attractive to insects either in the log or when converted to sawn timber. It is perishable in contact with the ground.

The heartwood is classed as moderately durable in contact with fungal attack in the U.K. tests. Denser wood in two sample trees had higher resistance

to Polystrictus versicolor than lighter wood in the remaining three trees tested in the United Kingdom, using Gambian material.

Resistance to termite attack varies with the species of termite present. In Burma, house posts 30 years old were sound, Dawkins (1919), but in Malaya, termites attacked the heartwood of growing trees.

Samples were destroyed by Teredo worms in tests in Madras, India, Pearson & Brown (1932).

In Malaya the average life of test sticks (2" x 2" x 2') (presumably heartwood) was 1.3 years; termites were the main cause of destruction. In Malaya it has been classified as non-durable. However, in Malawi similar tests of heartwood showed it to be resistant to African termites.

All agree that the heartwood is difficult to impregnate by normal pressure processes. In the case of the Gambian samples absorption of Creosote under pressure treatment was 1.9 lb. per cu. ft. and for sapwood 6.9 lb. per cu. ft. This would put the sapwood into the moderately resistant class. No reports give the results of impregnation by diffusion. Its high moisture content and slow diffusion rate when drying would make the time required for treatment longer than is normal in other hardwoods.

In Malaya heartwood took 1 - 2 lbs. per cubic foot and sapwood 7 - 10 lbs. per cubic foot of creosote-dieseline 50:50 mixture by the open tank process. In Nigeria test pieces (presumably heartwood, size not stated) gave the following results:-

Full cell pressure process Tanalith C	10.4 lb./cu.ft.	(range 2-35.3)
Full cell pressure process Creosote	4.6 lb./cu.ft.	(range 1.2 - 12.5)
Open Tank hot and cold process Creosote	3.7 lb./cu.ft.	(range 0.60 - 12.7)

In no case did lateral penetration of any process reach 1/32nd inch. Longitudinal penetration was very slight, 1/16th inch mainly through the vessels. These results would be expected from the slow seasoning rate and the "resin" content of the wood reported earlier in pulping tests.

7.7 Utilization of the Wood

7.71 Working Properties

The timber saws cleanly, planes easily, has a fine lustre and ripple effect on quarter sawn faces and takes a good polish. The blunting effect on saw teeth and sharp edged tools is slight. It peels without the necessity of preliminary boiling. Sound veneers are obtained which made good second class plywood and selected sheets could be used for facing plywood. Knots are

objectionable; the wood tends to tear near knots and patches of interlocking grain during planing, but this can be greatly reduced by reducing the cutting angle from 30° to 20°. Best results were obtained during moulding when collars were used. It is too soft for turnery. Twelve gauge nails caused splits of the Gambia samples but thin gauge nails did not. In Malaya, resistance to splitting was reported to be excellent. It stained unevenly unless a filler was used.

Nigeria has carried out tests of many species, local and exotic for use in the Ilorin match factory, Nigeria 1965, and found wild rubber (Funtumia) and Gmelina to give the best results. Gmelina logs 12" to 20" diameter from Ilorin and Ibadan were peeled to give 2.25 mm veneers. Veneers were smooth and even, straight grained and medium textured. The cutting angle was 19°. Splints absorbed paraffin readily and burned with a smokeless and odourless flame. Gmelina was slightly inferior to Funtumia in burning property; it burned only when the splints were held downwards or upwards but not when held horisontally. Gmelina took the match heads firmly. The impact strength of Gmelina (27 inches) was good but the shear strength was low (1,600). It was very suitable for inner and outer boxes and splints.

Lee (1964) reported on peeling and glueing experience in Malaya. Rotary peeling was easy even without pretreatment of the logs. Veneers 1/16 inch and 1/32 inch (1.6 mm and 0.8 mm) were both easy to handle without much tendency to tear. After drying, the veneer sheet remained flat. Glueing properties were good.

7.72 Uses

In India and Burma, Troup (1921), and Pearson & Brown (1932), give a long list of uses. It is used for house posts, cattle bells, clogs, boat decking, drums, general carpentry, door panels, canoes, etc. In Sierra Leone it is greatly favoured for the sides and back of drawers, wardrobes, cupboards and kitchen furniture because of its light colour, ease of working and stability. In Nigeria it was grown for mining timber at Enugu on a coppice rotation of 8 years and has recently been planted as a raw material for match-splints and match boxes in Ilorin and Kabba provinces and as a source of peeler logs and timber in Ondo-Ijebu provinces.

The Farmers Marketing Board in Malawi found that tobacco cured with Gmelina smoke was equal to tobacco cured with mixed local hardwoods. Twenty-five cubic yards of Gmelina cordwood were required to cure a ton of tobacco. The fuel was used one third dry and two thirds greenwood.

Although it is neither a particularly straight pole nor a long-lasting firewood the ease with which it can be established and its very rapid early growth under very varied conditions has resulted in widespread planting in country districts for poles and fuel, especially in Malawi, Nigeria and Sierra Leone by

private farmers.

8.0 Tree Improvement Programme

Very little has yet been done to improve the properties or yield of this species. No provenance trials are known to exist. Troup, (1921), pointed out the differences between provenances in India and it is likely that a species of such wide distribution will contain variations of sufficient magnitude to justify such trials in India, Malaya, Malawi and Nigeria at least.

Nigeria has found no difficulty in budding selected parents from the Enugu plantations onto seedling stock at Ikom, Enugu and Agbede (Ubiaja). The spacing in seed orchards so formed has to be wide (25 ft. x 25 ft. minimum). Many shoots arise from budded stock which gives the seed orchard an unattractive appearance. The stock was planted in 1962 and budded in 1963 in the field.

No work has yet been done on the pollination of this species. It may be self pollinated. The large flowers provide suitable material for such research.

9.0 Conclusions

9.1 The Risks

Tropical foresters must consider the risks involved in growing Gmelina in pure plantations. There is the risk of soil deterioration by exposure under this deciduous species; the risk of soil erosion if fires sweep through the leaf litter and the risk of catastrophic insect or fungal attack common to all pure crops. The likelihood of soil deterioration by exposure is greatest in the high rainfall sandy soil areas such as occur in Benin and Enugu districts in Nigeria where an understorey to Gmelina should be encouraged in plantations grown for timber. If it is grown for pulp on a coppice rotation, the risk is greater, no understorey is possible and careful consideration should be given to this risk when drawing up pulp schemes. Fire accelerates soil deterioration and should be entirely excluded from Gmelina plantations by efficient protection methods.

9.2 The Assets

It can be established easily and more cheaply than most of its rivals in tropical forestry but far more attention must be given to working out the best thinning regime to produce the maximum output of large logs (5 feet girth and over) for sawing and peeling. As it does not grow straight or cylindrical without competition, good silviculture, good sites and integrated utilization are essential factors of management if Gmelina is to become a major species in the tropical humid forest zones. Grown on a coppice rotation of 7 - 8 years for pulpwood,

very high increments and yields per acre are possible on good sites, probably exceeding 500 cu. ft. per acre per annum.

9.3 The Wood

Its ability to produce wood as dense when grown fast as when grown slow puts it in a unique position as far as present knowledge of tropical woods goes. Its working properties are excellent and make Gmelina one of the best utility timbers in the tropics. It dries slowly but without degrade.

9.4 Pulp Properties

As a source of pulp Chittenden et al (1964) consider Gmelina an extremely promising species for pulpwood production in Nigeria and in other tropical countries where suitable growing conditions exist. The short juvenile period of the species (3 years) results in a high proportion of good length fibres (for a hardwood) in pulpwood grown on a short rotation. The unbleached chemical sulphate pulp could find use in the production of the lower grades of wraping paper while the bleached product should be very suitable for a wide range of writing and printing papers. The lower-quality higher-yield semi-chemical pulp would be suitable, in an unbleached condition, for the manufacture of paperboard for cartons and similar applications. A rather higher quality semi-chemical pulp (although produced in lower yield) should find application for the manufacture of zinc papers. Papers of higher grades could be made from both these types of pulp by the incorporation of small amounts (10 - 20 per cent) of coniferous pulp.

9.5 Durability

The resistance of its heartwood to impregnation makes it unsuitable compared with some other species for use in contact with the ground. Heartwood is moderately durable except where certain species of termite attack it, as in Malaya.

9.6 Improvement Potential

A study of between-tree variations in density and fibre length and a series of provenance trials to assess genetic range of variation and properties within the species should be instigated as soon as possible in interested countries such as India, Malaya, Nigeria and Malawi.

9.7 Economic Value

Economic returns usually decide which species should be preferred. From this point of view Gmelina has few rivals in the short term, and provided fertility can be maintained by good silviculture, widespread planting of the species is justified. However, on high forest sites where rapid soil deterioration

is probable, short rotations for pulpwood production are not recommended.

9.8 Integrated Utilization

Where the object of management is to grow Gmelina to large size for timber and peeler log production, integrated utilization plants are essential to absorb the large volume of thinnings. Such plants could produce pulp, particle board, plywood, matches and sawn timber.

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